READY EXERCISER ONE: EXAMINING THE EFFICACY OF IMMERSIVE TECHNOLOGIES IN THE EXERCISE DOMAIN

A thesis submitted for the degree of Doctor of Philosophy

by

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Abstract

The present programme of research sought to examine the effects of audio-visual stimuli during exercise, using immersive, commercially available technologies. Three original studies were conducted using a range of settings (i.e., real-world, laboratory), methodologies (i.e., qualitative and quantitative), exercise modalities (i.e., gym workouts, cycle ergometry) and consumer products (e.g., music-video channels, virtual reality head-mounted displays) in order to explore the main research question from various perspectives. A substantive theory was proposed in Study 1 that sought to explain and predict the social process of exercising in the presence of a music-video channel. The model provides support for a three-stage process that commences with the content of the music-video channel. The second stage depicts a series of moderators that revolve around the core category, appraisal of appropriateness. Lastly, a range of effects pertaining to exercisers and facility staff are predicted. Study 2 sought to examine the influence of a range of audio-visual stimuli on cycle ergometer exercise at the ventilatory threshold. The findings indicated that a 360-degree video with music condition elicited the most positive affective valence, greatest perceived activation, most dissociative thoughts, and highest ratings of perceived enjoyment. Study 3 sought to veer towards greater ecological validity with the inclusion of a commercially available virtual reality-enabled cycle ergometer. The findings demonstrated the efficacy of such technology, as conditions that entailed virtual reality elicited the most positive affective valence, highest perceived activation, largest number of dissociative thoughts, and greatest perceived enjoyment. Taken holistically, the present body of work demonstrates that audio-visual stimuli can serve as a catalyst for several affective, cognitive, and behavioural effects across various exercise modes and intensities. Researchers are beginning to recognise the importance of affective responses in shaping future exercise behaviours. The addition of audio-visual stimuli within the exercise environment represents a cost-effective and easily implementable intervention that might encourage individuals to partake in regular exercise.

Dedication

To my parents, Liz and Tony, for their love and support.

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It is difficult to mention everyone who has helped me in this scholarly venture. If I were to thank everyone individually, it would require an additional chapter. The path that I have taken has not always been easy and I am indebted to those who have been there for me.

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List of Abbreviations

AG:	Affect Grid
ANOVA:	Analysis of variance
ANS:	Autonomic nervous system
ART:	Affective–Reflective Theory
AS:	Attention Scale
BMRI:	Brunel Music Rating Inventory
bpm:	Beats per minute
CET:	Cognitive Evaluation Theory
dBA:	Decibels
DMT:	Dual-Mode Theory
ECG:	Electrocardiograph
EEG:	Electroencephalography
FAS:	Felt Arousal Scale
*f*MRI	Functional magnetic resonance imaging
FS:	Feeling Scale
HMD:	Head-mounted display
HR:	Heart rate
HRR:	Heart rate reserve
HRV:	Heart rate variability
M:	Mean
MANOVA:	Multivariate analysis of variance
METs:	Metabolic equivalents
MHR:	Maximal heart rate
OIT:	Organismic Integration Theory
PACES:	Physical Activity Enjoyment Scale

PANAS: Positive and Negative Affect Schedule

PAR: Physical Activity Recall

PAR-Q: Physical Activity Readiness Questionnaire

PMV: Personal motivational video

POMS: Profile of Mood States

RAA: Reasoned Action Approach

RCP: Respiratory compensation point

RMSSD: Root mean square of successive RR interval differences

RPE: Ratings of perceived exertion

rpm: Revolutions per minute

SAM: Self-Assessment Manikin

SCT: Social Cognitive Theory

SD: Standard deviation

SDMES: Semantic Differential Measures of Emotional State

SDNN: Standard deviation of normal-to-normal RR intervals

SDT: Self-Determination Theory

SE: Standard error

STAI: State-Trait Anxiety Inventory

TRA: Theory of Reasoned Action

TTM: Transtheoretical Model

$\dot{V}CO_2$: Carbon dioxide production

$\dot{V}O_2$: Oxygen consumption

VR: Virtual reality

VT: Ventilatory threshold

WHO: World Health Organization

Preface

Fifteen thousand years ago, a forager is awoken abruptly by the sounds of a neighbouring faction attempting to steal his resources. After successfully fending off his rivals, the ancient forager and his company commence their daily work by covering several kilometres in search of food, an activity that is affected by the annual migration of animals and the cycle of plants. The forager works tirelessly to gather berries and dig up roots, before hunting bison and mammoth with the aid of his brethren. When the daily pursuit of food is complete, the forager spends his evening mastering practical skills such as making stone knives, which will ultimately serve to enhance the chances of survival in this hostile environment. The company will soon move on and settle in a new location, as seasonal changes begin to influence the supply of food. Nonetheless, the forager is quick to fall into a deep sleep that night as a consequence of his physically demanding day.

Today, a modern professional awakes to the calming sounds of birdsong emanating from the alarm system placed on his bedside table. After sitting for a period of 2 hours on a crowded train, the commute to his place of work is complete. The employee spends a further 8 hours in a seated position while he works tirelessly to finish an urgent report that he had promised to deliver to his superiors by the end of the day. He leaves his desk only briefly to purchase food from the nearest café, which is conveniently situated on the ground floor of the building; a perk that attracted him to the job in the first place. Upon completing his commute home, the individual orders food to be delivered to his front door with just a few clicks of his smartphone, before settling down to watch a selection of his favourite television shows that are available on demand. Before going to sleep, the modern professional glances at his shiny new watch that serves as an activity tracker and is startled to find that he has contributed just 35% towards his daily step goal. “Oh, I’ll make it up tomorrow,” he says to himself. But tomorrow is almost identical to today.

Chapter 1: Introduction to the Research Programme

1.1 Physical (In)Activity

As illustrated by the preface, the earliest humans were required to engage in daily physical activity (e.g., hunting and gathering food) in order to sustain their immediate survival as a species. Conversely, modern-day society provides relatively few physical challenges (Päivärinne, Kautiainen, Heinonen, & Kiviranta, 2018). There is, however, an abundance of evidence that regular physical activity is fundamental to the prevention of several chronic diseases such as heart disease, type 2 diabetes, and some cancers as well as psychological disorders such as depression and anxiety (Biddle, Ciaccioni, Thomas, & Vergeer, 2019; Murri et al., 2018; Rhodes, Saelens, & Sauvage-Mar, 2018). The benefits of physical activity are so widely documented that the World Health Organization's (WHO) Global Action Plan for the Prevention and Control of Non-Communicable Diseases includes the target to reduce physical inactivity by 10% by 2025 (World Health Organization, 2016). Unfortunately, recent reports indicate that "no country in the WHO European Region is on track to meet the [physical activity] target" (World Health Organization, 2018a, p. 6).

Researchers using self-report data estimate that 23.3% of the adult population fails to achieve 150 min of moderate-intensity activity or 75 min of vigorous-intensity activity per week (Sallis et al., 2016). However, the severity of physical inactivity is often underestimated when predicated on self-report data when compared to objective assessments using accelerometer data (Ekkekakis & Zenko, 2016a). Accordingly, physical inactivity remains a global pandemic, responsible for an estimated 5 million deaths per year (Lee et al., 2012; D. Riebe et al., 2015). Physical inactivity not only poses a significant health risk to the population, but the associated economic burden is substantial, conservatively estimated in 2013 to cost health-care systems $53.8 billion worldwide (Ding et al., 2016). Therefore, physical inactivity has been described by researchers as the greatest public health problem of our generation (Blair, 2009; Sallis, 2009; Trost, Blair, & Khan, 2014).

1.2 Sedentary Behaviour

If the general population are failing to meet the recommended quantity of physical activity per week, an important question arises: *What behaviours are individuals partaking instead of physical activity?* Sedentary behaviours are defined as any behaviours with low energy expenditure (i.e., ≤ 1.5 metabolic equivalents [METs]), while an individual is in a sitting or reclining posture during waking hours (Sedentary Behaviour Research Network, 2012). Modern-day society is replete with opportunities for individuals to engage in sedentary behaviours (Castro, Bennie, Vergeer, Bosselut, & Biddle, 2018). Such behaviours have been associated with several negative health outcomes such as cardiovascular disease, type 2 diabetes, and some cancers (Hutchinson, Headley, et al., 2018). Importantly, these outcomes appear to exist irrespective of an individual's physical activity level (Gardner, Smith, Lorencatto, Hamer, & Biddle, 2016). Given the deleterious effects of sedentary behaviours, the Chief Medical Officers recommended almost a decade ago that individuals across the lifespan should minimise the amount of time spent being sedentary (Department of Health, 2011). Nonetheless, sedentary behaviours remain pervasive in modern-day society (Hutchinson, Headley, et al., 2018).

In the UK, it is estimated that 29% of adults spend an average of 6 or more hr of sedentary time per weekday (NHS Digital, 2017). In Europe, it is estimated that the average adult spends 5 hr per weekday sitting (Bennie et al., 2013). These estimates are based on self-report data and as a similarly to physical activity measurements, might be less valid and reliable when compared to more objective forms of data (Gupta et al., 2015). Researchers have proposed many factors that are likely to influence an individual's engagement in sedentary behaviour, such as employment, socio-economic status, and intentions to reduce sitting (Prince, Reed, McFetridge, Tremblay, & Reid, 2017). Another leading contributor to sedentary behaviour pertains to the increasing use of consumer technology (Biddle et al., 2017; Parker, Salmon, Brown, Villanueva, & Timperio, 2019).

1.3 The Digital Revolution

Technology is presently developing at a rate that is unrivalled throughout human history (Elliott, 2019). In the UK, the communications regulator Ofcom revealed that adults are spending an average of 25 hr per week online, almost double the amount reported in 2007 (i.e., 12.1 hr; Ofcom, 2018). During this time, individuals frequently listen to digital music streaming services, watch television shows on demand, and engage with social media. The significant rise in time spent online might be attributed to the growing variety of digital devices that are available to modern consumers. Figure 1.1 depicts the household take-up of digital devices from 2007–18, indicating a sharp increase in the ownership of smartphones, tablets, and virtual reality (VR) head-mounted displays (HMD; Ofcom, 2018). The use of such screen-based technology has contributed to an increase in sedentary behaviour (Lewis, Napolitano, Buman, Williams, & Nigg, 2017; Straker, Zabatiero, Danby, Thorpe, & Edwards, 2018). Moreover, the popularity of portable devices has given rise to the phenomenon of "sedentary multitasking" (LeBlanc & Chaput, 2017, p. 235). Accordingly, it is common for individuals to simultaneously watch television, respond to emails on a laptop, and hold a conversation using their smartphone.

It is important for exercise psychologists to further understanding of the mechanisms that underlie the decision to engage in sedentary behaviours and refrain from physical activity. In other words, why does the aforementioned modern professional choose to sit and watch television instead of partaking in physical activity? I will return to this question in the Review of Literature (see Chapter 2). For now, it is important for the reader to understand that technology is evolving at such a pace that it exceeds the ability of the research community to track and document its deleterious effects (LeBlanc & Chaput, 2017). Instead of attempting to prise individuals away from the technology from which they appear to have become inseparable in recent years, we should strive to explore the potential for technology to help promote physical activity.

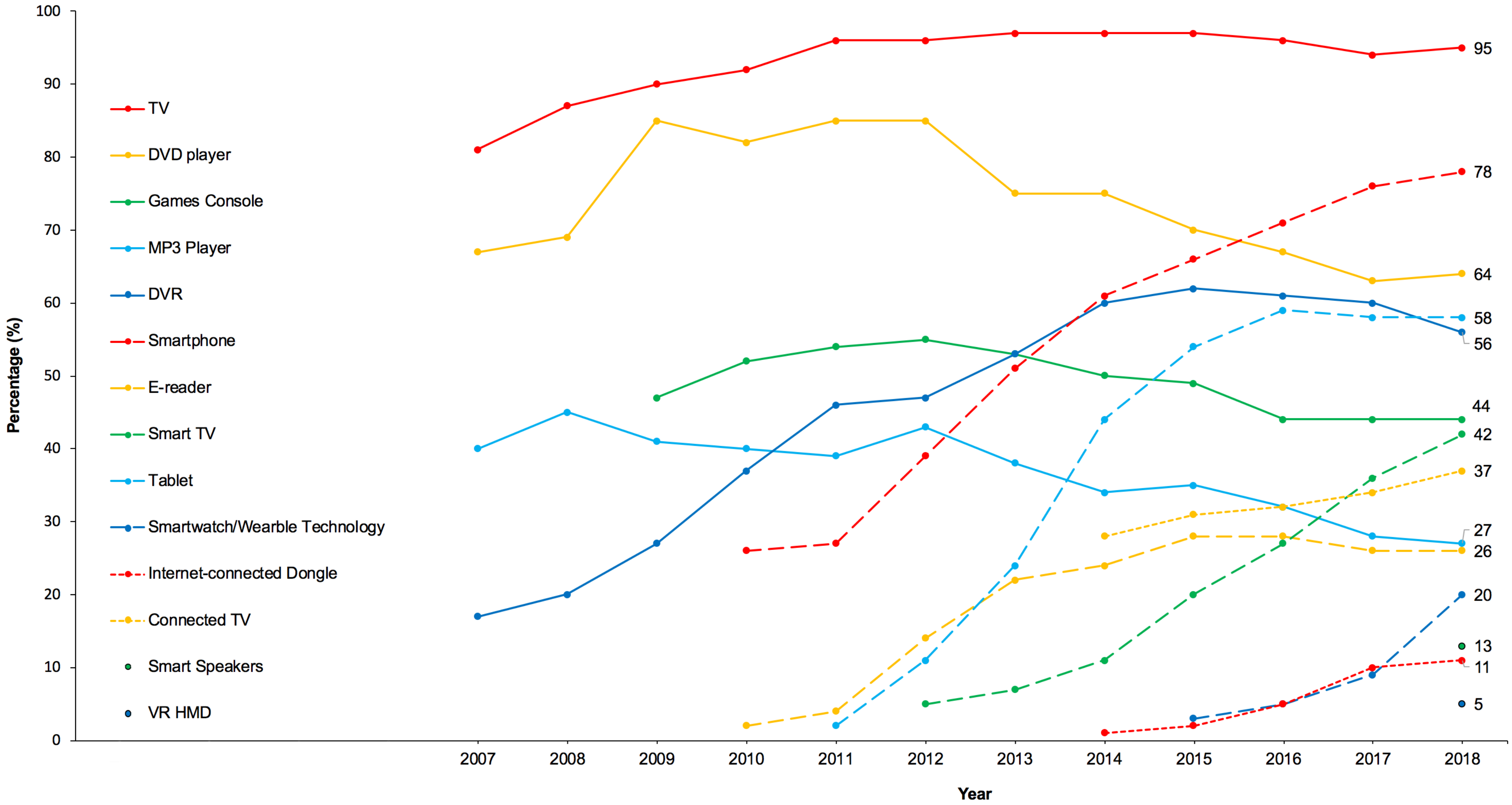

Figure 1.1. Household take-up of digital devices in the UK (2007–18).

This is a view that is echoed by many in the research community, who have emphasised that the use of technology is an important future direction for physical activity intervention research (Gier et al., 2018; B. A. Lewis et al., 2017; Straker et al., 2018). Technology is often cited as a contributor to widespread sedentariness (Carson et al., 2016). Therefore, the notion of using technology to promote physical activity might appear paradoxical to the reader. However, the rationale for this line of scientific inquiry is a simple one: There is evidence to suggest that it works.

1.4 Auditory Stimuli and Exercise

The digital revolution has ensured that music consumption is no longer restricted to live performances, physical recordings, or radio broadcasts (Krause, North, & Hewitt, 2015; Sinclair & Tinson, 2017; Vonderau, 2019). Conversely, music can be accessed via several of the digital devices depicted in Figure 1.1, such as mp3 players, smartphones, tablets, and smart speakers (Aguiar & Waldfogel, 2018). Accordingly, the reader will be unsurprised to hear that listening to music is frequently cited as a sedentary behaviour when coupled with sitting (Prince et al., 2017; Rhodes, Mark, & Temmel, 2012). Advances in audio technology have ensured that individuals have more opportunities to listen to music in contexts that were not previously associated with music use (Maasø, 2018). Such contexts are typically characterised by sedentary behaviours. For example, it has been reported that 27% of adults in the UK aged 18–34 years listen to online music streaming services during their commute to the workplace (Ofcom, 2018). Encouraging, advances in audio technology have also ensured that music can be easily implemented into the exercise context as a means by which to promote an enjoyable experience (Hallett & Lamont, 2015; Karageorghis, 2017).

The *Run to the Beat* series of half-marathons and 10 km races provide an example of a successful integration of music in exercise (Karageorghis, 2014). The event provided live music throughout the course, distracting participants' attention away from physical fatigue and helping them to maintain their motivation for the length of the race. The event has featured artists such as *Jessie J*, *Tinie Tempah*, and *Calvin Harris* and has attracted over 100,000 participants. Recently, Virgin Radio broadcaster and multiple London Marathon finisher Chris Evans announced the launch of *RunFestRun*. The three-day festival is set to feature a line-up of well-known bands and DJs, as well as featuring a series of running routes from 2.5 km to the half-marathon distance.

In contemporary exercise facilities, music remains fundamental to popular classes such as BODYPUMP and Zumba, indicating that music has become more of a necessity than a luxury (Hallett & Lamont, 2015; Karageorghis, 2017). Additionally, music streaming services such as *Apple Music* regularly update a variety of "fitness" playlists that span several genres and are curated to stimulate a pleasurable exercise experience. Smartwatches, such as those recently developed by *Garmin*, can store music without any need for streaming/an internet connection. Accordingly, exercisers can listen to music through Bluetooth headphones without the need of a smartphone or mp3 player. Collectively, these examples support the notion that music is a viable stimulus within an exercise context (Clark, Baker, & Taylor, 2016a; Karageorghis, 2017).

1.5 Audio-Visual Stimuli and Exercise

Not only has the advancement of digital technology affected the way that we obtain and listen to music, it has also ensured that audio-visual stimuli is ubiquitous (Fan et al., 2018; LeBlanc et al., 2017). For example, it has been reported that 95% of households in the UK own a digital television (Ofcom, 2018), which allows for the consumption of a variety of audio-visual stimuli (e.g., music-videos, documentaries, news reports) from the comfort of one's own home. Although televisions once represented the predominant medium for audio-visual consumption, the comparatively more recent take-up in portable devices (e.g., smartphones, tablets; see Figure 1.1) has facilitated unprecedented access to audio-visual stimuli in any context where mobile data or a stable Wi-Fi connection are available (Burgess & Green, 2018; Wayne, 2018).

The widespread popularity of audio-visual stimuli is also evident within an exercise context (Karageorghis & Priest, 2012a, 2012b). Upon entering most contemporary exercise facilities, individuals are subjected to strategically placed television screens depicting messages that reinforce the benefits associated with the sustenance of a fitness regime. Furthermore, it is a common occurrence for individuals to engage in cardio exercise such as running or cross-training while simultaneously consuming audio-visual stimuli that are delivered via a personal device (Annesi, 2001). Workout videos, such as those found on *YouTube*, are increasingly popular with the masses and allow individuals to mirror the exercise depicted onscreen at a time and location convenient to them (Gier et al., 2018).

Audio-visual applications, such as *Zwift*, have been developed to enhance the pleasure derived from indoor cycle ergometry, which can be considered a relatively monotonous exercise modality (Cunha, Midgley, McNaughton, & Farinatti, 2016). The platform allows exercisers to peruse a variety of courses and then depicts a cyclist traversing the course at the user's pace. Similarly, *Peloton's* commercially available cycle ergometers come fully equipped with a personal screen that has the capacity to stream live exercise classes. This novel approach ensures that exercisers receive encouragement from instructors in real-time while tracking a range of performance metrics. Recently, companies such as *VirZOOM* and *Nordic Track* have developed audio-visual applications that can be used in combination with VR HMDs as a means by which to fully immerse individuals in a range of exercise experiences. It is evident that the application of audio-visual stimuli in the exercise context appears to be flourishing.

1.6 Statement of the Problem

The volume of those refraining to engage in regular physical activity is increasing and, simultaneously, individuals are choosing to partake in a variety of sedentary behaviours, many of which entail the use of technology (Castro et al., 2018; Parker et al., 2019; World Health Organization, 2018a). Listening to music has been described as a sedentary behaviour

(Prince et al., 2017; Rhodes et al., 2012). Nonetheless, researchers have demonstrated that music has the potential to promote an enjoyable exercise experience (Hallett & Lamont, 2015; Karageorghis, 2017). Early music-exercise research was plagued with methodological weaknesses and often adopted an atheoretical approach, which contributed to inconsistent findings (Karageorghis & Terry, 1997). The subsequent development of theory and conceptual frameworks has enabled research that is of a higher quality, enhancing our understanding of the scientific application of music in exercise (Clark, Baker, & Taylor, 2016b; Karageorghis, 2016).

Despite increased accessibility of audio-visual stimuli (LeBlanc et al., 2017), their interactive effects within an exercise context have been subject to little empirical investigation (Karageorghis & Priest, 2012a, 2012b). Moreover, there is a paucity of research exploring the efficacy of recent consumer technology, such as VR HMDs, despite its rising popularity among exercisers. Similarly, there is a lack of conceptual frameworks to assist practitioners in the development of audio-visual interventions. Accordingly, it appears that this line of scientific inquiry is at its first critical juncture, in which there are two possibilities. Researchers can continue to adopt an atheoretical approach and accept the possibility of encountering the problems that plagued the early music-exercise literature (Karageorghis & Terry, 1997). Alternatively, the aforementioned shortcomings must be addressed; the development of theory that paves way for clear conceptual frameworks is essential if researchers and practitioners are to gain a greater understanding of audio-visual stimuli in applied exercise settings.

1.7 Overview of the Research Programme

The present programme of research seeks to further understanding of audio-visual stimuli within an exercise context, although the findings may also be relevant to the related domain of sports training and competition. A review of literature was conducted to facilitate a critical evaluation of the extant literature (see Chapter 2). Thereafter, the studies that comprise this programme of research follow a logical progression and fill a number of gaps in the knowledge base.

The purpose of the first study is to develop a substantive theory, grounded in empirical evidence, that explains and predicts the social process of exercising in the presence of a music-video channel (see Chapter 3). An exercise facility located in Cheltenham, Gloucestershire, is chosen as a suitable site for data collection and a grounded theory approach is employed as a "total" methodology throughout the entire research process (Corbin & Strauss, 2015; Weed, 2017). An iterative process of data collection and analysis is conducted until a substantive theory emerges that informs practitioners' use of music-video interventions, guides exercisers' music-video selections, and advances this line of scientific inquiry.

The second study uses the substantive theory developed in Chapter 3 to underpin an investigation into the psychological and psychophysical effects of audio-visual stimuli on indoor cycle ergometry (see Chapter 4). It has been suggested that a possible mechanism underlying the effects of audio-visual stimuli in an exercise context concerns *attentional dissociation* (Karageorghis, Ekkekakis, Bird, & Bigliassi, 2017). This refers to the way in which audio-visual stimuli can divert attention away from the unpleasant somatic sensations associated with strenuous exercise (Hutchinson & Karageorghis, 2013). Despite such suggestions, the effects of audio-visual stimuli during exercise has received scant research attention and warrant further investigation (Karageorghis & Priest, 2012a, 2012b). In addition to delivering audio-visual stimuli via traditional screen-based technology, a VR HMD is employed in order to examine the effects of 360-degree video footage during exercise. The dependent measures span affective (affective valence and perceived activation), perceptual (state attention and ratings of perceived exertion [RPE]), and enjoyment variables.

The third study in the research programme explores the psychological, psychophysical, and psychophysiological effects of music and VR on indoor cycle ergometry (see Chapter 5). Drawing upon the Dual-Mode Theory (DMT; Ekkekakis, 2003) of exercise-related affect and building upon the foundation laid in the second study, a commercially available cycle ergometer is employed that is specifically designed for use with VR HMDs (i.e., VirZOOM). A range of conditions help further understanding of the influence of music and VR singularly and in tandem. Moreover, an additional layer of complexity is achieved through the inclusion of heart rate variability (HRV) to elucidate the psychophysiological effects of audio-visual stimuli during aerobic exercise (Bigliassi, Greca, et al., 2019).

The final chapter provides the reader with a general discussion of the present programme of research (see Chapter 6). The main findings that emanate from each of the original studies contained herein are expounded and the points of convergence and divergence across the research programme are identified. Thereafter, relevant limitations are acknowledged before a range of practical implications and directions for future research are offered to the reader.

1.8 Operational Definitions

Key terms that are used throughout and/or open to multiple interpretations have been operationally defined in order to facilitate understanding of the subject matter.

Active synchronisation: This occurs when an individual or group is consciously aware of auditory-motor synchronisation (see Synchronous music; Karageorghis, Bigliassi, Guérin, & Delevoye-Turrell, 2018).

Affect: A neurophysiological state that is consciously accessible as a simple primitive nonreflective feeling most evident in mood and emotion but always available to consciousness (Russell & Feldman Barrett, 2009).

Affective phenomena: An umbrella term comprising the constructs affect, emotion and mood (Ekkekakis & Zenko, 2016b).

Affective valence: All states in which a person feels good or bad, including free floating pleasure and displeasure (Brand & Ekkekakis, 2018).

Arousal: Or perceived activation, a blend of physiological and psychological activity in a person which varies on a continuum from deep sleep to intense excitement. Arousal is not associated with either pleasant or unpleasant events (Weinberg & Gould, 2018).

Association: Regarded as turning attention towards bodily sensations, such as muscle tension and respiration rate (Morgan & Pollock, 1977).

Asynchronous music: Application of music in the background to accompany exercise without any *conscious* synchronisation between movement and music tempo (Karageorghis, Bigliassi, Guérin, et al., 2018).

Categories: Or themes, categories are higher-level concepts under which analysts group lower-level concepts according to shared properties within grounded theory research (Corbin & Strauss, 2015).

Codes: A core component of grounded theory research (Weed, 2017). Coding refers to extracting concepts from raw data and developing them with respect to their properties (i.e., defining characteristics) and dimensions (i.e., variations; Corbin & Strauss, 2015).

Concepts: A fundamental component of grounded theory research (Weed, 2017). Concepts are words that stand for ideas contained in data. Accordingly, codes are interpretations and the product of analysis (Corbin & Strauss, 2015).

Constant comparison method: A process of comparing incident with incident for similarities and differences when classifying grounded theory research data. As the analysis proceeds, comparisons are made across incidents and developing concepts, among concepts, and finally, between categories and existing theory (Corbin & Strauss, 2015).

Constructivism: In contrast to realism, constructivism is an ontological viewpoint that assumes reality is not singular, but rather there exists multiple realities created by individuals (Charmaz, 2017).

Contour: A musical term referring to the overall shape of the melody, taking only the pattern of “up and “down” into consideration (Levitin, 2008).

Dissociation: Regarded as turning attention away from bodily sensations and towards external distractions, such as audio-visual stimuli (Morgan & Pollock, 1977).

Emotion: Affective states that are elicited following the appraisal of a specific situation that is seen as having important implications for the wellbeing of an individual (Oatley & Johnson-Laird, 2014). Due to their high intensity, emotions are shorter in duration when compared to mood (Ekkekakis, 2013b).

Entrainment: Related to resonance, a process wherein two rhythmic processes interact with each other, eventually adjusting and locking in to a common phase or synchrony (Stevens, 2012).

Ergogenic: The enhancement of work output or engendering higher-than-expected power output, endurance, or productivity (Terry & Karageorghis, 2011).

Exercise: A subcategory of physical activity that is planned, structured, repetitive, and aims to improve or maintain one or more components of physical fitness (World Health Organization, 2018b).

Extramusical association: Extrinsic information that is produced in response to certain musical pieces. Such associations typically pertain to personal or communal experiences and can evoke emotions of the original listening episode (Juslin, 2013b).

Fit: A concept that helps evaluate the quality of grounded theory research. Fit pertains to how closely the concepts and substantive theory fit the incidents and phenomena they represent (Weed, 2017).

Grounded theory: A "total" methodology that provides a set of principles for the entire research process, from conceptualisation to the final product of the research (Weed, 2009).

Harmony: A musical term relating to the simultaneous combination of two or more notes. The degree of consonance within the harmony is important in shaping the affective character of the music. For example, a consonant combination of notes produces a pleasing sound whereas a dissonant combination of notes produces a displeasing sound (Levitin, 2008).

Heart rate (HR): The frequency at which the left ventricle of the heart pumps blood into the aorta artery (Shaffer, McCraty, & Zerr, 2014). The cardiac cycle is measured in beats per minute (bpm).

Heart rate variability (HRV): The change in time intervals between adjacent heartbeats (Shaffer & Ginsberg, 2017). Analysis of HRV allows for the identification of sympathetic and parasympathetic activity on the sinoatrial node.

Immersion: The technical capabilities of a system that allow a user to perceive through natural sensorimotor contingencies (Slater & Sanchez-Vives, 2016).

Interpretivism: In contrast to positivism, interpretivism assumes that direct knowledge of phenomena is not possible and that knowledge is gained via a process of interpretation (Weed, 2009).

Loudness: Or intensity, the volume or magnitude of sound, usually measured using a decibel (dBA) meter (Bishop, Wright, & Karageorghis, 2014).

Melody: A succession of single notes forming a distinctive sequence. Non-musicians often refer to the melody as the tune (Karageorghis, 2017).

Memos: A core component of grounded theory research that allows for ideas to be formally noted and included in the iterative analytical process (Corbin & Strauss, 2015; Weed, 2017).

Meter: A component of music that refers to how fast a piece of music feels irrespective of its tempo (Karageorghis, 2017). Accordingly, meter concerns how tones are grouped with one another over time (Levitin, 2008).

Modifiability: A concept that helps evaluate the quality of grounded theory research. Modifiability concerns the degree in which the generated substantive theory can accommodate further development or extension as a result of future empirical research (Weed, 2017).

Mood: A global and diffuse affective state of long duration and low intensity that frequently, but not always, lacks a specific object or cause (Ekkekakis & Zenko, 2016b). When moods are about an object, they share with emotion an appraisal of the environment. However, moods often concern the larger, pervasive, existential issues of one's life (Lazarus, 1991b).

Oudeterous: A Greek term used to describe music that is neither motivating nor demotivating (Karageorghis, Terry, & Lane, 1999).

Passive synchronisation: This refers to a motor process wherein a digital interface adapts the tempo of the music in real-time to match the movement rate of an individual or group (see Synchronous music; Karageorghis et al., 2018).

Perceived exertion: A subjective estimation of effort based on Borg's (1998) RPE scales. Psychological and physiological factors are considered equally responsible in determining one's perception of effort (Borg, 1998).

Physical activity: Any bodily movement produced by skeletal muscles that requires energy expenditure, including activities undertaken while working, playing, travelling, carrying out household chores and engaging in recreational pursuits (World Health Organization, 2018b).

Pitch: A component of music that concerns the subjective representation one has of the frequency of a sound (Levitin, 2008).

Positivism: In contrast to interpretivism, positivism assumes that it is possible to achieve direct knowledge of the world through objective observation of the investigated phenomena (Weed, 2009).

Pragmatism: A philosophical paradigm that views all knowledge as provisional in accord with its usefulness in a given context (Morgan, 2014).

Presence: The psychological sense of perceiving a virtual environment as their primary reality, as opposed to the physical world surrounding them (Bailenson, 2018).

Realism: In contrast to constructivism, realism is an ontological viewpoint that assumes the existence of a singular objective reality independent from individuals' perceptions of it (Charmaz, 2017).

Recuperative music: Refers to music that is used immediately after an exercise task and can be used to supplement *active* (i.e., movement-based) and *passive* (i.e., static) recovery (Terry & Karageorghis, 2011).

Relevance: A concept that helps evaluate the quality of grounded theory research. Relevance relates to the extent in which a substantive theory engages the real-world concerns of those involved in the processes it seeks to explain (Weed, 2017).

Respite music: Concerns music that is used during periods of recovery within an exercise session to assuage negative affective states (Jones, Tiller, & Karageorghis, 2017).

Reverberation: The perception of distance through which sound travels from the source to our ears (Levitin, 2008).

Rhythm: A component of music that concerns the way in which notes are distributed and accented (Karageorghis, 2017).

Resonance: Related to entrainment, resonance refers to an oscillation in a sound-producing body that occurs when the frequency of the sound source is close to the frequency of the body (Morehead & MacNeil, 1991).

Respiratory Compensation Point (RCP): A physiological term that marks the onset of hyperventilation during incremental exercise (Meyer, Faude, Scharhag, Urhausen, & Kindermann, 2004).

Sedative music: This type of music reduces the listener's arousal and usually lacks strong rhythmic and percussive elements (Karageorghis & Terry, 2011).

Sedentary behaviours: Behaviours that entail low energy expenditure (i.e., ≤ 1.5 METs), while in a sitting or reclining posture during waking hours (Sedentary Behaviour Research Network, 2012).

Sensitising concepts: A core component of theoretical sensitivity (see below) within grounded theory research. Sensitising concepts serve as points of departure that allow researchers to form loose interview questions and think analytically about the data obtained (Holt & Tamminen, 2010a).

Stimulative music: This type of music enhances the listener's arousal and promotes bodily action. Moreover, stimulative music is characterised by strong rhythmic and percussive elements (Karageorghis & Terry, 2011).

Substantive theory: The product of grounded theory research is a substantive theory that is applicable to a specific group and/or place (Corbin & Strauss, 2015). Nonetheless, it is possible to link substantive theories to create a formal grounded theory (Weed, 2017).

Symbolic interactionism: A form of interaction that occurs between individuals, entailing a process of interpretation. Accordingly, a "response" is not made directly to the actions of a person. Rather, a response is predicated on the meaning that a person attaches to such actions (Blumer, 1969).

Synchronous music: An application of music that contains synchronisation between rhythmical aspects of music and movement patterns (see Active synchronisation and Passive synchronisation; Karageorghis et al., 2018).

Syncopation: An unexpected rhythmic feel that occurs when the rhythmic emphasis is placed off the main beat (Karageorghis, 2017).

Tempo: The speed at which a piece of music is played, measured in bpm (Levitin, 2008).

Theoretical sampling: A method of data collection based on concepts/themes derived from data. Theoretical sampling helps refine and develop emerging theoretical concepts (Corbin & Strauss, 2015).

Theoretical saturation: This is reached within grounded theory research when the collection of new data seems counterproductive and does not add to the explanation of the phenomena under investigation (Willig, 2013).

Theoretical sensitivity: A key component of grounded theory research. Theoretical sensitivity ensures that researchers commence investigations with an awareness of the area, but without any preconceived notions about what they might find (Weed, 2009).

Timbre: A component of music that refers to the sound made by different instruments, irrespective of its pitch and intensity. Timbre allows us to distinguish, for example, between a French horn and vibraphone playing the same note (Karageorghis, 2017).

Ventilatory threshold (VT): An index of transition between aerobic–anaerobic metabolism during exercise, associated with an exponential increase in minute ventilation relative to an increase in oxygen consumption ($\dot{V}O_2$; Balady et al., 2010; Tempest & Parfitt, 2013).

Work: A concept that helps evaluate the quality of grounded theory research. Work refers to the extent in which a substantive theory can offer analytical explanations for processes within the context in which it is situated (Weed, 2017).

Chapter 2: Review of Literature

The present thesis examines the application of audio-visual stimuli in the exercise context. It is necessary for the reader to understand the paradigmatic lens through which the author views this line of academic research (Kuhn, 1962). Accordingly, this review commences with the critical evaluation of prominent theories that are predicated on the cognitive paradigm, that is presently dominant (Ekkekakis & Zenko, 2016a; Vealey, 2006). Thereafter, dual-process models are introduced as a means of explaining people's inability to consistently make rational behavioural decisions (Evans, 2014; Evans & Stanovich, 2013). A central theme throughout the present programme of research concerns affective responses, the study of which is characterised by considerable debate and confusion (Ekkekakis, 2013b; Ekkekakis & Zenko, 2016b). Hence, key affective terms are defined (i.e., affect, emotion, and mood), and measures of affective responses are critically evaluated.

The reader is presented with the notion of enhancing affective responses to exercise using audio-visual stimuli. The core components of music are expounded (e.g., tempo, harmony; Levitin, 2008), and the anatomy of the ear is introduced. Music is then considered within the domain of exercise and key studies and conceptual frameworks are critically appraised (Clark, Baker, & Taylor, 2016b; Karageorghis, 2016). Thereafter, the review focuses on the scientific application of audio-visual stimuli and initial research findings from an exercise setting are presented. A range of proposed mechanisms (e.g., attentional processing; Rejeski, 1985; Tenenbaum, 2001) underpinning the effects of audio-visual stimuli are then offered to the reader before the chapter closes with a rationale for the present programme of research.

2.1 Exercise Psychology

The study of exercise psychology focuses on enhancing our understanding of the psychological effects of acute and chronic exercise and the behavioural mechanisms of exercise adoption and maintenance (Biddle & Fuchs, 2009; Buckworth, Dishman, O'Connor,

& Tomporowski, 2013). Although the formal study of exercise psychology has a relatively short history, the ideas underlying the discipline can be traced back as early as 600 Before Common Era (Tipton, 2014). For example, the Indian physician Susruta is credited as the first physician to prescribe moderate-intensity exercise to his patients, suggesting that “it should be taken every day” (Tipton, 2014, p. 110). Furthermore, the Greek physician Herodicus (500 Before Common Era) practiced gymnastic medicine and predicated his treatments on vigorous exercise (Kollesch, 1989). Hippocrates, who is considered the father of medicine, was the first physician to provide a written prescription for exercise as a means of treating mental illness (Buckworth et al., 2013; Tipton, 2014).

Exercise psychology originated from the parent disciplines of psychology (i.e., the study of cognitions) and exercise science (i.e., the study of all sport- and exercise-related concepts). Furthermore, exercise psychology is considered to have multiple sister disciplines such as rehabilitation psychology, health psychology, behavioural medicine and sport psychology (Lox, Martin Ginis, & Petruzzello, 2017). It has been suggested that the slower emergence of exercise psychology, compared to its sister discipline sport psychology, can be attributed to the previously held belief that well-being was a physiological concept as opposed to a psychological one (Vealey, 2006).

William P. Morgan of the University of Wisconsin-Madison is often cited as the founder of exercise psychology (Buckworth et al., 2013; Dishman & O’Connor, 2005). Morgan conducted several influential studies during the 1970s in areas including anxiety (Morgan, Roberts, & Feinerman, 1971), perceived exertion (Morgan, 1973) and exercise adherence (Morgan, 1977). It is noteworthy that many of the topics that Morgan researched almost 50 years ago (e.g., the use of exercise as an antidepressant; Morgan, Roberts, Brand, & Feinerman, 1970) remain the focus of contemporary empirical investigation (e.g., Ekkekakis, Hartman, & Ladwig, 2018).

The writings of Morgan helped lay the foundations for the inception of exercise psychology as a formal discipline in the 1980s, as the general population became receptive to the notion that its collective behaviour had to change as a means of extending and improving quality of life (Lox et al., 2017). This epoch was characterised by the "fitness craze" which saw individuals engaging with weight training, aerobics, and jogging in order to attain a lean physical appearance that was deemed preferable by society (Ekkekakis & Brand, 2019). In 1988, the *Journal of Sport Psychology* was renamed the *Journal of Sport & Exercise Psychology,* reflecting the notion that exercise had become a viable domain for scientific inquiry (Vealey, 2006). Furthermore, an increase in exercise psychology research over the past 20 years has led to the creation of several new journals (e.g., *Psychology of Sport and Exercise* in 2000, *Sport, Exercise, and Performance Psychology* in 2012).

Despite a rapidly growing field of scientific research, Ekkekakis and Zenko (2016a) advised that the progress of the discipline should also be measured according to its societal relevance and impact. The researchers identified that other subdisciplines of exercise science (e.g., biomechanics) have produced knowledge that has resulted in norms that are practiced on a global scale, such as teaching individuals to bend their knees when lifting heavy objects (Ekkekakis & Zenko, 2016a). Following an ad hoc meta-meta-analysis of physical activity promotion trials, Ekkekakis and Zenko (2016a) found that the majority of pooled effects was "small". Accordingly, it appears that there is considerable scope for exercise psychologists to increase the number of individuals who are able to sustain high levels of physical activity and exercise.

2.1.1 Prominent theories. In order to fully comprehend the conceptual framework that underpins the present programme of research, the reader is firstly acquainted with prominent theories from the domain of exercise psychology. Theories are important because they can be used as a foundation for exercise-related interventions and they also allow researchers to predict exercise behaviours (Lox et al., 2017). Nonetheless, it appears that researchers have typically drawn upon a limited set of theories as a means of understanding and changing exercise behaviour (Ekkekakis, Zenko, Ladwig, & Hartman, 2018). Such theories include the Social Cognitive Theory (SCT; Bandura, 1977, 1986, 1997, 2001), the Reasoned Action Approach (RAA; Ajzen, 1991; Fishbein & Ajzen, 1975, 2010), the Self-Determination Theory (SDT; Deci, 1975; Deci & Ryan, 1985, 2002; Ryan & Deci, 2017), and the Transtheoretical Model (TTM; Prochaska & DiClemente, 1983; Prochaska, DiClemente, & Norcross, 1992).

2.1.1.1 Social Cognitive Theory. The SCT represents the evolution of Social Learning Theory and can be attributed to the work of clinical psychologist Albert Bandura (1977, 1986, 1997, 2001). An underlying premise of SCT is that human functioning is the product of reciprocal interactions among three factors: interpersonal influences, behaviours that individuals engage in, and environmental factors (see Figure 2.1; Bandura, 2013). Accordingly, when viewed through the lenses of SCT, individuals are considered actors as well as products of their environment (Luszczynska & Schwarzer, 2005).

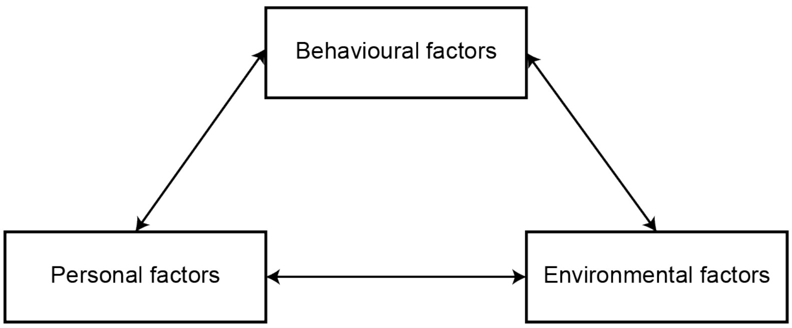

Figure 2.1. Reciprocal interactions in Social Cognitive Theory. Adapted from "Social Cognitive Theory and Motivation," by D. H. Schunk and E. L. Usher, in R. M. Ryan (Ed.), *The Oxford Handbook of Human Motivation* (p. 14), 2012, New York, NY: Oxford University Press. Copyright 2012 by Oxford University Press.

The causal structure underlying SCT is presented in Figure 2.2. According to the theory, behavioural change is initially realised through a personal sense of control. Therefore, unless individuals believe that they can produce desired behaviours, they have little incentive to initiate activities or persevere in the face of adversity (Bandura, 2013). The concept *self-efficacy* is used within SCT to reflect the belief that an individual can employ the skills necessary to meet the demands of a challenging situation by means of adaptive action (Hamilton, Warner, & Schwarzer, 2017; Luszczynska & Schwarzer, 2005). It is important to note that self-efficacy does not simply concern a generic perception of one's abilities (Lox et al., 2017). Rather, self-efficacy refers to a situation specific form of confidence to undertake a particular behaviour according to an individual's current abilities.

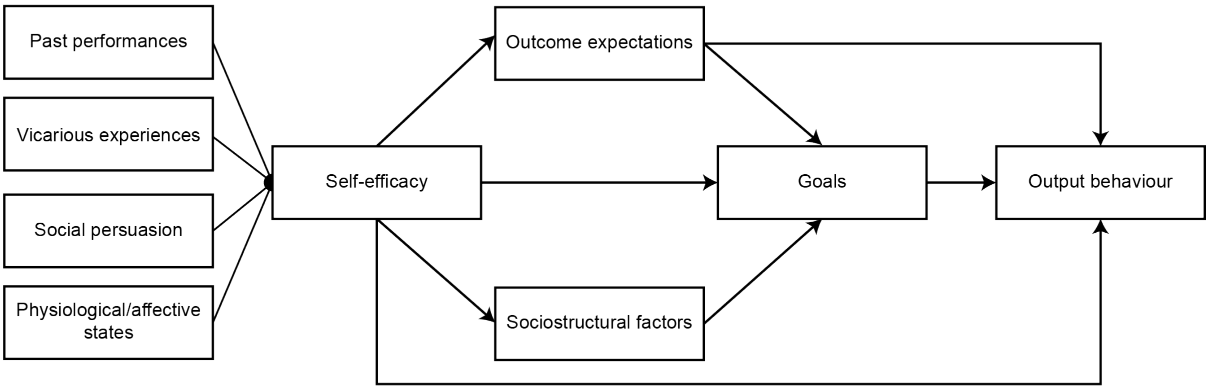

Figure 2.2. An illustration of Social Cognitive Theory. Adapted from "Cultivate self-efficacy for personal and organizational effectiveness," by A. Bandura, in E. A. Locke (Ed.), *The Blackwell Handbook of Principles of Organizational Behavior* (p. 121), 2000, Oxford, UK: Blackwell. Copyright 2000 by Blackwell.

Bandura (1977) postulated four sources of information that serve to enhance self-efficacy (see Figure 2.2). *Past performances* represent the most effective means of increasing self-efficacy and refer to activities that are similar to the proposed behaviour where the individual has experienced some degree of success (Bandura, 2013). To illustrate, an individual that is about to embark on an exercise programme is theorised to derive self-efficacy if they have successfully initiated an exercise programme in the past.

The second source of self-efficacy is *vicarious experiences*, also referred to as social modelling (Bandura, 2013). When a model person successfully masters a difficult situation, social comparison processes can enhance self-efficacy in the viewer (Luszczynska & Schwarzer, 2005). It is noteworthy that the influence of this social comparison process is mediated according to the degree of similarity between the viewer and model. For example, if a postnatal woman wishes to engage in exercise, she is likely to derive self-efficacy if she attends an exercise class with other postnatal women. Researchers have also demonstrated that virtual models (i.e., avatars) can positively impact exercise behaviour (Fox & Bailenson, 2009).

Social persuasion represents the third source of self-efficacy and refers to verbal and non-verbal messages used by others as a means of strengthening an individual's self-efficacy (Bandura, 2013). Accordingly, if previously inactive individuals are encouraged that they have what it takes to succeed in an exercise context (e.g., "I know you can do this"; Bandura, 1997), they are more likely to exert greater effort which promotes the probability of success. Social persuasion is most potent when it originates from a credible source (e.g., a significant other or knowledgeable person), because it enhances the individual's belief that success is attainable (Schunk & Usher, 2012).

Finally, individuals are theorised to rely on their *physiological and affective states* when judging their self-efficacy (Bandura, 2013). For example, if an individual enters an exercise context and experiences a rapid increase in HR (i.e., a physiological state) and feelings of threat (i.e., affective states), their self-efficacy is proposed to decrease as they begin to doubt their capabilities (Lox et al., 2017). Conversely, if an individual enters an exercise environment and experiences positive affective states (e.g., happiness, joy), they are likely to derive higher self-efficacy of mastering the situation (Luszczynska & Schwarzer, 2005).

According to SCT, an individual's *output behaviour* is influenced by self-efficacy, outcome expectancies, socio-structural factors, and goals (see Figure 2.2; Bandura, 2000). *Outcome expectancies* refer to the expected consequences of an individual's actions and can be organised along three dimensions: (a) area of consequence; (b) positive or negative consequence; and (c) short-term or long-term consequence (Luszczynska & Schwarzer, 2005). The area of consequence comprises physical outcome expectancies (e.g., "If I engage in regular exercise, I will improve my physical self-appearance"), social outcome expectancies (e.g., "If I engage in regular exercise, I will make new friends"), and self-evaluative outcome consequences (e.g., "If I engage in regular exercise, I will feel good about myself"; Bandura, 2000). Individuals are theorised to develop outcome expectancies based on previous experience and the observations of others (Bandura, 1986).

Socio-structural factors refer to the barriers (i.e., impediments) and opportunities (i.e., facilitators) that face individuals when attempting to adopt the desired behaviour (Bandura, 2000). Self-efficacy is proposed to play a key role in determining how individuals view socio-structural factors within their lives (Luszczynska & Schwarzer, 2005). To illustrate, self-efficacious individuals who plan to engage in regular exercise might focus on environmental cues that serve as opportunities for such behaviour (e.g., cycle paths or parks). On the contrary, individuals who have less exercise-related self-efficacy might focus on the environmental cues that impede their intended behaviour (e.g., the lack of a gym in the local community).

Individuals motivate themselves in the pursuit of desired behaviours through the use of *goals* (Bandura, 2000). Positive self-evaluations of progress towards goals are theorised to strengthen self-efficacy and maintain motivation (Schunk & Usher, 2012). However, it should be noted that the influence of goals are dependent on their properties: (a) specificity, (b) level of challenge, and (c) temporal proximity (Bandura, 2013). Goals that specify the type and amount of effort required to succeed are proposed to influence motivation to a greater extent than generic goals (e.g., "Do your best"; Bandura, 1986). Furthermore, goals should be challenging yet achievable, as opposed to being too easy or difficult to attain (Bandura, 2013). With regards to temporal proximity, long-term goals are suggested to be too distant to serve as current motivators (Bandura, 2000). Hence, short-term goals are advocated within SCT as they allow individuals to frequently determine their progress towards their objectives.

There is evidence to suggest that the SCT can account for almost one-third of the variance in physical activity behaviour (Young, Plotnikoff, Collins, Callister, & Morgan, 2014), meaning that the SCT can be considered a useful framework for intervention design ($R^2 \geq 0.30$; Baranowski, Anderson, & Carmack, 1998). Self-efficacy, the primary explanatory construct within the SCT, has been shown to be a robust predictor of physical activity behaviour (Bauman et al., 2012; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017). A strength of self-efficacy is that it explains why individuals are motivated to perform physical activity behaviours, as opposed to simply predicting which individuals are likely to engage in such behaviour (Williams & Rhodes, 2016). Moreover, the sources of self-efficacy are offered within the SCT and can be used as the foundation for physical activity interventions. However, a weakness of self-efficacy is that its ability to predict behaviour is greatly reduced as exercise behaviour becomes habitual (Lox et al., 2017). Accordingly, the application of SCT might be most potent at the preparation phase of exercise, when individuals perceive exercise as a challenging endeavour.

2.1.1.2 Reasoned Action Approach. The RAA was proposed by Martin Fishbein and Icek Ajzen (2010) as a means of predicting and changing human social behaviour. The RAA has a substantial history that spans over 40 years of development; the original formulation was termed the Theory of Reasoned Action (TRA; Fishbein & Ajzen, 1975) and sought to enhance our understanding of the relationships between attitudes, intentions, and behaviours (see Figure 2.3). A fundamental premise of the TRA is that *behavioural intentions* are the main predictor of whether a person will engage in a specific volitional act (Downs & Hausenblas, 2005; Jeffries, 2013). Behavioural intentions are theorised to consist of attitudes towards performing the behaviour and subjective norms associated with a behaviour (Fishbein & Ajzen, 1975).

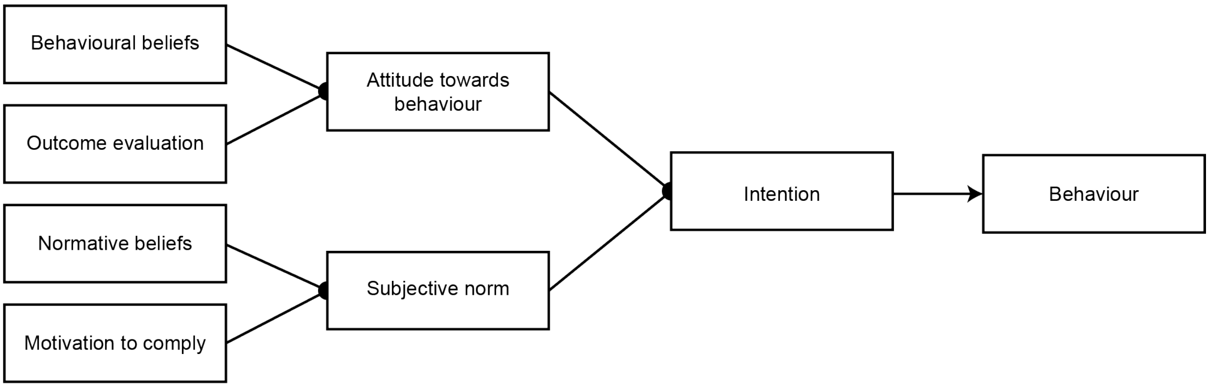

Figure 2.3. An illustration of the Theory of Reasoned Action. Adapted from *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research* (p. 16), by M. Fishbein and I. Ajzen, 1975, Reading, MA: Addison-Wesley. Copyright 1975 by Addison-Wesley.

Attitudes refers to an individual's positive or negative thoughts pertaining to the performance of a behaviour and is thought to be influenced by two factors: (a) an individual's belief about the consequences of performing the behaviour; and (b) an evaluation (i.e., positive or negative) of the consequences (Montaño & Kasprzyk, 2015). Accordingly, if an individual has strong beliefs that positively valued consequences will arise from the execution of a behaviour, then they are likely to hold a favourable attitude towards the behaviour. Conversely, if an individual has strong beliefs that negatively valued consequences will ensue, they are likely to obtain a negative attitude towards the target behaviour. Hence, attitude is suggested to comprise cognitive and affective components (Lox et al., 2017).

Subjective norms refer to the extent to which an individual feels social pressure to perform the behaviour and is considered to be influenced by two factors: (a) whether significant others will approve or disapprove of performing the behaviour, and (b) motivation to conform with the perceived expectations of significant others (Montaño & Kasprzyk, 2015). Hence, an individual who believes that significant others think they should perform a particular behaviour and is motivated to comply with their expectations will hold a positive subjective norm. Conversely, an individual who perceives that others think they should not perform a particular behaviour are likely to hold a negative subjective norm. In this instance, if an individual is not motivated to comply with the expectations of others, they are likely to hold a relatively neutral subjective norm.

The TRA assumes a causal chain, wherein attitudes and subjective norms are theorised to predict behavioural intentions, which subsequently predict individual behaviour (Fishbein & Ajzen, 1975). The success of the TRA in explaining behaviour is dependent on the degree to which the target behaviour is under volitional control (Ajzen, 2005). Consequently, researchers have raised concerns about the applicability of this theory in an exercise context, which often entails several behavioural barriers that prevent exercise being completely volitional (e.g., responsibilities to others; Smith & Biddle, 1999).

Moreover, the TRA (Fishbein & Ajzen, 1975) was originally developed to predict the behaviour of voters, which represents a single instance activity. Comparatively, exercise represents a repeatable behaviour that is executed over a prolonged period of time. Although intentions to exercise might predict an individual's behaviour in the immediate future, the TRA doesn't accurately predict long-term behaviour, given that the relationship between intentions and behaviours diminish over time (Lox et al., 2017). This is emphasised by the notion of the "revolving door phenomenon", wherein a large proportion of individuals dropout of exercise programmes within a couple of months of their inception (Dishman, 2001; Lind, Joens-Matre, & Ekkekakis, 2005).

Addressing the limitation that intentions might not represent the most effective means of predicting behaviour that is not completely volitional, Ajzen (1991) extended the TRA by adding the construct perceived behavioural control, formulating the Theory of Planned Behaviour (TPB; see Figure 2.4). *Perceived behavioural control* is influenced by two factors:

(a) control beliefs pertaining to the presence or absence of facilitators and barriers to executing the target behaviour, and (b) the perceived power of each facilitator or barrier to help or impede the behaviour (Montaño & Kasprzyk, 2015). Accordingly, perceived behavioural control bares close resemblance to Bandura's (1977) construct of *self-efficacy* (Ajzen, 2002, 2012).

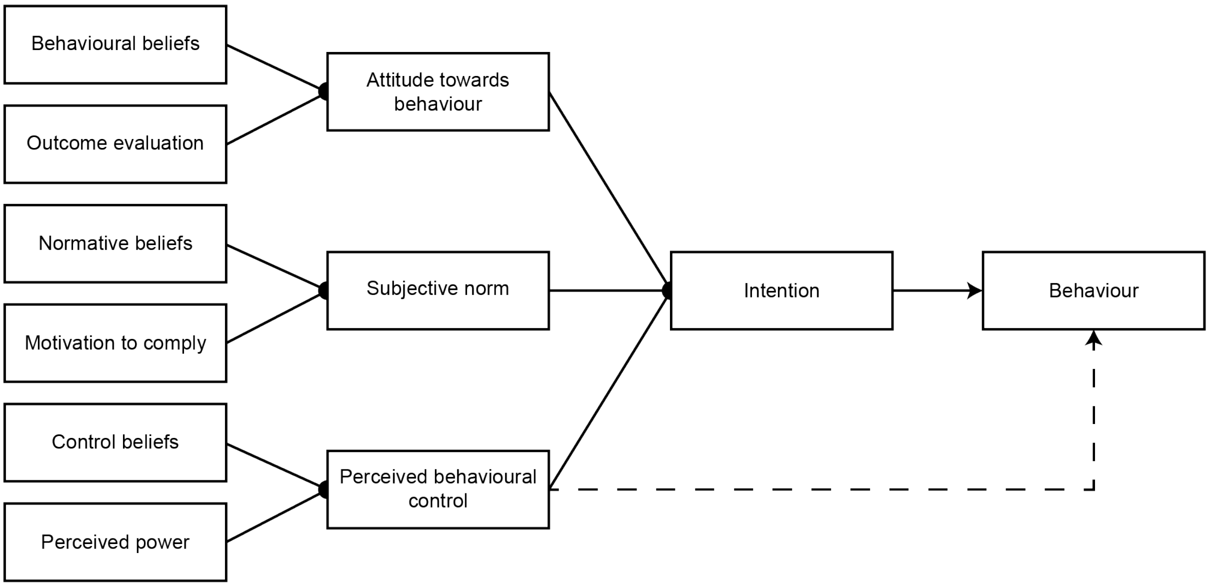

Figure 2.4. An illustration of the Theory of Planned Behaviour. Adapted from "The Theory of Planned Behavior," by I. Ajzen, 1991, *Organizational Behavior and Human Decision Processes, 50,* p. 182. Copyright 1991 by Academic Press.

The introduction of this construct is significant within the realm of exercise psychology, because the TPB (Ajzen, 1991) accounts for many of the barriers that individuals confront in the pursuit of sustained engagement with exercise (e.g., work, family, facilities; Lox et al., 2017). As a similarity to the construct self-efficacy (Bandura, 1977), if an individual perceives that they can overcome the potential barriers associated with exercise, they are more likely to perform the behaviour than if an individual believes their exercise-related behaviour is governed by external factors. According to the TPB (Ajzen, 1991), perceived behavioural control influences intention alongside attitudes and subjective norms.

Moreover, perceived behavioural control is theorised to predict behaviour independently when perceived control closely approximates actual control, as depicted by the dashed line in Figure 2.4 (Ajzen, 2005).

The RAA represents Fishbein and Ajzen's theory of behavioural prediction in its most current form (Fishbein & Ajzen, 2010; see Figure 2.5). The researchers acknowledged the limitation that the TBP did not address the origins of an individual's behavioural, normative, and control beliefs. Subsequently, the RAA includes a plethora of *background factors* that are suggested to potentially influence the beliefs that people hold. The background factors are subdivided into individual (e.g., personality, past behaviour), social (e.g., education, culture), and information (e.g., knowledge, media) variables. However, Fishbein and Ajzen (2010) emphasised that there is, potentially, an unlimited number of background factors that could influence an individual's beliefs.

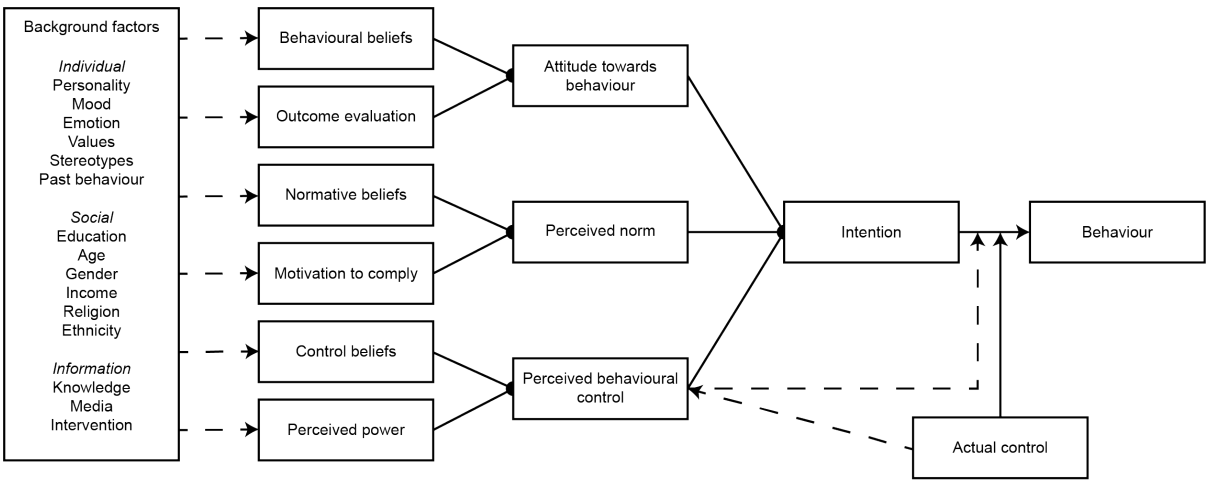

Figure 2.5. An illustration of the Reasoned Action Approach. Adapted from *Predicting and Changing Behavior: The Reasoned Action Approach* (p. 22), by M. Fishbein and I. Ajzen, 2010, New York, NY: Psychology Press. Copyright 2010 by Psychology Press.

Fishbein and Ajzen (2010) support the notion that the stronger the intention, the more likely it is that a target behaviour will be performed. Nonetheless, the researchers suggested that a lack of requisite skills or the existence of environmental constraints frequently prevents individuals from acting on their intentions. To this end, the RAA includes the construct *actual control* (see Figure 2.5), which is proposed to moderate the effects of intentions on behaviour. Essentially, intentions are theorised to be an accurate predictor of behaviour only in circumstances where individuals have actual control over the execution of a particular behaviour. Although measures for assessing an individual's actual control are scant, perceived behavioural control can be used as a proxy given that perceived control reflects actual control relatively well (Ajzen & Sheikh, 2013).

Evidence indicates that practitioners can employ the RAA as a means of predicting and understanding exercise behaviours. For example, McEachan et al. (2016) conducted a meta-analysis of the RAA for health behaviours, which included 41 tests pertaining to exercise and physical activity. The authors concluded that attitudes (i.e., experiential and instrumental), perceived norms (i.e., injunctive and descriptive), and perceived behavioural control (i.e., capacity) emerged as consistent predictors of intention. Moreover, intention, perceived behavioural control (i.e., capacity), attitudes (i.e., experiential), and norms (i.e., descriptive) emerged as predictors of behaviour (McEachan et al., 2016).

Acknowledging the limitation that RAA researchers have focused predominantly on aerobic exercise, Branscum and Fairchild (2019) evaluated the RAA with respect to both aerobic and muscle strengthening exercise. The researchers employed logistic and linear regression analyses and found that intentions predicted a significant amount of aerobic (14.9%) and muscle strengthening (30.7%) exercise. Furthermore, attitudes, perceived norms, and perceived behavioural control predicted a significant amount of aerobic (46.2–55.8%) and muscle strengthening (53.9–59.8%) exercise. Despite these findings, it is important to note that the RAA suffers from the same limitations as its predecessors, the TRA and TPB. Specifically, the efficacy of intentions to predict exercise behaviour is moderated by the time elapsed between the intention and the behaviour (Lox et al., 2017; McEachan et al., 2016).

2.1.1.3 Self-Determination Theory. The SDT is a macro-theory of human motivation proposed by Edward Deci and Richard Ryan that has evolved over the past 40 years in the form of six mini-theories (Deci, 1975; Deci & Ryan, 1985, 2002; Ryan & Deci, 2017). Fundamental to the SDT is that individuals strive to satisfy three basic psychological needs: (a) autonomy, (b) competence, and (c) relatedness (Ryan & Deci, 2017). *Autonomy* is characterised by a sense of choice and ownership over one's own behaviour. *Competence* refers to the feeling that an individual is capable of meeting the demands of the desired behaviour. Finally, *relatedness* is typified by meaningful connections or a sense of belonging with significant others (González-Cutre, Sierra, Beltrán-Carrillo, Peláez-Pérez, & Cervelló, 2018; Hancox, Quested, Ntoumanis, & Thøgersen-Ntoumani, 2018). Satisfying the three basic psychological needs has been theorised to facilitate more self-determined functioning in a given context, as well as promoting the development of resilience and enduring psychological health (Ryan & Deci, 2017).

Ryan and Deci (2017) make the distinction between two types of motivation. *Intrinsically* motivated behaviour refers to engagement for reasons of inherent enjoyment and interest (Deci & Ryan, 2002). Alternatively, *extrinsically* motivated behaviours are performed for some consequence such as the promise of a reward or social approval (Deci & Ryan, 2002; Teixeira, Carraça, Markland, Silva, & Ryan, 2012). In addition, the term *amotivation* is proposed as a non-self-determined factor referring to an absence of motivation or lack of intention to engage in a particular activity (Ryan & Deci, 2017). Within an exercise context, individuals might be amotivated for several reasons, including a perceived lack of ability or the belief that exercise is unimportant (Lox et al., 2017).

Cognitive Evaluation Theory (CET; Deci & Ryan, 1980, 1985) was developed to explain the processes through which events in the social environment (e.g., rewards, punishments, feedback) impact intrinsic motivation (Ryan & Deci, 2017). The concept *perceived locus of causality* refers to an individual's perception of why they engage in a given behaviour and is closely related to the basic psychological need for autonomy (Ryan & Deci, 2000). Social-contextual events that promote an internal locus of causality (i.e., participation out of free choice) are theorised to increase feelings of autonomy and enhance intrinsic motivation. Conversely, events that promote an external locus of causality (i.e., participation because an individual is compelled to do so) are suggested to thwart autonomy and decrease intrinsic motivation (Ryan & Deci, 2017). Moreover, social-contextual events are proposed to affect intrinsic motivation according to the degree to which they impact an individual's *perceived competence* (Deci & Ryan, 1980, 1985). Accordingly, social-contextual events that promote perceived competence are suggested to facilitate intrinsic motivation whereas events that undermine perceived competence are theorised to hinder intrinsic motivation (Ryan & Deci, 2017).

Deci and Ryan (1985) suggested that the effects of social-contextual events are dependent on how an individual interprets them. Therefore, such events were proposed to have three key aspects, each with a functional significance for the recipient (Ryan & Deci, 2017). Events that are deemed *informational* help individuals interact effectively within an environment and are suggested to promote an internal locus of causality and perceived competence, thereby raising intrinsic motivation. Events that are deemed *controlling* pressure people to think or act in particular manner and are suggested to facilitate an external locus of causality, thereby undermining intrinsic motivation. *Amotivating* aspects facilitates perceived incompetence, thereby promoting amotivation.

Organismic Integration Theory (OIT; Deci & Ryan, 1985) was developed to explain the complex phenomenon of *internalisation*, which pertains to the process in which individuals internalise extrinsic motivations that are valued by significant others (Deci & Ryan, 2002; Gunnell, Crocker, Mack, Wilson, & Zumbo, 2014). Regulations that are more internalised are proposed to elicit an internal perceived locus of causality, meaning that individuals are likely to experience autonomy. In contrast, regulations that are less internalised are proposed to elicit an external locus of causality, resulting in behaviours that are considered more dutiful (Ryan & Deci, 2017).

Deci and Ryan (1985) proposed the following four types of extrinsic motivation, which can be considered to range along a continuum of self-determination (see Figure 2.6). *Integrated regulation* is the most self-determined form of extrinsic motivation and refers to the process of engaging in a behaviour because it represents an individual's sense of self. *Identified regulation* describes extrinsic motivation that has been accepted as personally significant. *Introjected regulation* is proposed to reside in those who perform a particular behaviour as a result of self-imposed pressure (e.g., guilt or contingent self-worth). *External regulation* is the least self-determined form of extrinsic motivation and occurs when behaviours are performed as a means of attaining external rewards or gaining the approval of others (Deci & Ryan, 2002).

Within a health context, intrinsic motivation, integrated and identified regulations (commonly referred to as *autonomous motivation*; Deci & Ryan, 2008) have been associated with a range of adaptive outcomes (e.g., well-being, treatment adherence; Ntoumanis et al., 2018). Conversely, introjected and external regulation (commonly referred to as *controlling motivation;* Deci & Ryan, 2008) have been related to a range of maladaptive outcomes (e.g., a lack of behavioural engagement; Ntoumanis et al., 2018).

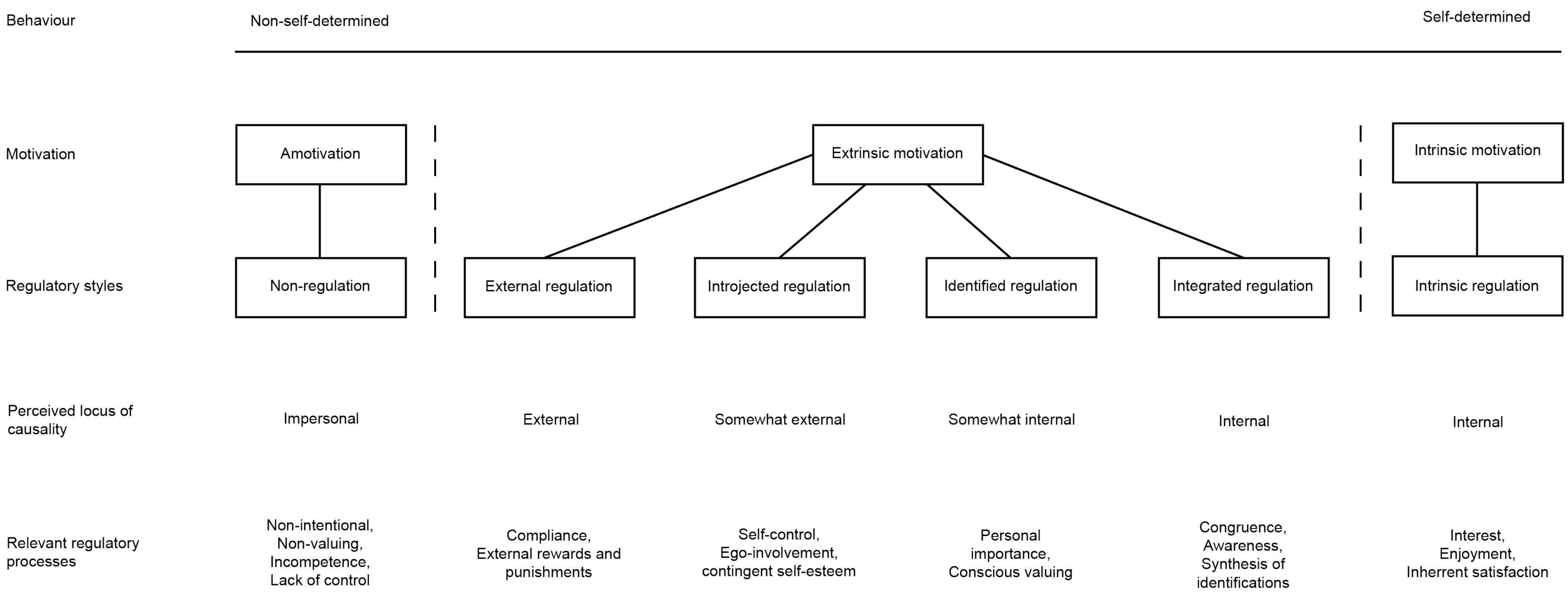

Figure 2.6. The Organismic Integration Theory taxonomy of regulatory styles. Adapted from "Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being," by R. M. Ryan and E. L. Deci, 2000, *American Psychologist, 55,* p. 72. Copyright 2000 by the American Psychological Association.

2.2.1.4 Transtheoretical Model. The TTM was developed by James Prochaska and colleagues (Prochaska & DiClemente, 1983; Prochaska et al., 1992) to help explain intentional behaviour change. The prefix *trans* means "across" and hence the TTM was given its name because it integrates elements *across* several leading theories of psychotherapy and behaviour change (Lox et al., 2017; Prochaska, 2008). Initially, the TTM was oriented towards smoking cessation. However, the model has since been employed in the context of exercise to further understanding of readiness to maintain physical activity behaviours (Sarkin, Johnson, Prochaska, & Prochaska, 2001).

According to the TTM, behaviour change is a progressive process through a series of five different stages of change (Prochaska, 2008). In the *precontemplation stage,* there is no intention to change behaviour in the foreseeable future (usually measured as the next 6 months; Prochaska & Norcross, 2018). Individuals in the precontemplation stage believe that the disadvantages associated with exercise far exceed the advantages and this might be attributed to a lack of information pertaining to a sedentary lifestyle or a history of failed attempts to initiate exercise (Lox et al., 2017).

In the *contemplation stage,* individuals have intentions to commence exercising within the next 6 months (Prochaska, 2008). Individuals in this stage understand the advantages and disadvantages associated with exercise but are not ready to make a commitment to take action (Lox et al., 2017). According to Prochaska and Norcross (2018), individuals in the contemplation stage can remain ambivalent for lengthy periods of time. Hence, it appears that contemplators will continue to evaluate their options pertaining to exercise behaviour, unless there is some form of intervention.

The third stage within the TTM is the *preparation stage,* whereby individuals intend to take action immediately (usually measured within the next month; Prochaska, 2008). Individuals in this stage of behaviour change believe that the advantages associated with exercise outweigh and the disadvantages. Accordingly, individuals start to make plans and undertake small behavioural changes (Prochaska & Norcross, 2018). Within an exercise context, individuals in the preparation stage might begin to enquire about local facilities and walk to work rather than take public transport or drive. Individuals should set appropriate goals and priorities within the preparation stage. Moreover, individuals should strive to dedicate themselves towards their devised action plan.

The *action stage* involves the most overt behavioural changes and therefore demands a substantial investment of time and energy (Prochaska & Norcross, 2018). Individuals in this stage of behaviour change are required to attain a criterion that is sufficient to reduce the risk associated with the problem behaviour (Prochaska, 2008). When applied to an exercise context, individuals in the action stage are likely to be engaged in at least 150 min of moderate aerobic activity and two strength-based workouts per week (Department of Health, 2011). Despite individuals continuing to believe that the advantages associated with exercise outweigh the disadvantages, the action stage is the most unstable owing to the difficulty of maintaining a new exercise routine (Lox et al., 2017). Accordingly, individuals are required to maintain persistent effort to reduce the likelihood of lapsing back into a sedentary lifestyle.

The final stage of the TTM is the *maintenance stage,* which is achieved when the recommended levels for health and fitness have been met for a minimum of six months (Prochaska, 2008). Individuals in this stage continue to believe that exercise-related pros outweigh the cons. Moreover, individuals are likely to find exercise easier in the maintenance stage when compared to the action stage and are increasingly confident that they can sustain the desired behaviour (Lox et al., 2017; Prochaska, 2008).

The five stages of change can be employed by exercise practitioners in order to help them explain *where* individuals are located in terms of their motivation. However, the stages of change do not offer any advice pertaining to *how* to motivate individuals or *why* they proceed through the stages (Romain, Caudroit, Hokayem, & Bernard, 2018). To this end, the TTM supports the notion that the transition across the stages of change is mediated by the following three constructs: (a) decisional balance, (b) self-efficacy, and (c) processes of change (Lipschitz et al., 2015).

Based on Janis and Mann's model of decision making (1977), *decisional balance* refers to the perceived advantages and/or disadvantages associated with the decision to undertake exercise (Prochaska et al., 1994; Williams, Lewis, et al., 2008). Figure 2.7 illustrates the decisional balance process categorised by each stage of change. The pros associated with behaviour change increase across the stages and often peak in the action stage (Prochaska, 2008). Conversely, the cons of change decrease with each advancing stage. In the contemplation stage, the pros and cons are essentially equal, reflecting the ambivalence that characterises this stage of change (Prochaska, 2008). Exercise practitioners can ask individuals to list the pros and cons associated with exercise as a means of checking their progress through the stages of change.

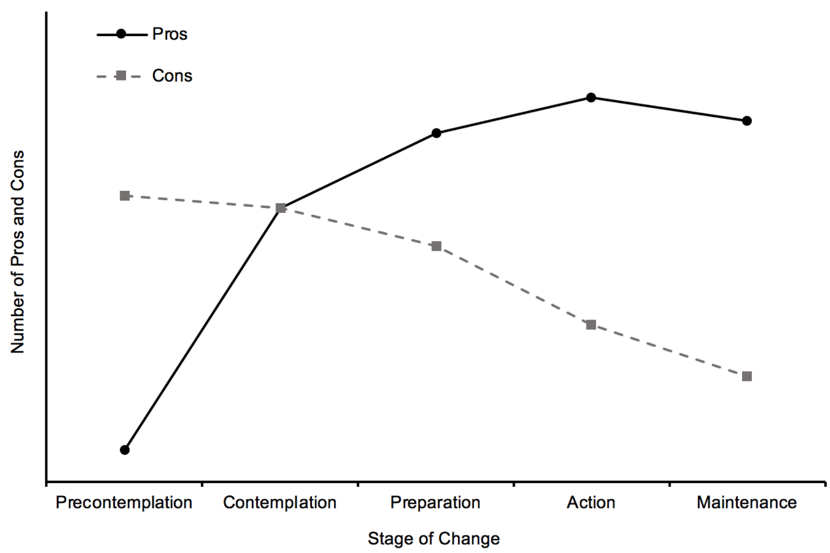

Figure 2.7. The decisional balance associated with the stages of change. Adapted from "Decision Making in the Transtheoretical Model of Behaviour Change," by J. O. Prochaska, 2008, *Medical Decision Making, 28,* p. 847. Copyright 2008 by Sage.

Self-efficacy, a component of SCT (Bandura, 1977), reflects the level of confidence that an individual has in their ability to successfully exercise in the face of challenging situations (Velicer, Diclemente, Rossi, & Prochaska, 1990). Situations that might cause an exerciser to lapse into their old sedentary ways include a heavy workload, family commitments, or adverse weather conditions. According to the TTM, an individual's self-efficacy increases with stage progression (see Figure 2.8). Hence, individuals have the lowest self-efficacy in the precontemplation stage and the highest in the maintenance stage. Moreover, a dramatic increase in self-efficacy is expected when transitioning from preparation to action phases, due to the accumulation of exercise-related mastery experiences (Lox et al., 2017).

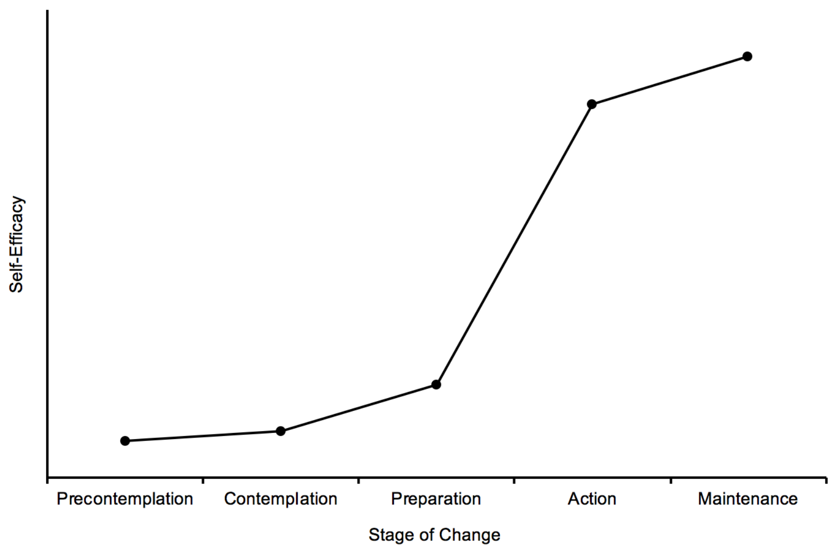

Figure 2.8. Self-efficacy associated with the stages of change. Adapted from *Psychology of Exercise: Integrating Theory and Practice* (p. 83), by C. L. Lox, K. A. Martin Ginis, and S. J. Petruzzello, 2017, New York, NY: Routledge. Copyright 2014 by Taylor & Francis.

Prochaska and DiClemente (1983) proposed 10 basic *processes of change,* which refer to the covert and overt activities that individuals employ in order to progress through the stages (Prochaska & Velicer, 1997; Williams, Lewis, et al., 2008). The processes of change were organised into two higher-order categories: experiential and behavioural (see Table 2.1). *Experiential processes* are those that result in the gathering of exercise-related information. For example, *consciousness raising* involves enhancing awareness and understanding of the benefits associated with exercise (Prochaska & Velicer, 1997). Hence, suitable interventions might include education or feedback from a previously sedentary individual. Alternatively, *behavioural processes* are used to modify the environment to help encourage exercise behaviour. For example, *helping relationships* refer to a process of drawing upon others' support during attempts to exercise (Prochaska & Velicer, 1997). Therefore, appropriate interventions might include building rapport with others in the environment or exercising with a friend. There is evidence to suggest that exercisers employ a combination of experiential and behavioural processes across all stages of change (Marshall & Biddle, 2001; Romain et al., 2018).

A strength of the TTM is that it was designed to reach individuals at all stages of readiness to engage in behaviour change (Prochaska, 2008). Hence, the TTM treats behaviour change as a dynamic process, as opposed to an "all or nothing" phenomenon (Marshall & Biddle, 2001, p. 229). Moreover, the intuitive nature of the TTM allows practitioners to subdivide large segments of the population according to their stage of change (Lox et al., 2017).

A critical limitation of the TTM is that its constructs (i.e., decisional balance, self-efficacy, processes of change) cannot reliably predict which stage of change an individual will move to and when (Bandura, 1997). For example, it is possible that an individual could go from being completely sedentary (i.e., contemplation stage) to meeting the recommended guidelines for health and fitness (i.e., action stage), in which case they would have omitted the preparation stage. Moreover, the 6-month timeframe that is required for individuals to progress from action to maintenance stages has been described as unjustifiable and arbitrary (Bandura, 1997). Consequently, researchers have argued that the TTM should not be used to help guide behavioural interventions (West, 2005). However, it is important to note that researchers have mostly cherry picked one or two constructs of the TTM when designing physical activity interventions (Romain et al., 2018).

Table 2.1

Processes of Change and Their Definitions

Processes of Change	Definition
Experiential processes of change	
Consciousness raising	Seeking new information and raising awareness of exercise
Dramatic relief	Addressing the affective aspects associated with and without exercise
Self-re-evaluation	Cognitive or emotional appraisal of one's self-image with and without regular exercise
Environmental re-evaluation	Considering the impact of exercise on individual's social and physical environment
Social liberation	Raising awareness of the social norms that encourage individuals to exercise
Behavioural processes of change	
Self-liberation	Engaging in activities that help commitment to change and believing in this commitment
Counter-conditioning	Replacing sedentary activities with physical activities
Stimulus control	Removing cues for sedentary behaviour and adding prompts that encourage exercise
Contingency management	Use of reinforcement and reward to sustain exercise behaviour
Helping relationships	Drawing upon the support of caring others during attempts to exercise

2.1.2 The cognitive paradigm. A commonality across the aforementioned prominent theories within exercise psychology is that they are all originate from the cognitive paradigm, which has prevailed as the dominant meta-theoretical perspective in psychology for the past 70 years (Ekkekakis & Zenko, 2016a; Vealey, 2006). A limitation associated with the cognitive paradigm is the assumption that an individual's decision to engage in a specific behaviour is based on a rational decision-making process (Lox et al., 2017). Accordingly, the most prominent theories within exercise psychology are predicated on the assumption that individuals collect, rationally evaluate, and act upon information that promotes their greatest self-interest (i.e., staying alive, healthy, and happy; Ekkekakis, 2017; Fishbein & Ajzen, 2010).

Under the cognitive paradigm, instances of irrational behaviour can be attributed to a breakdown of the information-processing system, which can be rectified by supplying the individual with more accurate or additional information, raising awareness, or correcting the individual's evaluation of the information available (Ekkekakis & Zenko, 2016a). The influence of the cognitive paradigm is undeniable within the practice of health promotion, which has largely followed a *rational educational* model (Weare, 2002). Interventions based on the rational educational approach are predicated on the assumption that if individuals are provided with accurate information pertaining to the anticipated benefits versus costs of the behaviour, they are expected to change their behaviour in the desired direction (Ekkekakis, Zenko, et al., 2018). For example, the UK Chief Medical Officers' *Start Active, Stay Active* report features a series of infographics in which the benefits of exercise feature prominently throughout the material (see Figure 2.9; Department of Health, 2011). These resources are readily available online to healthcare professionals under the premise that "many people don't realise that physical activity has significant benefits for health, both physical and mental" (Public Health England, 2018, para. 5).

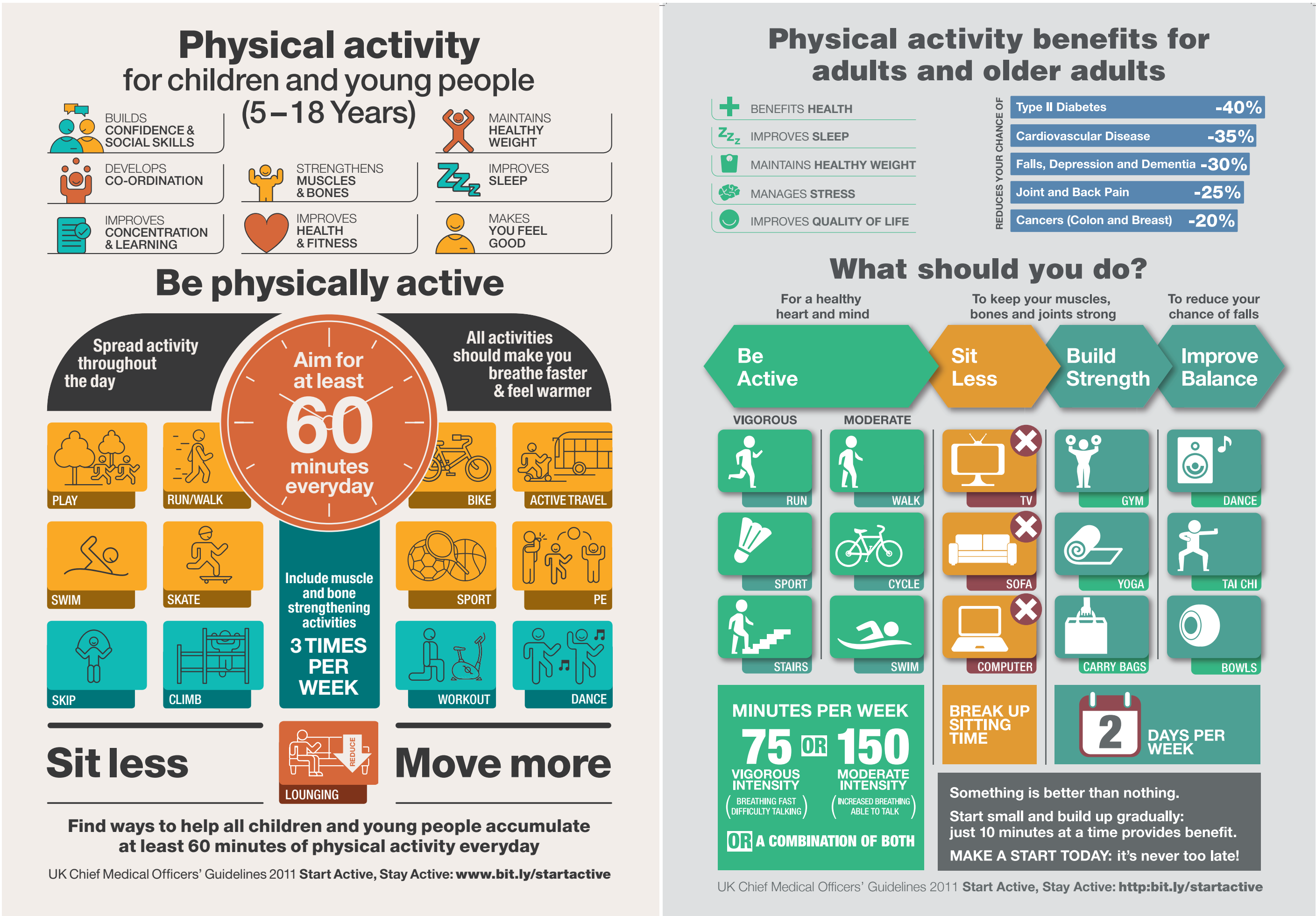

Figure 2.9. Physical activity infographics. Reprinted from "Start Active, Stay Active: Infographics on Physical Activity," by Department of Health, 2011, (https://www.gov.uk/government/publications). Copyright 2011 by the Crown.

Unfortunately, the available evidence does not support the assertion that individuals are unware of the health benefits associated with exercise. For example, Donovan and Shave (2007) administered a survey to 1191 individuals aged 16–65 years in the UK and found that 89% of men and 91% of women believed that regular physical activity conferred meaningful health benefits. Nonetheless, only 66% of men and 58% of women were found to meet the recommended guidelines for health and fitness in the UK (NHS Digital, 2018). In the USA, 97% of respondents of a telephone survey believed physical inactivity to be a health risk-factor that was at least somewhat important (Martin, Morrow, Jackson, & Dunn, 2000). However, self-report data indicated that only 51.7% of Americans meet the recommended levels for aerobic activity (Clarke, Norris, & Schiller, 2017). Therefore, it appears that individuals are aware of the benefits associated with physical activity and yet choose to refrain from engaging in it. Despite its ubiquity within the practice of health promotion, the rational education approach has been described as naïve, owing to the failure to take into account the constraints that prevent individuals from making decisions that result in healthy choices (Weare, 2002).

Bearing the above statistics into consideration, the assumptions underlying the cognitive approach appear to be flawed. Individuals frequently engage in behaviours that oppose their self-interests, despite possessing knowledge about the consequences of their actions. Recognising that individuals do not always make rational decisions, researchers have proposed the term *bounded rationality* (Simon, 1979). This concept supports the notion that individuals lack the reasoning ability to consistently make fully rational decisions (Shafir & LeBoeuf, 2002; Simon, 2000). Accordingly, individuals are more likely to "satisfice" (i.e., a combination of suffice and satisfy) instead of optimise during the decision-making process (Kahneman, 2003).

The idea that rationality is bounded was demonstrated in an exercise context by Zenko, Ekkekakis, and Kavetsos (2016). These researchers found that individuals altered their judgements of exercise by shifting an arbitrary anchor that did not provide participants with any additional information about the exercise bout. Moreover, it was reported that the preference for a target exercise session could be altered by the introduction of a decoy exercise option, opposing the assumption of rationality. Collectively, the findings support the notion that individuals' judgements and decisions do not follow basic rules of logic and probability. Given the cognitive paradigms inability to explain systematic mistakes and errors such as those reported by Zenko, Ekkekakis, and Kavetsos (2016), researchers are starting to conceptualise exercise behaviour using alternative paradigms that can capture such deviations from rationality, such as dual-process models (Ekkekakis, Zenko, et al., 2018).

2.1.3 Dual-process models. Dual-process models assert that there are two main types of cognitive processes involved in judgements and decision making (Pennycook, Neys, Evans, Stanovich, & Thompson, 2018; Stanovich & West, 2000). Researchers have used a variety of labels for each type of process in the extant literature (e.g., impulsive vs. reflective; Hofmann, Friese, & Wiers, 2008). However, the present programme of research employs the labels *Type 1* and *Type 2,* as such terms indicate distinct forms of processing while recognising that multiple neural systems might underlie them (Evans & Stanovich, 2013).

Type 2 processes are reflective, slow, conscious, involve mental simulation and require working memory (Evans, 2014; Evans & Stanovich, 2013). Judgements and decisions predicated on Type 2 processes involve careful consideration of the pros and cons of each available option and their associated consequences. Accordingly, the deliberate mental effort associated with Type 2 processes are reflected in current cognitive theories within the domain of exercise psychology. On the other hand, Type 1 processes are intuitive, fast, nonconscious, autonomous and do not require working memory (Evans, 2014; Evans & Stanovich, 2013). The automaticity of Type 1 processes mean that they often have the capacity to modify and bias Type 2 processes. Type 1 processes are proposed to be governed by *heuristics,* which refer to simplified rules of thumb or shortcuts that allow individuals to make judgements and decisions quickly (Evans & Stanovich, 2013; Rice, 2013).

2.1.4 Affect heuristic. Based on the hedonic principle (Kahneman, 1999), the affect heuristic asserts that individuals are likely to engage in behaviours that result in pleasure and avoid behaviours that result in displeasure. Hence, if a specific behaviour has resulted in feelings of pleasure and is positively evaluated by Type 2 processes, an individual is likely to engage in the behaviour. Alternatively, if a particular behaviour is not paired with feelings of pleasure or evaluated positively, then an individual is likely to refrain from the behaviour (Kahneman, 1999).

Despite several behaviours resulting in pleasure and often being evaluated positively by individuals (e.g., sleeping, eating), engagement in exercise appears to occupy an interesting space that has the potential to cause a conflict between Type 1 and Type 2 processes (Brand & Antoniewicz, 2016; Ekkekakis & Zenko, 2016a). To illustrate, individuals clearly understand the numerous physical and mental health benefits associated with exercise via conscious Type 2 processes (O'Donovan & Shave, 2007). Yet many individuals associate exercise with reductions in pleasure, owing to the inability to maintain a physiological steady state and a history of discomfort (Brand & Antoniewicz, 2016). Accordingly, the affect heuristic proposes that the automatic affective responses at the time of decision making influences the decision to engage or refrain from exercise (Ekkekakis & Zenko, 2016a). The mechanisms underlying the prevalence of physical inactivity might be illuminated by the recent finding that just 47% of children aged 11–18 years claimed to *enjoy* exercise (Youth Sport Trust, 2018).

The line of scientific inquiry examining the relationship between exercise-related affect and subsequent exercise behaviour remains at a nascent stage (Ekkekakis, Zenko, et al., 2018). Nonetheless, reviews of the extant literature indicate an association between pleasant affective responses and greater physical activity (Ekkekakis & Dafermos, 2012; Rhodes &

Kates, 2015). For example, Williams et al. (2008) recruited a sample of sedentary adults (*N* = 37) and exposed them to a graded submaximal exercise test on a treadmill. The researchers recorded participants' affective responses every 2 min during the exercise bout. Subsequently, participants were required to indicate their physical activity participation over the past 7 days using the Physical Activity Recall (PAR; Blair et al., 1985; Sallis et al., 1985) at baseline, as well as 6 and 12 months into a physical activity promotion trial. The results indicated that sedentary participants who reported more positive affective responses during the single exercise bout at baseline reported more minutes of physical activity both 6 and 12 months later (Williams, Dunsiger, et al., 2008). Accordingly, there is evidence to suggest that the affect heuristic might play an important role in the promotion of future physical activity behaviour (Smith, Eston, Tempest, Norton, & Parfitt, 2015; Tempest & Parfitt, 2013; Williams, Dunsiger, Jennings, & Marcus, 2012).

2.1.5 Affective–Reflective Theory. The Affective–Reflective Theory (ART) of exercise and physical inactivity was proposed by Ralf Brand and Panteleimon Ekkekakis (2018) as a means of explaining why people in a state of physical inactivity do or do not initiate action for exercise (see Figure 2.10). The ART of physical inactivity and exercise is a dual-process theory that acknowledges the role of momentary and anticipated affect, while recognising that cognitive thought and reflection is important to long-term changes in exercise behaviour (Brand & Ekkekakis, 2018). The theory commences at the exact point in which an exercise-related stimulus occurs. Hence, external stimuli (e.g., hearing that one should engage in exercise) and internal stimuli (e.g., remembering the instruction to exercise) trigger automatic associations pertaining to the exercise-related stimulus. Brand and Ekkekakis (2018) postulated that repeated experiences of exercise-related pleasure or displeasure facilitates an automatic affective valuation, which refers to a tacit assignment of a positive or negative value towards the stimulus. Pleasure and displeasure are associated with impulses to approach or avoid (Ekkekakis & Brand, 2019). Therefore, the theory supports the notion that individuals are likely to engage in exercise if their automatic affective valuation is positive and unlikely to engage in exercise if their automatic affective valuation is negative. The route from stimulus perception to action impulse is fast, automatic, and an inherently affective Type 1 process (Brand & Ekkekakis, 2018).

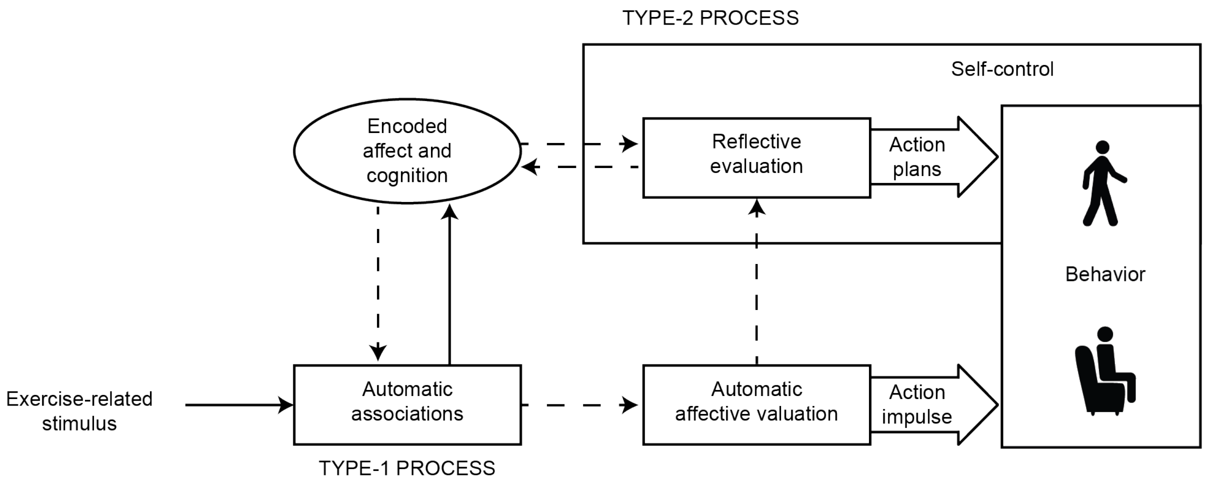

Figure 2.10. Graphical illustration of the Affective–Reflective Theory of physical inactivity and exercise. Adapted from “Affective–Reflective Theory of Physical Inactivity and Exercise: Foundations and Preliminary Evidence,” by R. Brand and P. Ekkekakis, 2018, *German Journal of Exercise and Sport Research, 48,* p. 54. Copyright 2017 by Ralf Brand and Panteleimon Ekkekakis.

The theory further postulates that a slower and more effortful Type 2 process will follow the automatic affective valuation, subject to the availability of self-control resources. This process might entail higher-level cognitive operations that have been expounded in several prominent theories from the realm of exercise psychology (Brand & Ekkekakis, 2018), including the pros and cons of behaviour change (i.e., SCT; Bandura, 1977, 1986, 1997, 2001), subjective beliefs (i.e., RAA; Fishbein & Ajzen, 2010), or deliberate reasoning about one’s needs and values (i.e., SDT; Deci, 1975; Deci & Ryan, 1985, 2002; Ryan & Deci, 2017). Type 2 processing results in action planning, such as the formation of behavioural goals and intentions (Brand & Ekkekakis, 2018). While it is possible to override the automatic affective valuation, individuals' self-control resources are often depleted owing to stress and/or competing pressures. In these instances, the more efficient Type 1 process is theorised to prevail (Ekkekakis & Brand, 2019). This is likened to the modern professional described in the preface, who refrained from physical activity after a stressful day at work.

Physical inactivity has been introduced as a global pandemic and the scientific study of exercise psychology was presented (Ding et al., 2016; Vealey, 2006; World Health Organization, 2016). Thereafter, it was suggested that the majority of models used to help explain exercise behaviour have limited predictive efficacy, as they are predicated upon the cognitive paradigm, which assumes that individuals are rational beings (Ekkekakis, 2017). Conversely, the notion of bounded rationality was offered, which acknowledges individuals' inability to consistently make decisions that are fully rational (Simon, 2000). Moreover, the dual-process paradigm, exemplified by Type 1 and Type 2 processes, was introduced as a means of capturing a greater degree of exercise-related behavioural variance (Pennycook et al., 2018). Heuristics, or shortcuts, were presented to the reader in order to explain the automatic Type 1 processes and the affect heuristic was suggested to play a vital role in the exercise decision-making process (Kahneman, 1999), as illustrated in the ART (Brand & Ekkekakis, 2018; see Figure 2.10). There is considerable scope for researchers to devise interventions that seek to enhance affective responses to exercise, the effects of which might serve to reduce physical inactivity (Ekkekakis, Zenko, et al., 2018; Rose & Parfitt, 2012; Williams, 2018). Before considering such interventions, the present review provides the reader with an overview of affective phenomena.

2.2 Affective Phenomena

The study of affect, emotion, and mood is more challenging than most other topics in psychology due to the sheer volume and complexity of information that needs to be digested by researchers (Ekkekakis, 2012, 2013b). Unlike other topics such as self-efficacy, social norms, and behavioural intentions, there is no one authoritative source, embedded within one well-known theoretical framework for the study of affective phenomena (Russell & Feldman Barrett, 1999). This research domain is characterised by a very long history, an enormous diversity of theoretical views, and considerable confusion and controversy that revolves around the conceptualisation and measurement of affective responses (Ekkekakis & Zenko, 2016b; Mauss & Robinson, 2009).

The terms *affect*, *mood*, and *emotion* are often used interchangeably in the domain of psychology, without any conceptual differentiation (Batson, Shaw, & Oleson, 1992; Russell & Feldman Barrett, 1999). For example, state anxiety is suggested to be an *emotional* reaction or response that is triggered when a person perceives a situation as threatening (Spielberger, Lushene, & McAdoo, 1977) and yet state anxiety is often referred to as a *mood* (Herring, O'Connor, & Dishman, 2010). When distinctions are made among the terms affect, emotion, and mood, they are often based upon the researcher's particular field of expertise (Beedie, Terry, & Lane, 2005). For example, psychophysiologists might choose to differentiate the terms by comparing their respective neural or somatic correlates (Panksepp, 1994, 2007). On the other hand, psycholinguists might choose to emphasise semantic distinctions in everyday language (Wierzbicka, 1992). Therefore, investigations that emanate from different research domains reveal considerable variation in the defining features of affect, emotion, and mood.

If the study of affective phenomena is to advance, a shared purpose within the research community must be established (Ekkekakis, 2013b). By way of illustration, the reader is encouraged to consider each terminological viewpoint as a building brick; if each brick fits with others within a larger design, a firm structure of collective consensus is achieved. However, the current situation within the study of affective phenomena depicts numerous bricks of all shapes and sizes scattered across the floor (Lang, 2010).

As a result of the terminological ambiguity, the measurement of affective phenomena becomes an enormously challenging undertaking (Ekkekakis, 2012, 2013b). Several instruments are available to scholars that claim to measure affect, emotion, or mood. Nonetheless, it is essential that researchers understand the theoretical underpinning of each measure prior to employing them (Ekkekakis & Zenko, 2016b). The lack of conceptual clarity associated with affective phenomena has led to the development of measures that are based upon inherently different theoretical underpinnings. Accordingly, researchers that have employed such measures have inadvertently perpetuated further confusion that surround the terms affect, emotion, and mood.

Encouragingly, progress is being made to draw lines of distinction between this "inherently fuzzy set" of constructs (Smith & Lazarus, 1990, p. 611). However, problems arising from the absence of a universally agreed-upon terminology continue to plague research in affective psychology, which has produced largely equivocal findings to date (Beedie et al., 2005; Ekkekakis, 2013b). Subsequently, any review of affective phenomena literature must take this lack of clarity into consideration. The following sections of this review do not attempt to provide authoritative definitions of key affective constructs, as this would be a rather unrealistic goal. Rather, the purpose is to navigate the murky waters of affective phenomena research in the hope of identifying points of convergence and divergence, and to present the approach that will be adopted within the present programme of research.

2.2.1 Affect. In an attempt to address the terminological problem within affective phenomena, researchers questioned which term should be used for states of the organism that have both organic and psychological components, only some of which should be termed emotions (Scherer, 1984). Subsequently, the term *affective states* was proposed to be used as an umbrella term and many researchers have adopted this since (Ekkekakis & Zenko, 2016b). Similarly, Russell and Feldman Barrett (1999) suggested that affect is the most elementary accessible affective feelings that do not necessarily have direction towards anything. Affect is often described as basic or core because it is considered an irreducible component (Russell, 2009). Moreover, researchers have emphasised that affect is mental but not cognitive or reflective, and this is its most crucial defining feature (Ekkekakis, 2013b; Russell, 2003). Examples of affect include pleasure and displeasure, tension and relaxation, energy and tiredness.

Affect can occur in a pure form, but it is also present within emotions and mood (Fredrickson, 2001; Russell & Feldman Barrett, 2009). For example, *pride* can be thought of as feeling good about oneself. The *feeling good* element is affect and the *about oneself* is an additional cognitive component that quantifies *pride* as an emotion. A function of affect is to inform the organism experiencing it about the states that it values more than others (Batson et al., 1992). Accordingly, affect reveals our preferences; change from a less desired to a more desired state facilitates positive affect and signals approach towards a stimulus. Conversely, change from a more desired to a less desired state facilitates negative affect and signals avoidance of a stimulus (Panksepp, 2005). Affect is considered the most elementary constituent of consciousness that lacks cognitive and reflective factors (Ekkekakis, 2013b; Russell, 2009). Moreover, affect is suggested to be an essential ingredient of emotions and moods. However, affect is viewed as being constantly accessible to conscious awareness, although its nature and intensity is subject to change in response to internal and external stimuli (Ekkekakis, 2014).

2.2.2 Emotion. The vast majority of problems faced by humanity involve emotion (Russell, 2003). Despite widespread use of the term emotion, the question of what actually constitutes an emotion has been debated through the ages, and is as old as psychological science itself (Feldman Barrett, 2006; Mauss & Robinson, 2009; Moors, 2009). Regardless of the ambiguity surrounding its definition or perceived utility, it is widely accepted that emotions are of high evolutionary significance (Izard, 2007, 2009).

Following *The Expression of the Emotions in Man and Animals* (Darwin, 1872), the first attempts to define emotion emanated from James (1884) and Lange (1885). Both theorists independently suggested that bodily changes, such as fleeing a dangerous environment, occur first and the perception of the emotion (e.g., fear) transpires thereafter. Cannon (1927) identified major flaws in the James-Lange theory of emotion, by observing that emotions could still be experienced regardless of visceral changes. Moreover, the researcher suggested that bodily responses are too general to be linked to specific emotions. For example, elevations in HR are associated with several emotions (e.g., anger and fear; Cannon, 1927).

Researchers have subsequently sought alternative theories of emotion. Some scholars believe that an individual's appraisal is fundamental in determining whether an emotion is experienced (Frijda, 1986; Lazarus, 1991b), while others have postulated that each emotion possesses a unique physiological response pattern (Ekman & Davidson, 1994; Ekman, Levenson, & Friesen, 1983). Moreover, researchers have employed neuroscientific principles to facilitate our understanding of emotion (Lang, 2010). Despite several important steps in the right direction, there is no universally accepted definition for emotion (Frijda & Scherer, 2009). This might be partially attributed to linguistic barriers, as the word emotion does not even exist in all languages (Russell, 1991).

Frijda and Scherer (2009) proposed that emotions have a coordinated response of five major systems: (a) an information-processing cognitive (appraisal) component; (b) a neurophysiological component (bodily changes); (c) an executive component, which prepares and directs responsive actions; (d) an expressive component, which communicates the emotion via vocal and facial expressions; and (e) an experiential component, which monitors the internal state of the organism and its interaction with the environment, and generates subjective feelings. The aforementioned systems underlying emotion function independently most of the time, but what makes the nature of emotion special is the coordination and synchronisation of all of these systems during an emotional episode driven by appraisal (Scherer, 2005).

Emotions entail an absorbing combination of organismic resources. Accordingly, emotions are typically characterised by a relatively short duration and high intensity (Ekkekakis, 2013b). The duration of emotions must be relatively short in order not to tax the resources of the organism, allowing for behavioural flexibility (Scherer, 2005). Examples of emotions include anger, fear, jealousy, pride, and love. Emotions are elicited *by* something, are reactions *to* something, and are generally *about* something. Accordingly, the cognitive appraisal involved in the transaction between person and object is vital (Lazarus, 1991b, 1991a). However, the view that a cognitive appraisal is a defining feature of emotion is not shared by all (Ekman & Davidson, 1994; Lang, 2010)

Appraisal theorists have suggested that emotions are adaptive responses that reflect environmental appraisals that are significant to an individual's wellbeing (Moors, Ellsworth, Scherer, & Frijda, 2013). Although researchers have used the term "appraisal" and even describe it as a component (Ekman, 1994; Russell, 2003), there are a number of key differences between appraisal theories and other theories: (a) the definition of appraisal, concerning the content and type of process; (b) the role of appraisal in emotion and predictions regarding changes in appraisal and changes in other components; and (c) predictions about the individual, cultural, and development differences (Moors et al., 2013).

There are clear distinctions between appraisal theories and other theories of emotion, but it is important to emphasise that there are a number of issues of which there is disagreement between appraisal theorists too. Researchers have suggested that appraisal themes result in specific emotions (Lazarus, 1991b). For example, the theme underlying guilt is having disobeyed a moral imperative. On the other hand, researchers have suggested that appraisal themes often share commonalities, meaning that some emotions are likely to co-vary (Smith & Ellsworth, 1985).

The current programme of research adopts a cognitive approach to the study of emotion (Moors et al., 2013; Oatley & Johnson-Laird, 2014). Therefore, the term emotion is reserved for those affective states that are elicited following a process of appraisal, during which an object is seen as having the potential to facilitate or debilitate the survival or wellbeing of an individual. The cognitive approach to emotion is often employed within the realm of exercise psychology and represents a view that many prominent emotion theorists now share (Ekkekakis & Zenko, 2016b; Lane, Beedie, Jones, Uphill, & Devonport, 2012).

2.2.3 Mood. Despite there being clear differences between mood and emotion, the distinction between the two constructs is partially clouded because an emotion and a mood may feel very similar to an individual experiencing either (Beedie et al., 2005). Mood is usually regarded as a more or less pertinent state, with a longer duration and less intense nature when compared to emotion (Ekkekakis, 2013b). This view is echoed by Ekman (1992), who suggested that “emotions usually last only for seconds”, whereas moods “last for hours or days” (p. 186).

Perhaps a more meaningful differentiating characteristic of moods is that they are diffuse and are typically associated with low or no action tendencies (Ekkekakis & Petruzzello, 2000). Although moods frequently lack a specific target, they might seem as being similar to affect (Frijda, 1993, 1994). However, in these instances, it is possible that mood might have a vague object (Ekkekakis, 2013b). For example, when an individual is in an anxious mood, such a vague object might be her/his whole future or as distant as life in 20 years’ time (Ekkekakis, 2012). Accordingly, the causes of moods are difficult to identify due to their tendency to be temporally remote (Morris, 1992). In stark comparison, emotions follow their eliciting stimuli closely or even simultaneously.

When moods are about an object, they share with emotion the fact that they are both reactions to the way one appraises their relationship with the environment. Moods often concern the larger, pervasive issues of one’s life, whereas emotions refer to a specific, narrow goal in an adaptational encounter with the environment (Lazarus, 1991b). Furthermore, moods have a tendency to influence an individual’s appraisal of situational events. Hence, when in a given mood, the threshold for related emotions are lowered, meaning that similar moods and emotions frequently co-occur (Ekkekakis, 2013b). For example, when a person is in an irritable mood, the threshold for the emotion anger is lowered, enhancing the likelihood of that person becoming angry more frequently. Researchers have suggested that it is almost as though we look for an opportunity to indulge the emotion that is relevant to the mood (Ekman, 1994; Frijda, 2009).

Within the current programme of research, mood is viewed as similar to emotion given that they both have cognitive origins, involving an appraisal of the environment. However, the diffuseness of mood separates it from emotion; mood often lacks a specific target whereas emotion is always about something (Frijda, 1993, 1994). Additionally, moods are considered to have little or no association with action tendencies, are temporally remote from their cause, and are typically less intense and longer in duration than emotions (Ekkekakis, 2013b).

2.2.4 Hierarchy of affective phenomena. To help resolve the long-running confusion in relation to key affective terms, Ekkekakis (2013b, p. 70) proposed a hierarchical structure of the affective domain (Figure 2.11). He suggested that the basic dimensions of affect (i.e., pleasure-displeasure and activation) formed the basis of distinct emotions (e.g., love, pride, and anger), which in turn, evolved into subtle derivatives. All constructs are theorised to promote adaptation but constructs at higher levels of the figure represent those with a higher degree of differentiation, which is suggested to be resultant of complex social structures (Ekkekakis, 2013b).

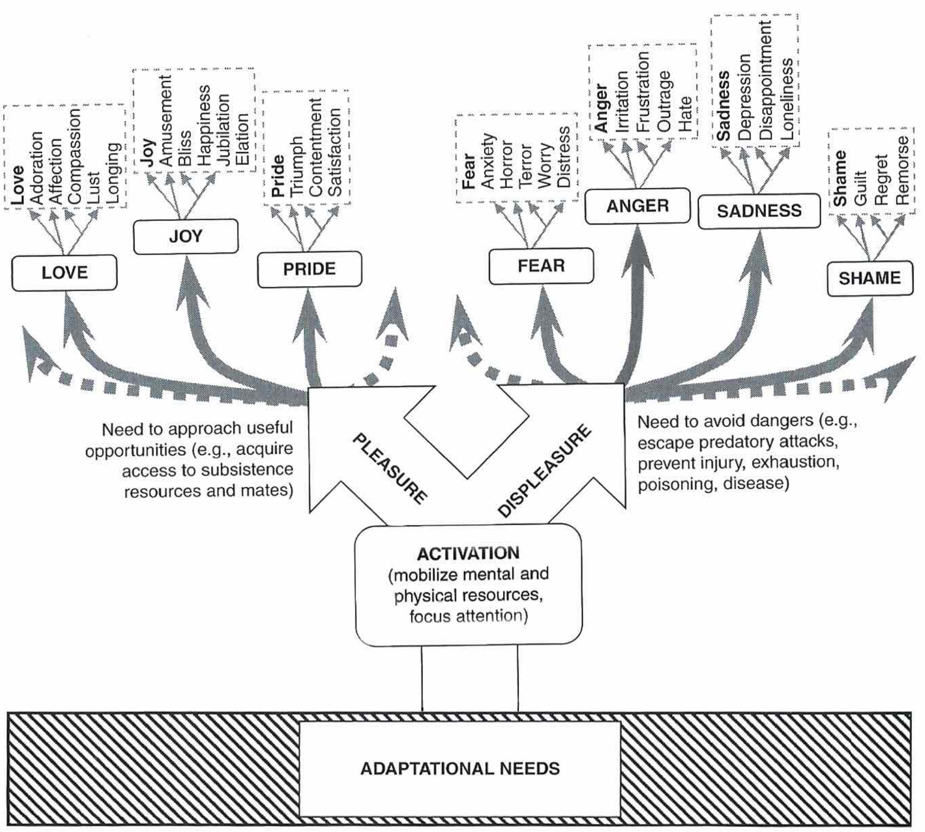

Figure 2.11. Hierarchy of the affective domain. Reprinted from *The Measurement of Affect, Mood, and Emotion* (p. 70), by P. Ekkekakis, 2013b, Cambridge, UK: Cambridge University Press. Copyright 2013 by Cambridge University Press.

2.2.5 Dual-Mode Theory. The relationship between exercise and affect is not unitary and involves multiple phenomena (Ekkekakis & Lind, 2005). Ekkekakis (2003) identified that the main obstacle for progress in research examining the exercise–affect relationship was the absence of a comprehensive theoretical framework. In order to overcome this limitation, Ekkekakis (2003, 2005) proposed the DMT as a depiction of the relationship between exercise intensity and affective responses. A key component of the DMT is that exercise is considered from an adaptational perspective (Stych & Parfitt, 2011). Exercise has been an integral part of human life throughout evolutionary history, despite changes in certain aspects of the adaptational significance of exercise-related behaviours (i.e., we no longer have to fight off predators), many of the adaptational implications of physical activity remain (Ekkekakis, 2005).

An underlying premise of the DMT is that exercise intensity should be defined according to a fixed metabolic profile, such as VT, as opposed to a percentage of maximal capacity. This ensures that individuals are in the same metabolic state when responding affectively to exercise, something that cannot be guaranteed when defining exercise intensity by percentage of HR_{max}. Defining exercise intensity by fixed metabolic profiles removes a potential confound when comparing affective responses across individuals (Rose & Parfitt, 2010; Welch, Hulley, Ferguson, & Beauchamp, 2007).

The DMT posits that affective responses to exercise are influenced by the continuous interplay between two factors, both of which have access to the affective centres of the brain: (a) cognitive factors originating primarily in the frontal cortex and involving processes such as appraisals of the meaning of exercise, goals, physical self-efficacy, attributions, and considerations of the social context of exercise; and (b) interoceptive cues from a variety of receptors that are stimulated by exercise-induced physiological changes. Neither mode is likely to have complete control over the affective response to exercise. Rather, the relative dominance and respective influence of these two mechanisms are likely to shift systematically as a function of exercise intensity (Benjamin, Rowlands, & Parfitt, 2012; Ekkekakis, 2003).

Ekkekakis (2003, 2005) theorised that at low exercise intensities below the VT, cognitive factors have a small-to-moderate influence on affective responses, with interoceptive cues associated with metabolic strain bearing little influence. Accordingly, the theory predicted that affect would be largely positive at intensities below the VT. At exercise intensities around the VT, interoceptive cues have a small impact and cognitive factors become the main determinants of affective responses. Cognitive appraisals are unique and therefore affective responses around the VT will differ considerably among individuals, with some reporting positive affect and others reporting negative affect. Finally, at exercise intensities above the VT, interoceptive cues gain salience and become the main determinants of affective responses. At this intensity, affective responses are proposed to be less positive as a physiological steady state becomes difficult or impossible to maintain (Ekkekakis, Parfitt, & Petruzzello, 2011). Furthermore, Ekkekakis (2003, 2005) explained that a robust rebound towards pleasure is expected to occur upon cessation of exercise that induces displeasure (Figure 2.12).

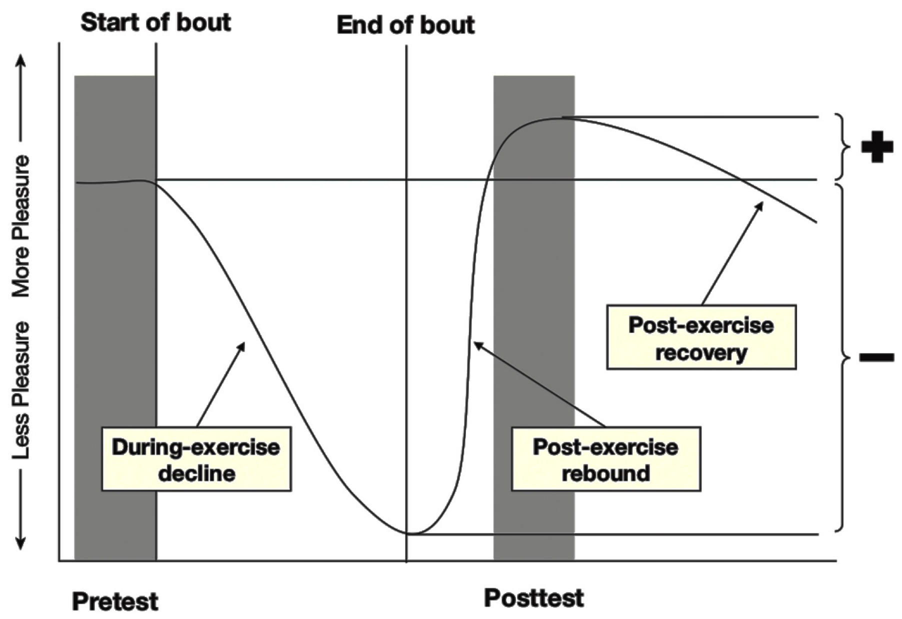

Figure 2.12. Representation of a typical affective response to strenuous exercise that exceeds the ventilatory threshold. Adapted from "Pleasure from the Exercising Body: Two Centuries of Changing Outlooks in Psychological Thought," by P. Ekkekakis, in P. Ekkekakis (Ed.), *Routledge Handbook of Physical Activity and Mental Health* (p. 50), 2013a, New York, NY: Routledge. Copyright 2013 by Panteleimon Ekkekakis.

2.2.6 Measurement of affective phenomena. The previous section proposed that the interchanging and/or mislabelling of the terms affect, emotion, and mood have become so frequent over the past few decades that such ambiguities are commonly replicated without criticism. Accordingly, this review highlighted the relevant points of convergence and divergence within the affective phenomena literature and explained how affect, emotion, and mood is conceptualised within the current programme of research. A related problem that has received considerable interest from researchers concerns the measurement of affective phenomena (Ekkekakis & Petruzzello, 2000; Ekkekakis & Zenko, 2016b).

There are several measurement options available to researchers. For example, those interested in measuring mood must actively make the decision whether to consider moods as bipolar dimensions (e.g., Lorr, Shi, & Youniss, 1989) or unipolar states (e.g., Rafaeli & Revelle, 2006). The implications for choosing a measure are extremely important. Indeed, when a researcher chooses one measure over another, the researcher adopts the theoretical basis upon which the measure was developed (Ekkekakis, 2013b). Unfortunately, the selection of a measure typically revolves around superficial concerns, such as the popularity of the measure within the wider research community (Ekkekakis & Zenko, 2016b). Conversely, the selection of a measure should be a theory-driven process, with researchers fully aware of the strengths and limitations of the measures they select (Ekkekakis, 2013b). Researchers can choose to conceptualise and measure affective states as distinct entities, or as being positioned along a continuum.

2.2.6.1 Distinct-states approach. Those who adopt the distinct-states approach view affective phenomena as unique and separate from all others (Roseman, Wiest, & Swartz, 1994). In a variant of the distinct-states approach, researchers have constructed lists of *basic emotions* (Ekman, 1992; Panksepp, 1994). Such emotions are classed as basic by their difference from each other with regards to antecedent appraisals, experiential qualities, behavioural manifestations, psychophysiological patterns, and regulatory efforts (Ekkekakis, 2013b). A strength of the basic emotions approach is that it affords a great deal of specificity and precision in making fine distinctions between psychological meanings (Ekkekakis & Petruzzello, 2000). However, theorists' opinions often vary as to what constitutes the criterion for assessing the *basicness* of emotions. Therefore, theorists often disagree about which emotions should be classified under this approach (Ekman, 1992).

Another variant of the distinct-state approach is the categorical approach, wherein researchers have striven to create groups of states that closely resemble each other, while bearing less relevance to those states in other groups (Russell, 1991). For example, the category of *love* may contain other states that share similarities such as affection and fondness, but these are different from the category of *fear*, which might contain states such as terror and panic (Ekkekakis, 2013b). The categorical approach offers a high degree of specificity and is useful for highlighting subtle distinctions among affective states (Ekkekakis & Petruzzello, 2000). However, the categorical approach can prove restrictive when a researcher's aim is to capture and describe an affective response for which the exact nature cannot be predicted (Ekkekakis & Petruzzello, 2001).

2.2.6.1.1 The Profile of Mood States (POMS). The POMS is one of the most widely used self-report measures within the domains of exercise sciences and mainstream psychology (Ekkekakis, 2013b). The developers initially designed this measure to facilitate the identification and assessment of mood states in psychiatric outpatients and the former name given to this measure reflects this purpose (i.e., The Psychiatric Outpatient Mood Scale; McNair & Lorr, 1964). The commercially available version of the POMS was offered with a six-factor structure comprising Tension-Anxiety, Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, and Confusion-Bewilderment (McNair, Lorr, & Droppleman, 1971). The measure includes 65 items (e.g., Lively) accompanied by a 5-point frequency scale ranging from *not at all* to *extremely*.

The main pitfall that researchers have fallen into when using the POMS is the inappropriate extrapolation from the six aforementioned states to the global domain of mood (Ekkekakis & Zenko, 2016b). Hence, researchers frequently make an assertion that their employed exercise protocol can elicit improved mood. In actuality, such a protocol might have prompted a reduction in the Depression scale and an improvement in the Vigour scale.

Accordingly, there is no evidence that the six states chosen by the developers of the POMS constitute the entire mood domain (Ekkekakis, 2013b).

2.2.6.1.2 The State-Trait Anxiety Inventory (STAI). The STAI was originally developed by Spielberger, Gorsuch, and Lushene (1970) and based upon Spielberger's theory of state and trait anxiety (1966, 1972). According to this theory, high-trait-anxious individuals are more likely to interpret a greater proportion of situations as entailing some form of treat when compared to their low-trait-anxious counterparts. Furthermore, the perception of threat was theorised to differ according to an appraisal of the degree of threat in each situation and/or an individual's perceived coping capabilities.

The STAI (Spielberger et al., 1970) contains two scales, each of which comprises 20 items. One scale assesses state anxiety and the items (e.g., I feel frightened) are accompanied by a 4-point frequency scale ranging from *not at all* to *very much so*. The other scale assesses trait anxiety and the items (e.g., I lack self-confidence) are accompanied by a 4-point frequency scale ranging from *almost never* to *almost always*. The STAI was revised 13 years after the original in order to address a range of items that displayed poor psychometric properties (Spielberger, 1983).

Although the STAI is frequently employed by researchers within the realm of exercise sciences, there are a number of limitations that should be considered prior to its implementation (Ekkekakis, 2013b). For example, the state-anxiety scale is often used to measure "how people feel" when they exercise (Ekkekakis & Zenko, 2016b). However, this particular use case falls outside of the stated scope of the measure, which was developed to assess a specific response (i.e., state anxiety) following an appraisal of threat. Hence, in order for the items to be considered valid indicators of state anxiety, it is assumed that the research participant is presented with a potentially threat-inducing stimulus that is cognitively appraised as threatening. Additionally, researchers have suggested that exercise is a unique scenario that is inconsistent with Spielberger's conceptualisation of anxiety (Ekkekakis &

Zenko, 2016b). For example, exercise respondents are likely to report being less “calm” and less “relaxed”, which implies high levels of state anxiety, but simultaneously less “nervous” (Ekkekakis, Hall, & Petruzzello, 1999). Subsequently, this renders the total score for state anxiety invalid.

2.2.6.2 Dimensional approach. The main conceptual alternative to the distinct-states approach is the dimensional approach, which considers affective states systematically inter-related, with their relationships modelled by a parsimonious set of dimensions (Ekkekakis & Petruzzello, 2000). A series of studies led by Osgood investigated the dimensional structure of affective space (Osgood, 1962; Osgood & Suci, 1955; Osgood, Suci, & Tenenbaum, 1957). The researchers identified the following three orthogonal (unrelated) dimensions: (a) Evaluation (now referred to as affective valance or pleasure/displeasure), which consisted of scales such as good–bad, pleasant–unpleasant, and positive–negative; (b) Potency (now referred to as dominance or control), which consisted of scales such as strong–weak, large–small, and hard–soft; and (c) Activity (now referred to as arousal or activation), which consisted of scales such as fast–slow, active–passive, and excitable–calm (Ekkekakis, 2013b).

This three-dimensional structure became the basis for both the Semantic Differential Measures of Emotional State (SDMES; Russell & Mehrabian, 1974, 1977) and the Self-Assessment Manikin (SAM; Lang, 1980). Further refinement has led to the elimination of the potency factor, on the basis that additional dimensions may, in fact, refer to antecedents or consequences of the affective experience (Russell, 1980, 1989). The removal of the potency factor left a two-dimensional structure consisting of affective valence, (ranging from pleasure–displeasure), and activation (arousal).

2.2.6.2.1 Circumplex model of affect. Russell (1980, 1989, 1997) suggested that affective space could be defined by two orthogonal and bipolar dimensions, affective valence and activation. Different affective states are considered to be combinations of varying degrees of these two constituent dimensions. Therefore, affective states can be depicted around the perimeter of a circle according to their degree of affective valence and activation (Ekkekakis & Petruzzello, 2002). Experientially similar affective states (e.g., excited and happy) are situated in close proximity on the circle (Figure 2.13). Conversely, affective states that are perceived as antithetical (e.g., pleasant and unpleasant) are depicted opposite one another. The circumplex can be divided into four quadrants, each corresponding with a meaningful variant of affective experience (Ekkekakis & Petruzzello, 2002): (1) High-activation pleasant affect, such as excitement and energetic, are located in the top-right quadrant; (2) High-activation unpleasant affect, such as afraid or tense, are located in the top-left quadrant; (3) Low-activation unpleasant affect, such as sluggish or droopy, are located in the bottom-left quadrant; and (4) Low-activation pleasant affect, such as peaceful or calm, are located in the bottom-right quadrant.

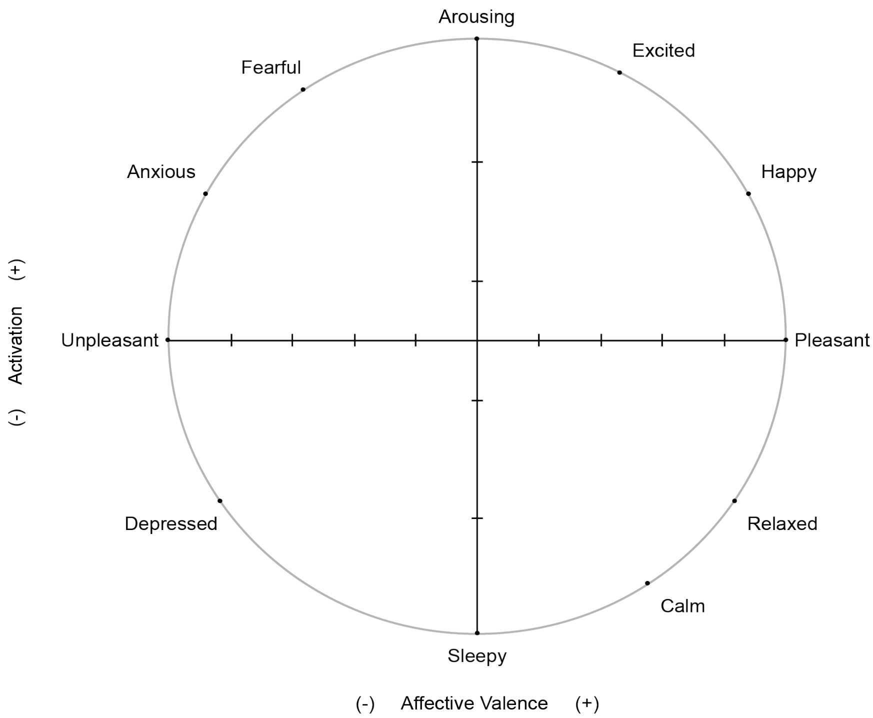

Figure 2.13. The Circumplex model of affect. Adapted from “A Circumplex Model of Affect,” by J. A. Russell, 1980, *Journal of Personality and Social Psychology, 39,* p. 1164. Copyright 1980 by the American Psychological Association.

There are several advantages associated with use of the circumplex model of affect within exercise psychology. Perhaps the greatest strength of the model is its ability to provide an adequate representation of the entire affective space with just two dimensions. For example, affective valence and activation have been demonstrated to account for most of the variance in the POMS scales (Russell & Steiger, 1982), and 42 additional measures of affective states (Russell & Mehrabian, 1977).

Categorical measures of affect rely on a set of predetermined scales in order to map individual differences in affect using quantitative differences in item ratings. In contrast, the circumplex affords exercisers the freedom to accurately describe their affective experiences in an unrestricted manner, over a prolonged period of time, which allows for an almost unlimited number of individual profiles (Ekkekakis & Petruzzello, 2002). The continuous measurement of affect within exercise settings is crucial, given that hedonically significant experiences extend over time (Kahneman, 1999; Walsh, 2012).

2.2.6.2.2 Single-item measures. The main advantage of using single-item instruments alongside the circumplex model of affect is that they can be used repeatedly during an investigation with minor risk of respondent overload, promoting participant engagement (Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007). However, because the score is derived from a single response, these measures are more prone to random measurement error when compared with multi-item questionnaires and therefore their reliability is generally modest (Ekkekakis & Petruzzello, 2002).

The Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989) is a 9 × 9 grid, with the vertical dimension representing the degree of perceived activation (ranging from sleepiness–high arousal) and the horizontal dimension representing valence (ranging from unpleasantness–pleasantness). Respondents are required to place a single "X" in one of the 81 cells of the grid and this response is scored with reference to both arousal and valence dimensions. The four corners of the grid are labelled with the following anchors in order to facilitate understanding: stress (*high arousal, unpleasant feelings*), excitement (*high arousal, pleasant feelings*), relaxation (*sleepiness, pleasant feelings*), and depression (*sleepiness, unpleasant feelings*). Despite the fact that satisfactory psychometric properties have been demonstrated for the AG (Russell et al., 1989), this single-item measure has not been used extensively in general psychology (Ekkekakis & Petruzzello, 2002). It is possible that the lack of uptake by researchers might be attributed to the format of the AG, which might serve to confuse respondents.

Lang (1980) developed the SAM on the basis of Mehrabian and Russell's (1974) three-dimensional model of emotion (which would now be considered a model of affect). The measure is unique in that each of the three scales is represented by a series of cartoon-like characters with different facial expressions. The valence scale ranges from happiness (*smiling face*) to sadness (*frowning face*), the arousal scale ranges from sleepiness (*eyes closed*) to high arousal (*shaking and heart pounding*), and the dominance scale ranges from submissiveness (*small size*) to dominance (*large size*; Lang, 1980).

The SAM is particularly well suited to cross-cultural research because it features facial and bodily cues as opposed to verbal descriptors (Morris, 1995). However, the SAM has been criticised for its inclusion of the dominance-submissiveness scale, which is not inherently affective, but cognitive in nature (Russell, 1980, 1989). Dominance-submissiveness is an antecedent or consequence of the affective experience, as opposed to being a core component of the affective experience (Ekkekakis, 2013b). Therefore, if a researcher is interested in measuring affect, the dominance-submissiveness scale of the SAM should be considered to be superfluous to their requirements.

Bipolar scales such as the Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985) have also been used to assess valence and activation. The FS is a single-item, 11-point scale anchored by -5 ([*I feel*] *very bad*) and 5 (*very good*). The FAS is a single-item, 6-point scale anchored by 1 (*low arousal*) and 6 (*high* *arousal*). A common limitation of most Likert-type scales, including the FS and FAS, is that there is often no empirical study underpinning the choice of verbal anchors and their scaling properties (Lishner, Cooter, & Zald, 2008). For example, there is no reported explanation as to why the FS has two equal spaces between the anchors *good* and *very good*. However, an advantage of administering the FS and FAS side-by-side pertains to the differing format of the measures (e.g., number of anchors, number of possible responses). Accordingly, participants are forced to consider their responses independently for each scale, which serves to enhance discriminant validity (Ekkekakis, 2013b).

2.2.6.2.3 Multi-item measures. The SDMES (Mehrabian & Russell, 1974) consists of three scales, with six semantic-differential items each, accompanied by 9-point response scales: Pleasure (e.g., *pleased–annoyed*), Arousal (e.g., *excited–calm*), and Dominance (e.g., *influential–influenced*). Despite possessing sound psychometric properties, the SDMES has received criticism for some of its paired terms. For example, the Pleasure scale contained items that imply a significant activation content, such as *relaxed-bored* (Ekkekakis, 2013b).

The Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) consists of 20 items, 10 for the positive affect scale and 10 for the negative affect scale. Using a 5-point scale ranging from *very slightly or not at all* to *extremely,* participants are required to rate each item depending on how they feel within a time-frame predetermined by the researcher. The PANAS represents an example of a measure that has perpetuated confusion within the study of affective phenomena (Ekkekakis & Zenko, 2016b). Watson et al. (1988) fail to draw clear distinctions between key terms relating to affective states. For example, the PANAS is labelled as a measure of affect and yet the researchers refer to positive and negative affect as *mood factors.* The instrument itself does little to clarify which affective phenomena it is attempting to tap; some of the items within the PANAS such as *distressed* and *jittery* have been categorised as affect (Russell, 2003, 2005), however the terms *proud* and *ashamed* are commonly considered emotions (Lazarus, 1991b). Moreover, the terms *upset* and *hostile* are typically considered moods (Ekkekakis, 2013b).

Another limitation of the PANAS concerns the selected items within the measure. On the basis that low-activation states were considered non-affective, Watson et al. (1988) only included those items that denote high activation and subsequently excluded items or scales that tap pleasant or unpleasant low-activation states (Figure 2.14). The main advantage of dimensional models is the ability to capture the global domain of content. Therefore, by neglecting low-activation states (e.g., *calmness*, *fatigue*) the PANAS has dramatically limited its scope to capture the global domain of affect. Despite its undeniable limitations, the PANAS is still one the most widely used measures of affect and has attracted over 30,000 citations to date (e.g., Baker et al., 2008).

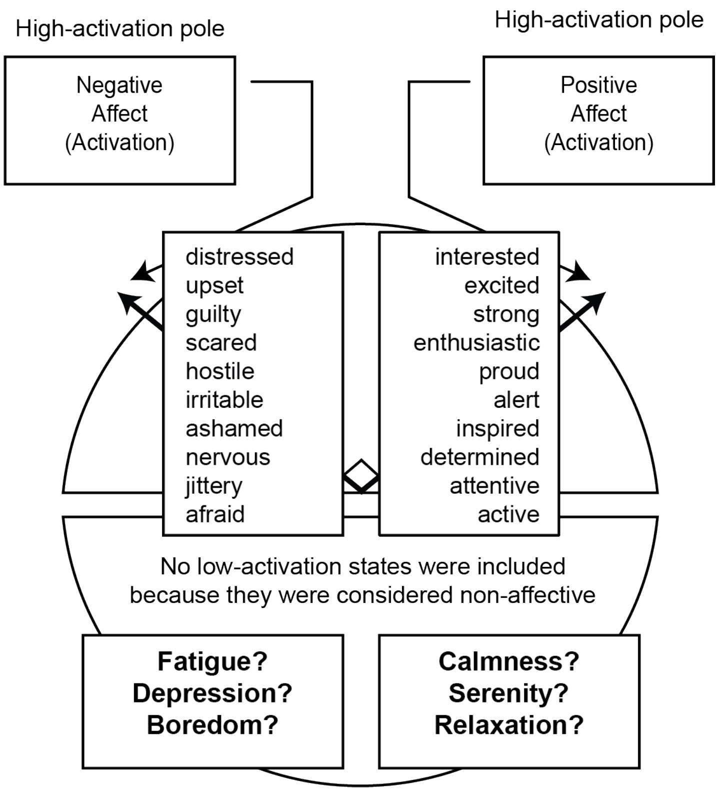

Figure 2.14. Feeling states selected and rejected for Watson et al.'s (1988) Positive and Negative Affect Schedule. Adapted from *The Measurement of Affect, Mood, and Emotion* (p. 20), by P. Ekkekakis, 2013b, Cambridge, UK: Cambridge University Press. Copyright 2013 by Cambridge University Press.

2.2.6.3 Distinct-states vs. dimensional approach. Dimensional models such as the circumplex have been criticised for being too general and that they are uninformative in revealing differences between emotions (Clore, Ortony, & Foss, 1987). Similarly, Larsen and Diener (1992) suggested that although dimensional models are useful, they fail to capture the vastness of emotions though cognitive labelling. Instead of labelling dimensional models as models of emotion, it is now accepted that the true usefulness of dimensional models does not reach that far (Ekkekakis, 2013b). Conversely, the two-dimensional structure captures affect and misses the other components that define emotions (Russell & Feldman Barrett, 1999). To illustrate, fear and anger are placed at identical positions on the circumplex, but this only represents one component involved (i.e., affect), and not the others (e.g., cognitive appraisal, attributions, future projections, action tendencies). It is these other components that separate fear from anger. Accordingly, affective valence and perceived activation alone do not fully account for most emotional episodes, because they cannot explain how states such as shame, jealousy, or fear differ from one another. To allow for the separation of these states, a categorical as well as dimensional approach must be employed (Russell, 2003).

The choice of whether to adopt a distinct-states or a dimensional approach to the measurement of affective phenomena is a matter of understanding that both approaches have their place, with relative strengths and weaknesses. Ultimately, the decision will depend on the nature of the research question being considered (Ekkekakis & Petruzzello, 2002). If a researcher attempts to investigate an experimental manipulation likely to evoke a pattern of cognitive appraisal underlying a specific emotion or mood (or a set of specific emotional or mood states), the researcher should adopt a distinct-states or categorical approach, as this would maximise focus on the emotion/mood (Ekkekakis, 2013b). Conversely, if the researcher's focus concerns the effects of a more general manipulation, it would be more appropriate to focus on the broad domain of affect, using a dimensional model such as the circumplex (Russell, 1980).

2.2.6.4 A three-step approach to measurement. In an attempt to overcome the ambiguity surrounding key affective terms and associated measures, Ekkekakis and Zenko (2016b) encouraged researchers to employ a three-tiered decision-making process for choosing and justifying a measure within the exercise context. First, researchers are urged to consider whether they wish to study affect, emotion, or mood. Second, researchers should select the most appropriate theoretical framework for the chosen construct of interest. Finally, researchers should choose the psychometrically strongest measure based on their intended theoretical framework (Ekkekakis, 2013b).

With the aforementioned framework in mind, the present programme of research is oriented towards the measurement of affect, as opposed to emotion or mood, in an exercise context. This is because is there is limited evidence pertaining to a link between specific emotions or moods and repeated physical activity behaviour. Conversely, the affect heuristic (Kahneman, 1999) supports the notion that individuals are likely to repeat behaviours that induce pleasure and avoid those behaviours that induce displeasure. Herein, affect is conceptualised as a dimensional domain, comprised of affective valence and perceived activation, as it is currently unclear which specific affective states bear the greatest influence on future exercise participation (Williams, Dunsiger, et al., 2008). Viewing affect as a dimensional domain allows for greater coverage when compared to the distinct states approach. The author will measure the bipolar states of affective valence and perceived activation using the FS (Hardy & Rejeski, 1989) and the FAS (Svebak & Murgatroyd, 1985), respectively. Both measures possess sound psychometric qualities and have the advantage of being easily implemented with an exercise context, owing to the fact that they are single-item measures.

The researcher has emphasised that affective responses play a central role in determining exercise participation (Rose & Parfitt, 2010). Consequently, the author made the distinction between key affective terms (i.e., affect, emotion, and mood), as well as delineating a range of considerations regarding the measurement of affective phenomena (Ekkekakis, 2013b). The increased time spent engaging with technology within modern-day society has led to the assertion that exercise scientists should strive to develop innovative solutions for its implementation in order to promote an enjoyable exercise experience (Lewis, Napolitano, Buman, Williams, & Nigg, 2017). One such example of an innovative solution concerns the scientific application of audio-visual stimuli within the exercise environment (Karageorghis, 2017).

2.3 Audio-Visual Stimuli

Herein, a review of literature concerning the use of auditory stimuli singularly is provided; this serves as a precursor to the review of audio-visual stimuli in combination that follows. To help facilitate an understanding of how auditory stimuli influence individuals, one must become familiar with the basic anatomy of the human hearing system.

2.3.1 The auditory system. Psychoacoustics, a branch of psychophysics, is an inclusive science embracing the physical structure of the ear, the sound pathways and their functions, the perception of sound, and their interrelationships (Everest & Pohlmann, 2009). The three principal parts of the human hearing system consist of the outer ear, the middle ear, and the inner ear (see Figure 2.15; Ward, 2015).

The outer ear consists of the pinna (auricle), external auditory canal (meatus), and ear drum (tympanic membrane). The pinna is an external flap of tissue on either side of the head, which among other functions, operates as a sound gathering device. Hence, if an individual cups their hands behind their ears, they would increase the effective size of the pinna and therefore the apparent loudness by an amount that varies with frequency (Everest & Pohlmann, 2009).The outer ear also has an acoustic effect on sounds that enter the ear which enables us to locate sound sources and enhances some frequencies (Howard & Angus, 2009; Ward, 2015). The pinna funnels sound waves through the external auditory canal towards the eardrum. The auditory canal is roughly an inch long in adults and allows the eardrum, a thin disc of fibrous tissue, to be set inside the skull where is it safely protected (Leeds, 2010). Alterations of air pressure cause the eardrum to vibrate inwards and outwards in response to sound (Mathews, 1999).

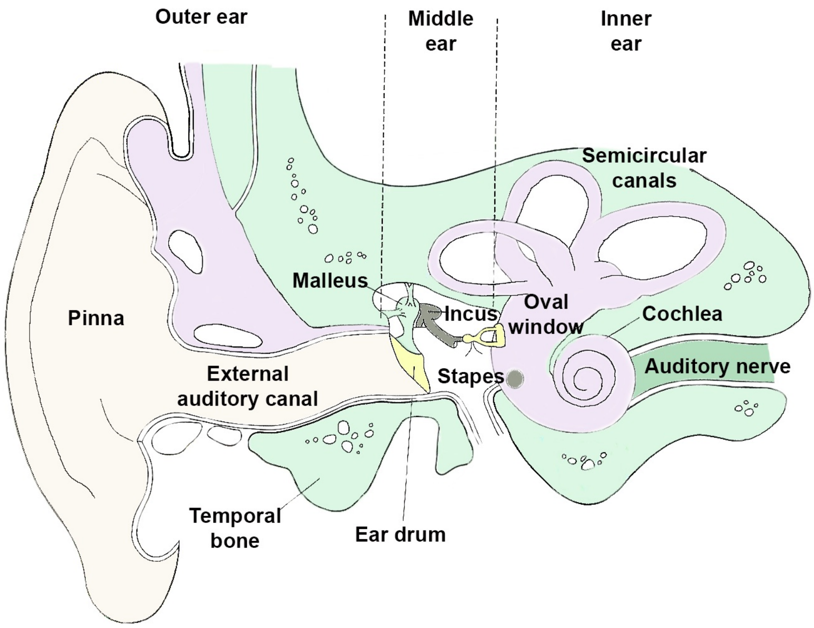

Figure 2.15. The human ear. Adapted from *The Student's Guide to Cognitive Neuroscience* (3th ed., p. 235), by J. Ward, 2015, London, UK: Psychology Press. Copyright 2015 by Jamie Ward.

Consider the following analogy of what the auditory system has to achieve in order to understand auditory objects in the world, using the eardrum as a guide. If you were to stretch a pillowcase tightly over the opening of a bucket, and people were to throw ping-pong balls at the pillowcase from different distances, your job would be to gauge how many people there are, who they are, and whether they are moving towards or away from the bucket just by studying how the pillowcase moves up and down over the opening of the bucket (Levitin, 2008). This analogy illustrates the sheer complexity of the auditory system.

The middle ear is the small connecting section of the sound highway and it has two main functions (see Figure 2.15). First, the middle ear transfers sound vibrations from the eardrum (outer ear) to the fluid-filled cochlea (inner ear) without significant losses of energy. Second, the middle ear serves to protect the hearing system from the effects of loud sounds that emanate from external sources or the individual (Howard & Angus, 2009). The middle ear is only about 2 mm in volume and consists of three tiny bones called the malleus, incus and stapes (also known as the hammer, anvil, and stirrup; Ward, 2015). Collectively, these three bones are known as ossicles (Howard & Angus, 2009). Working together, the ossicles form a lever system. The handle of the malleus sits against the inside of the eardrum. The incus rests between the malleus and the stapes. The foot of the stapes pressed against the oval window, which is the opening in the bony process that surrounds the cochlea (Leeds, 2010). The term acoustic reflex refers to the stiffening of the tiny bones as a means of protecting the inner ear from very loud sounds (Mathews, 1999).

Within the inner ear (see Figure 2.15), a structure is located that is similar in shape to that of a snail's shell and is known as the cochlea. The function of the cochlea is to convert sound vibrations into electrical signals to be eventually processed by the brain (Howard & Angus, 2009). The cochlea consists of three sections: The *scala vestibuli* and the *scala timpani* are chamberlike areas, filled with a fluid called perilymph, and divided by the *cochlea duct* (*scala media*). This duct is hollow and filled with the fluid endolymph. It is in and adjacent to the cochlea duct, that the major transformational activity of converting sound waves into electric impulses takes place (Leeds, 2010).

Inside the cochlea duct lies a section of the inner ear called the organ of Corti, which consists of the basilar membrane, approximately 15,000 hair cells, and the tectorial membrane (Howard & Angus, 2009; Leeds, 2010). The motion of sound waves causes the basilar membrane to move in relation to the tectorial membrane, which causes the hair cells, which are organised in rows according to height and known as cilia, to bend. Accordingly, if we could uncoil the cochlea and flatten it out, we would see hair cells on one end that are maximally responsive to low frequencies and hair cells on the other that are maximally responsive to high frequencies, similar to the way that keys are laid out on a piano (Levitin, 2013; Ward, 2015). It is the movement of cilia that induces a flow of ions which initiates neural activity (Leeds, 2010). There are multiple synapses in the auditory pathway from the ear to the brain, commencing with projections from the auditory nerve to the cochlear nuclei located in the brain brainstem, and ending with projections from the medial geniculate nucleus to the primary auditory cortex (see Figure 2.16; Ward, 2015).

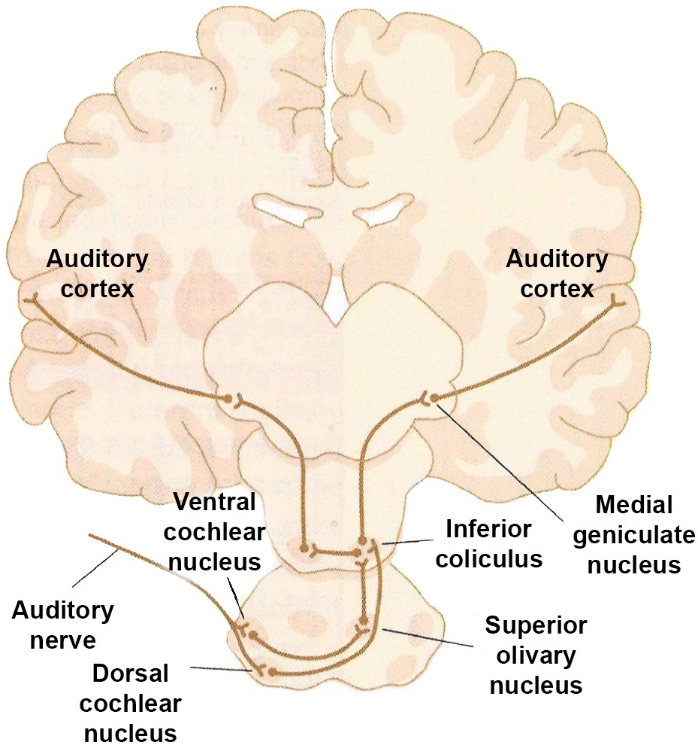

Figure 2.16. The ascending auditory pathway. Adapted from *The Student's Guide to Cognitive Neuroscience* (3th ed., p. 235), by J. Ward, 2015, London, UK: Psychology Press. Copyright 2015 by Jamie Ward.

2.3.2 Resonance and entrainment. *Resonance* refers to the impact of one vibration on another. Hence, something external sets something else into motion, or changes its vibratory rate. If you can match the vibratory rate of another object, it will *sympathetically* change (Leeds, 2010). The reader can compare this concept to pushing a child on a swing: to do this efficiently the pushes must be in time in order for the swing to move back and forth.

By adding energy to the swing in regular small amounts, the swing's movement gradually increases (van Noorden & Moelants, 1999). An example of resonance within the realm of music concerns opera singers who amaze crowds by shattering glass objects with their powerful voices. The singer initially taps the glass to gauge its natural frequency and then proceeds to sing at the same frequency, which builds up a strong resonant response that causes the glass to shatter.

The tenth cranial nerve is noteworthy for its response to sound stimulation. It is attached to both eardrums and extends to the gastrointestinal tract, where it stimulates several muscles and glands. Moreover, the tenth cranial nerve is connected to every organ other than the spleen (Davis, 2006). Accordingly, every sound that we hear affects organs in the human body by varying degrees. Substances that resonate are classed in one of two ways, those that vibrate at their natural frequency, and those that resonate at a variety of frequencies. The second type of resonance is referred to as *forced resonance* due to the way that the sounding frequency forces its tone on another body (Leeds, 2010).

Entrainment is described as a process wherein two rhythmic processes interact with each other, eventually adjusting and *locking in* to a common phase (Stevens, 2012). Hence, it is the synchronisation of a system with a variable frequency to an external frequency (Moens et al., 2014). An example of entrainment concerns the swinging motion of two clock pendulums placed on a wall, which synchronise with each other within half an hour or so, even if they are out of sync when initially placed on the wall.

There are two basic components involved in entrainment, there must be two or more autonomous rhythmic processes and they must interact with each other (Clayton, Sager, & Udo, 2005). An important feature that distinguishes entrainment from resonance pertains to the autonomous nature of the rhythmic processes. This implies that if the two processes are separated, they can still oscillate or function on their own. However, this cannot be said for resonance, if you were to take away the aforementioned individual pushing the child on the swing, the swing would eventually cease to a halt.

The laws of entrainment apply to the human body too, which consists of many internal rhythmic pulses in the form of brain waves, heartbeats, and respiratory rates that function in a periodic, repetitive fashion. *Self-entrainment* occurs when two or more of the body's pulses (e.g., respiration rate and heartbeat rhythms) synchronise. For example, the use of locomotor-respiratory coupling or breathing entrainment has been observed during repetitive exercises such as running, cycling, and rowing (Bonsignore, Morici, Abate, Romano, & Bonsignore, 1998; Webster et al., 2010; Wiley et al., 2001). Contrastingly, external stimuli such as music can influence internal pulses through entrainment to the periodicities in the rhythmic sequence (Large, 2000, 2008). Therefore, sound is the independent variable upon which our pulse systems change. If one pulse changes (e.g., brain waves), then the others (e.g., HR and respiration rate) will adapt accordingly (Leeds, 2010).

2.3.3 Music. Music is universal and a rich part of the human experience (Abrams et al., 2013; Krause & North, 2016). The basic elements of any sound are loudness, pitch, contour, rhythm, syncopation, tempo, timbre, and reverberation (Levitin, 2008). *Loudness* concerns how much energy an instrument creates, that is how much air it displaces, and is measured in dBA (Karageorghis, 2017). *Pitch* signifies how high or low a tone sounds to the ear and is a subjective impression (Levitin, 2008). The *contour* of a musical piece is the overall shape of the melody (Levitin, 2008). *Rhythm* refers to the durations of all sounding parts and how they group together into units (Cameron & Grahn, 2016). *Syncopation* occurs when a note is played earlier than the strict beat would call for, catching the listener by surprise (Morehead & MacNeil, 1991). *Tempo* signifies the overall speed of a musical piece and is measured in bpm (Levitin, 2008). *Timbre* is the quality that distinguishes one voice or musical instrument from another, based upon the harmonics of the sound (Karageorghis, 2017). *Reverberation* refers to the perception of how distant a sound source is from our ears and the size of the environment in which the sound is heard (Levitin, 2008).

Our brains categorise these fundamental perceptual attributes into higher-level concepts such as meter, melody, and harmony (Levitin, 2008). *Meter* can be considered as the way in which tones are grouped with one another (Cameron & Grahn, 2016). Accordingly, meter refers to how fast a piece of music feels regardless of its tempo (Karageorghis, 2017). The *melody* entails the succession of tones that are most salient in your mind and the part of a musical piece that is most frequently sung along to (Levitin, 2008). *Harmony* is the simultaneous combination of two or more notes and serves to shape the emotional character of the music (Karageorghis, 2017). When studied in the laboratory, investigators typically examine variations in one attribute of music while holding the remaining attributes constant, in order to maximise experimental control (Levitin & Tirovolas, 2009). Within the realm of exercise psychology, researchers have typically manipulated loudness (commonly referred to as *intensity*; e.g., Bishop, Karageorghis, & Kinrade, 2009; Bishop, Wright, & Karageorghis, 2014) and tempo (e.g., Bishop et al., 2014; Szabo & Hoban, 2004).

2.3.4 Music and exercise. In the context of exercise, the available literature has typically explored the psychological, psychophysical, ergogenic, and psychophysiological effects of music (Karageorghis, Bigliassi, Guérin, et al., 2018; Karageorghis & Priest, 2012a, 2012b). *Psychological* effects relate to the way in which music can influence an exerciser's affective states, cognitions (thought processes), and behaviours (Karageorghis, Bigliassi, Guérin, et al., 2018). *Psychophysical* effects concern the perceptions of physical effort and fatigue, most frequently assessed using RPE (Karageorghis & Priest, 2012a, 2012b). *Ergogenic* effects occur when music improves exercise performance by increasing work output or reducing feelings of fatigue. This very often results in the enhancement of exercisers' endurance, strength, power, or productivity (Karageorghis, 2016; Terry &

Karageorghis, 2011). *Psychophysiological* effects relate to how music can influence exercisers' physiological functioning, including measures of HR, blood pressure, and exercise lactate (Karageorghis, Bigliassi, Guérin, et al., 2018).

The application of music has been embraced for some time by exercise psychologists as a means by which to manipulate psychological and psychophysical states (Karageorghis & Priest, 2012a, 2012b). Music has become almost ubiquitous within exercise facilities, supporting the notion that exercise participants enjoy musical accompaniment. Furthermore, the widespread of use of music by professional athletes have furthered awareness of the power of sound (Karageorghis, Bigliassi, Tayara, Priest, & Bird, 2018).

2.3.4.1 Early research. A corpus of early research examined the impact of music on affective responses during exercise (Seath & Thow, 1995). In one such study, Boutcher and Trenske (1990) recorded affective responses during cycle ergometry at low, moderate, and high workloads using the FS (Hardy & Rejeski, 1989). Participants reported significantly enhanced positive affect when music was provided during the moderate and high workloads when compared to a condition of visual and auditory deprivation. Moreover, Kodzhaspirov, Zaitsev, and Kosarev (1988) adopted a longitudinal design to explore the use of music to accompany weightlifters' training. The researchers reported that music could positively influence the mood of weightlifters and 94.5% of participants revealed that they eagerly looked forward to training sessions accompanied by music. Collectively, the findings of Boutcher and Trenske (1990) and Kodzhaspirov et al. (1988) support the notion that music can positively influence affective responses at a range of work intensities (Karageorghis & Terry, 1997).

Researchers who examined the psychophysical effects of music in exercise settings reported largely inconsistent findings. For example, music was found to prompt a reduction in RPE during low-intensity cycle ergometry (Boutcher & Trenske, 1990). As a possible explanation for their findings, the researchers suggested that music's capacity to reduce RPE was load dependent, supporting Rejeski's (1985) parallel information processing model. Additionally, Copeland and Franks (1991) included retrospective measures of RPE when investigating the effects of music on a treadmill running protocol. The researchers measured RPE at five equally spaced points throughout the exercise bout and reported that soft/slow music could reduce participants' RPE.

In contrast to the aforementioned findings, investigators have also reported nonsignificant differences in RPE with musical accompaniment. For example, White and Potteiger (1996) compared three passive attentional manipulations, one of which contained fast upbeat music, on college students' RPE during cycle ergometry performed at 70% peak aerobic power. Only marginal differences in RPE between the music (M_{RPE} = 14.1) and control (M_{RPE} = 14.2) conditions were reported. Furthermore, researchers have reported that stimulative music could not alter the RPE of untrained college women and men cycling at 75% $\dot{V}O_{2max}$ when compared to a control condition (Schwartz, Fernhall, & Plowman, 1990). A possible explanation for these findings concerns the exercise intensity of the researchers' employed protocols. Accordingly, it appears that music exerts a greater influence over psychophysical measures at low exercise intensities (Boutcher & Trenske, 1990; Copeland & Franks, 1991) as opposed to those that approach peak aerobic power (White & Potteiger, 1996) or $\dot{V}O_{2max}$ (Schwartz et al., 1990).

Early investigations that explored the ergogenic effects of music also produced largely equivocal findings (Karageorghis & Terry, 1997; Lucaccini & Kreit, 1972). However, some of the positive findings indicated that music could enhance walking (Beckett, 1990) and running endurance (Copeland & Franks, 1991) when compared to no-music control conditions. Karageorghis, Drew, and Terry (1996) suggested that music might also positively influence tasks of a shorter duration. The researchers found that higher levels of grip strength could be attained after listening to stimulative music when compared to sedative music or a white noise control condition (Karageorghis et al., 1996). This finding complemented those attained earlier by Kodzhaspirov et al. (1988), who reported that 89.2% of weightlifters indicated that the quality of their training had increased with the addition of music.

A common feature of the aforementioned studies is that music was used to positively shape the exercise environment. However, there is also evidence that researchers sought to explore the effects of auditory-motor synchronisation. Findings indicated that music elicited an ergogenic effect during cycle ergometry (Anshel & Marisi, 1978), circuit training (Michel & Wanner, 1975), and callisthenic-type exercises (Uppal & Datta, 1990). Nonetheless, the findings were far from conclusive and other researchers reported no ergogenic effects pertaining to the use of music (Dorney, Goh, & Lee, 1992). For example, Pearce (1981) found that listening to stimulative music failed to facilitate the performance of a grip strength test when compared to a no-music control condition.

Scholars who sought to investigate the psychophysiological effects of music largely focused on measures of HR as their dependent variable of choice and reported conflicting findings (Brownley, McMurray, & Hackney, 1995). Copeland and Franks (1991) explained that HR was significantly lower during a treadmill endurance task with soft/slow musical accompaniment when compared to a control condition. However, the researchers employed a p value of $< .10$ which is higher than those generally accepted in the realm of exercise sciences (i.e., $p < .05$; Gratton & Jones, 2010). Copeland and Franks (1991) theorised that soft/slow music reduced physiological arousal during submaximal exercise and therefore facilitated participants' endurance performance. Investigators also assessed music's influence over measures of recovery HR. For example, it was reported that exercisers who walked with music accompaniment for 30 min demonstrated faster, albeit nonsignificant, rates of recovery than when walking in a no-music control condition (Beckett, 1990).

In addition to employing aerobic exercise protocols, researchers have also examined music's influence over measures of HR during protocols that involve the use of motor skills. It was reported that classical or fast music heard prior to dart-throwing performances could prompt a reduction in HR compared to a no-music control (Dorney et al., 1992). During a second study, participants who were assigned to an imagery-plus-music intervention displayed elevated HR when compared to an imagery-only group, prior to completing a sit-up task. The researchers concluded that music could strengthen the impact of imagery, which has positive implications for pre-performance strategies (Dorney et al., 1992).

In contrast to the aforementioned findings, investigators have suggested that music has no influence on measures of HR in an exercise context (Boutcher & Trenske, 1990). For example, Schwartz et al. (1990) reported no differences in HR when participants cycled at 75% $\dot{V}O_{2max}$ while listening to stimulative music. Moreover, the scholars did not find any statistical differences for aerobic capacity, ventilation, respiratory exchange ratio, and blood lactate when comparing the experimental music conditions to control (Schwartz et al., 1990).

2.3.4.1.1 Limitations of early research. The equivocal findings that emerged from early research in exercise and sport settings can be largely attributed to a host of methodological limitations (Karageorghis & Terry, 1997). One of the largest pitfalls of such research was the failure to report in sufficient detail the procedures relating to how and why the music was selected and subsequently used. To illustrate, Boutcher and Trenske (1990) described each of the 24 pieces of music used in their study as either *lively* or *more relaxing* but the criteria for what constituted *lively* or *more relaxing* was not disclosed. Furthermore, the intensity of the music played to participants within investigations received very little attention, which might have impacted reactivity to the music (Karageorghis & Terry, 1997).

Several other methodological weaknesses included: a lack of attention towards the temporal nature of when the music was introduced relative to the exercise task and the duration of the music played (e.g., Dorney et al., 1992); failure to acknowledge socio-cultural influences such as social class, ethnic background, and peer group influences, which partly determine psychophysical responses to music (e.g., Pearce, 1981); and ambiguity associated with musical terminology (e.g., Copeland & Franks, 1991). Consequently, investigators found it difficult to evaluate the findings and applicability of early research. Hence, it was impossible to replicate studies which impeded the progress of research within this line of scientific inquiry (Karageorghis & Terry, 1997).

An alternate explanation for the conflicting findings concerns the possibility of measurement error. To illustrate, Beckett (1990) described a procedure wherein participants were required to walk around a marked course for 30 min using a pedometer to gauge their distance travelled and simultaneously, participants were required monitor their HR without technical aid. Beckett (1990) could argue that testing participants outdoors enhanced the ecological validity of her study. However, it is important to recognise that the advancement and availability of modern-day technology, such as smartwatches with integrated support for the Global Positioning System and HR monitoring, have afforded researchers with greater measurement accuracy and consistency in the experimental realm. Research conducted post-1997 has attempted to overcome many of the aforementioned limitations that led to such ambiguous findings. Subsequently, a far greater understanding pertaining to the benefits of music within exercise settings began to emerge (Karageorghis & Priest, 2012b, 2012a). The development of conceptual frameworks helped guide investigators and considerably eased the process of addressing the methodological weaknesses associated with early research.

2.3.5 Conceptual frameworks. The first conceptual framework to predict the effects of music in exercise and sport settings was developed by Karageorghis and Terry (1995). The model predicted the psychophysical responses to *asynchronous* music, when individuals make no conscious effort to synchronise their movements to the rhythmical qualities of the music, during submaximal exercise. The model was based upon responses to *functional* music, which was defined as “goal-orientated work, well coordinated with the tasks and specifics of the session” (Kodzhaspirov et al., 1988, p. 39). Music that was considered functional promoted a change in arousal, reduced RPE, and improved mood. The psychophysical responses to asynchronous music were theorised to be determined by an interaction of *music factors* such as lyrics, tempo, melody and harmony, and *personal factors* such as socio-cultural background, associations and preferences (Karageorghis & Terry, 1995).

Karageorghis et al. (1999; see Figure 2.17) developed the second conceptual framework to predict the effects of music in exercise and sport contexts. Again, this model was limited to the asynchronous use of music. The researchers suggested that four factors contributed to the motivational qualities of a piece of music. *Rhythm response* referred to natural responses to musical rhythm, especially tempo, as measured in bpm. *Musicality* referred to pitch-related elements of music such as the melody and harmony. *Cultural impact* related to the pervasiveness of the music within society or a sub-cultural group, and *association* referred to the extra-musical associations that music may evoke (Karageorghis et al., 1999).

A basic premise of the model is that some aspects of music selection concern how the music is composed and performed, whereas others concern the interpretation of the music, which is shaped by the listener's cultural background (Karageorghis & Terry, 2011). Rhythm response and musicality pertain to how music is put together and are therefore *internal factors*. Alternatively, cultural impact and association pertain to the listeners' interpretation of the music and are therefore deemed *external factors*. Karageorghis et al. (1999) suggested that the internal factors are more important than the external factors in predicting how a person will respond to a piece of music.

The motivational qualities of a piece of music were theorised to: (a) act as a stimulant or a sedative to manipulate arousal levels; (b) reduce an exerciser's RPE at low-to-moderate exercise intensities; and (c) facilitate positive aspects of mood such as vigour, excitement, and happiness, while reducing negative aspects such as tension, boredom, depression, confusion, and fatigue. Collectively, it was thought that such responses to motivational music would prompt two chronic benefits, an enhanced pre-event routine for athletes, and increased exercise adherence by making the exercise experience more enjoyable (Karageorghis et al., 1999).

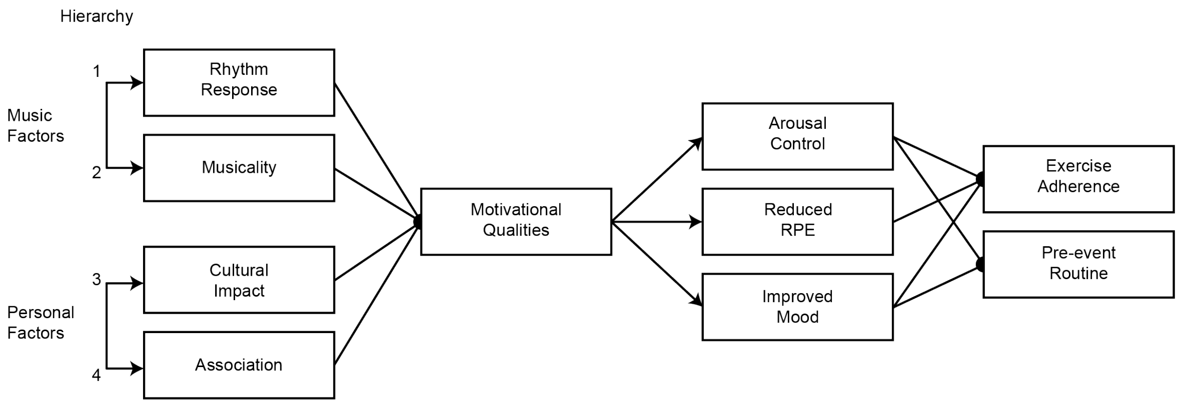

Figure 2.17. Conceptual framework for the prediction of responses to motivational asynchronous music in exercise and sport. Adapted from "Development and Initial Validation of an Instrument to Assess the Motivational Qualities of Music in Exercise and Sport: The Brunel Music Rating Inventory," by C. I. Karageorghis, P. C. Terry, and A. M. Lane, 1999, *Journal of Sports Sciences, 17,* p. 721. Copyright 1999 by Taylor & Francis.

Terry and Karageorghis (2006; see Figure 2.18) redeveloped their conceptual model, which featured a simplified structure and a broader list of potential benefits. Recognising that the influence of music is entirely dependent on the listener's preferences and the listening context, the redeveloped model included two supplementary antecedents. *Personal factors* included age, gender, personality type, commitment to exercise, fitness level, and attentional style. *Situational factors* involved the exercise environment and specifics of the exercise regimen (Karageorghis & Priest, 2012a, 2012b). The researchers proposed a number of benefits that exercise participants and/or athletes might derive from music listening such as improved mood and greater work output.

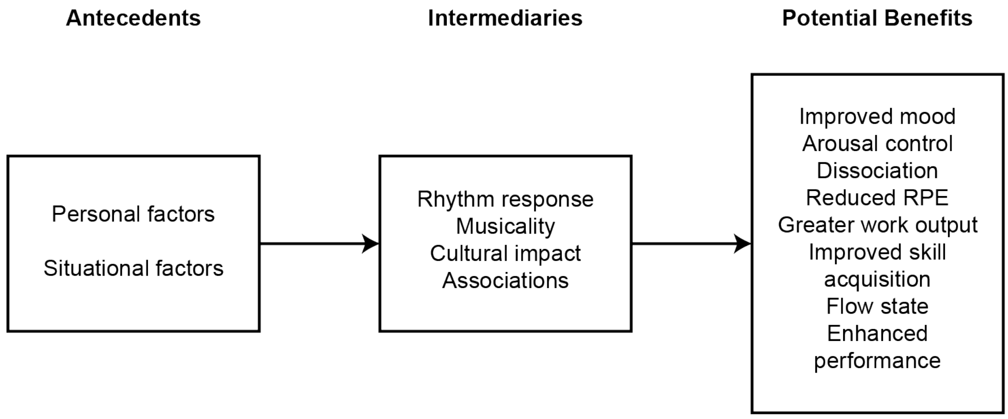

Figure 2.18. Conceptual framework for the benefits of music in exercise and sport contexts. Adapted from "Psychophysical Effects of Music in Sport and Exercise: An Update on Theory, Research, and Application," by P. C. Terry and C. I. Karageorghis, in M. Katsikitis (Ed.), *Psychology Bridging the Tasman: Science, Culture and Practice – Proceedings of the 2006 Joint Conference of the Australian Psychological Society and the New Zealand Psychological Society* (p. 416), 2006, Melbourne, VIC: Australian Psychological Society. Copyright 2006 by the Australian Psychological Society.

More recently, Karageorghis (2016) proposed a theoretical model to predict the effects of music in exercise and sport contexts (see Figure 2.19). The model was intended to be instructive as opposed to mechanistic and provided researchers and practitioners alike with a holistic visualisation of the relationships identified by researchers in this domain (Karageorghis et al., 2017). *Musical factors* were labelled as antecedents because they precede an individual's response to the piece of music and were divided into *intrinsic* (e.g., tempo, rhythm) and *extrinsic* (e.g., cultural associations) factors. Additionally, the intrinsic factors were theorised to be more influential than the external factors in determining how an individual might respond to a piece of music. Several *personal factors* (e.g., age, musical preferences) and *situational factors* (e.g., when music is played, sound source) were suggested to moderate an individual's response to music (Karageorghis, 2016).

The consequences of music use in exercise and sport settings were depicted in an order than corresponded with their prevalence in the extant literature (i.e., psychological consequences are the most frequently reported; see Figure 2.19). The model has a reciprocal structure that contains feedback loops that run from the consequences, through the moderators, and back to the antecedents. Accordingly, the consequences of music use in exercise and sport contexts were theorised to bear influence on future selection processes (Karageorghis, 2016).

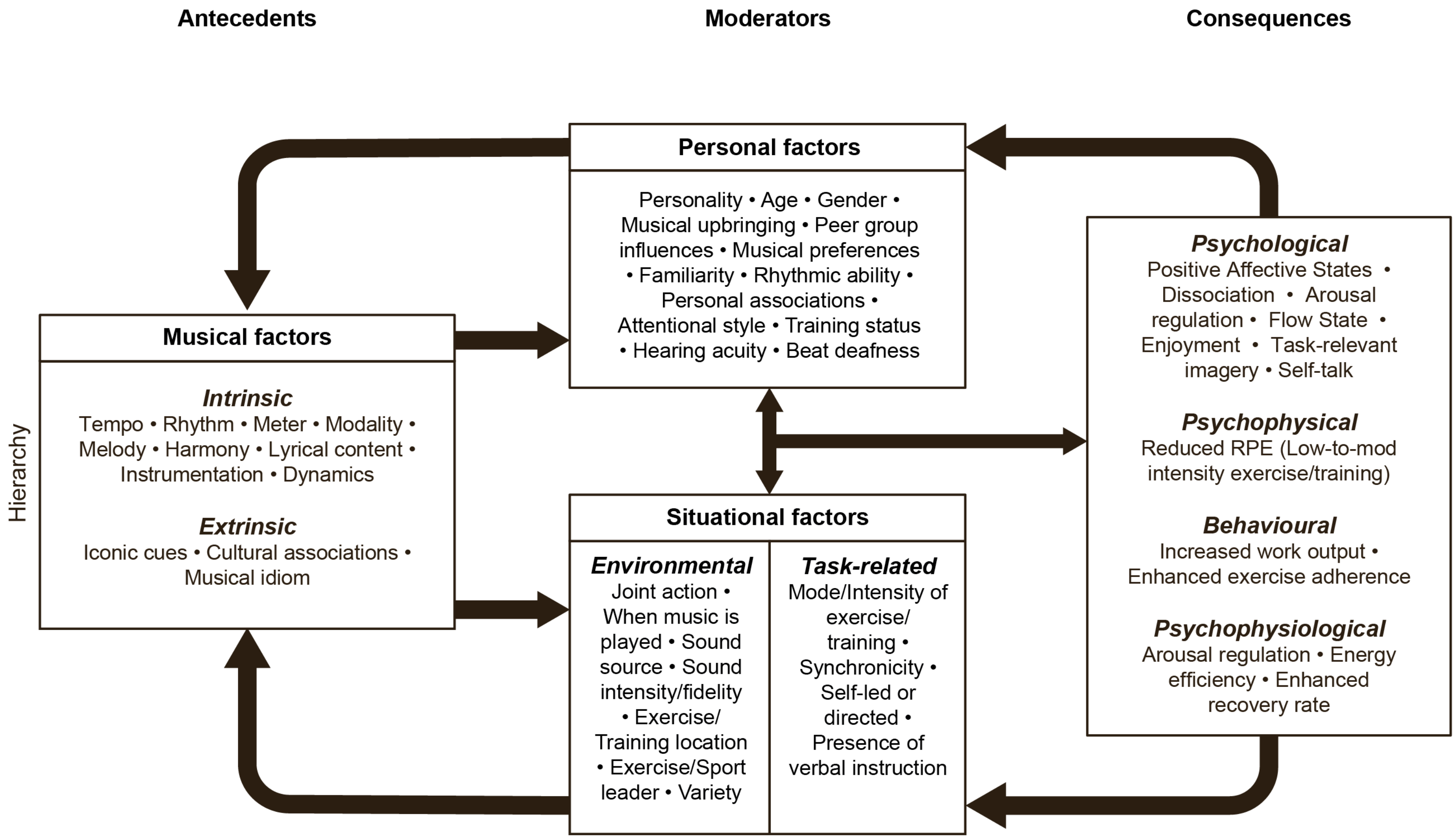

Figure 2.19. A theoretical model of the antecedents, moderators, and consequences of music use in the exercise and sport domain. Adapted from "The Scientific Application of Music in Exercise and Sport: Towards a New Theoretical Model," by C. I. Karageorghis, in A. M. Lane (Ed.), *Sport and Exercise Psychology* (2nd ed., p. 301), 2016, London, UK: Routledge. Copyright 2016 by Andrew M. Lane.

Following a systematic review and narrative synthesis of 23 theories, Clark, Baker, and Taylor (2016b) proposed a meta-theory that sought to explain the effects of listening to music during health-related exercise (see Figure 2.20). The researchers reported that music listening influences cortical and subcortical stimulation and responses during exercise. Consequently, such responses were theorised to facilitate physiological arousal and subjective experience, which were suggested to promote positive behavioural responses to exercise such as increased participation and adherence. The model includes a feedback/feedforward loop that was theorised to facilitate the execution of precise movements when rhythmic patterns in music are heard by the exerciser (Clark, Baker, & Taylor, 2016b).

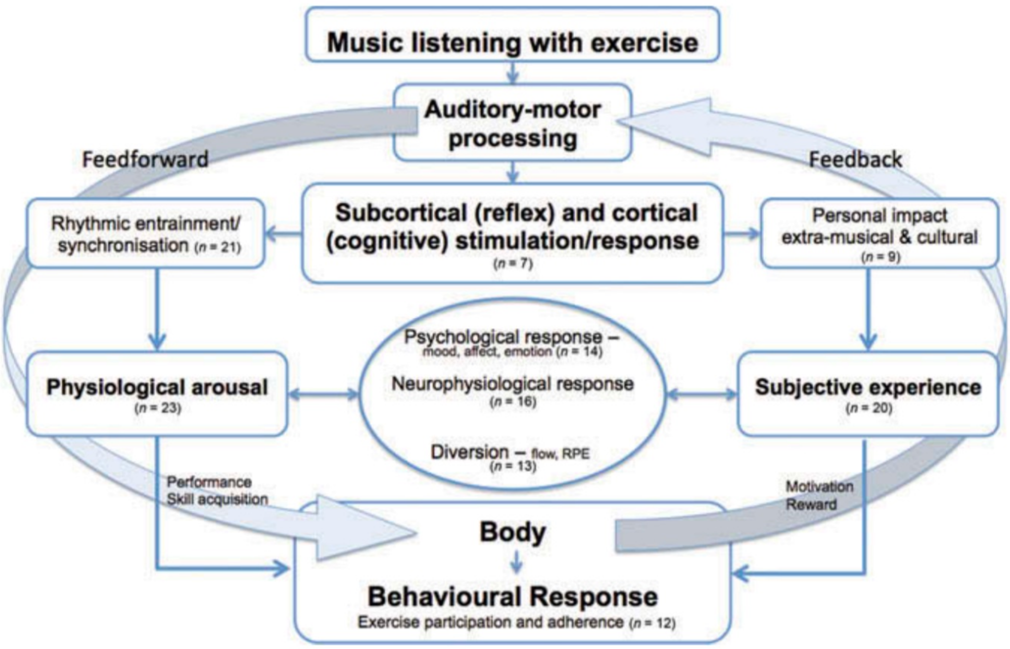

Figure 2.20. A meta-theory combining therapeutic, sports and exercise, and auditory-motor processing theories to describe the modulating effects of music listening on exercise and physical activity. Reprinted from "The Modulating Effects of Music Listening on Health-Related Exercise and Physical Activity in Adults: A Systematic Review and Narrative Synthesis," by I. N. Clark, F. A. Baker, and N. F. Taylor, 2016b, *Nordic Journal of Music Therapy, 25,* p. 92. Copyright 2015 by the Grieg Academy Music Therapy Research Centre.

Scholars have also proposed conceptual frameworks to enhance our understanding of how athletes use music. For example, Bishop, Karageorghis, and Loizou (2007) developed a grounded theory model to illustrate how young tennis players used music to manipulate their emotional states (see Figure 2.21). Participants were required to compile a list of musical pieces that they listened to prior to competing and these were the subject of discussion during an interview with the researchers. Further sources of data were obtained via questionnaires, diary entrees, and observations. It was suggested that extra musical associations, peer and family influences, film soundtracks and music videos, acoustical properties, and identification with the artist or lyrics interacted to determine the young tennis players' pool of emotive music (Bishop et al., 2007). From this pool of music, situational (e.g., present emotional state), modifiable emotional content and intensity (e.g., inspirational lyrics), and delivery (e.g., mode of delivery) mediators were theorised to influence the capacity of music to engender emotional states such as confidence.

The study conducted by Bishop et al. (2007) is one of the few that has adopted a qualitative approach to the study of music within the exercise and sport domain. However, this study has also received criticism from other researchers for its misuse of grounded theory as a total methodology (Weed, 2009). Indeed, Bishop et al. (2007) failed to consider key tenets such as theoretical sampling, a full constant comparative method and iterative process, and did not address issues pertaining to the fit, work, relevance, and modifiability of the model that arose from their analysis (Weed, 2009).

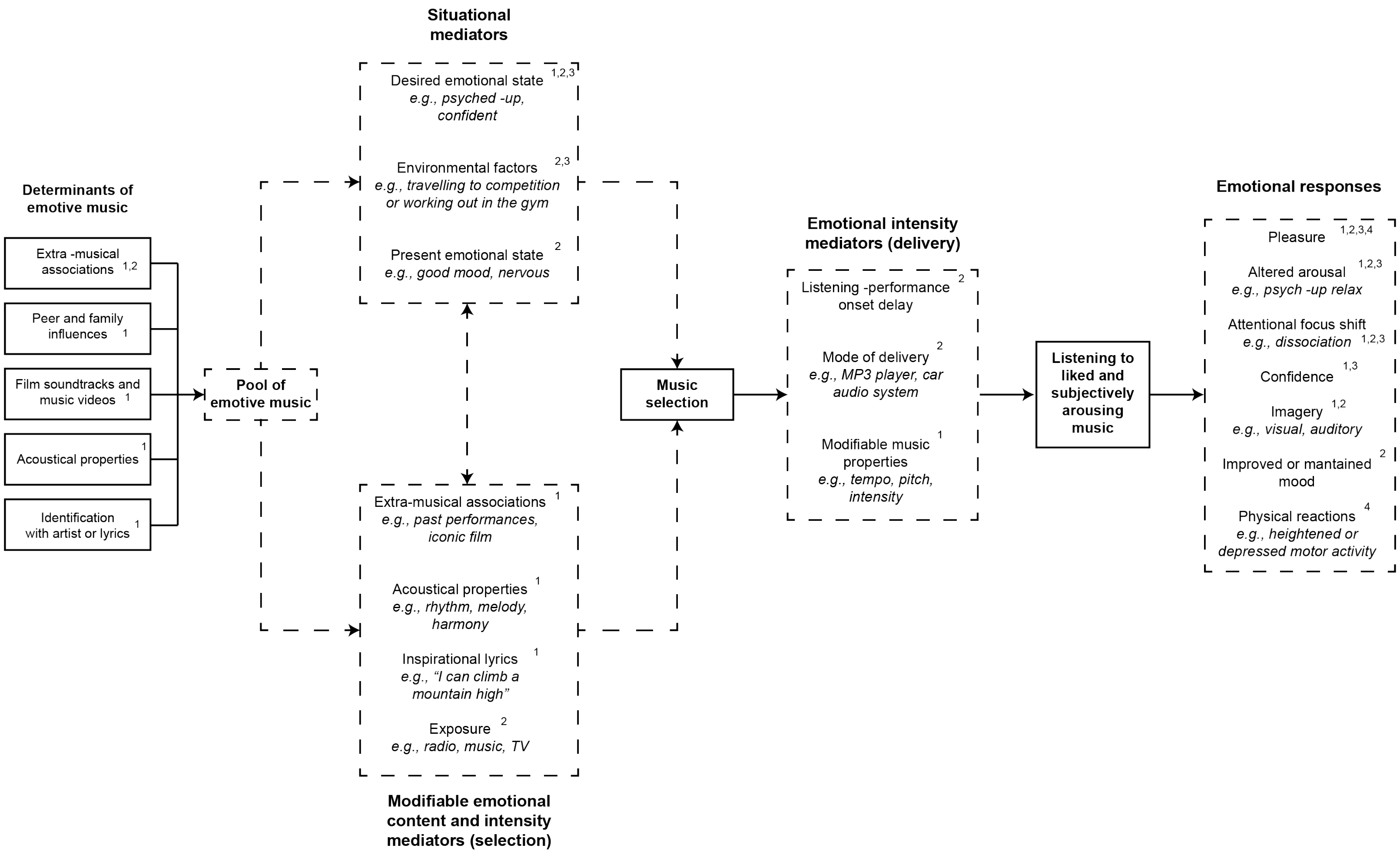

Figure 2.21. A model of young tennis players' use of music to manipulate emotional state. *Note.* Data from [1]interview, [2]diary, [3]questionnaire, and [4]interview. Adapted from "A Grounded Theory of Young Tennis Players' Use of Music to Manipulate Emotional State," by D. T. Bishop, C. I. Karageorghis, and G. Loizou, 2007, *Journal of Sport & Exercise Psychology, 29,* p. 593. Copyright 2007 by Human Kinetics.

In an attempt to address the methodological weaknesses identified in previous work (Bishop et al., 2007), Karageorghis, Bigliassi, Tayara, Priest, and Bird (2018) conducted a grounded theory study that sought to explain and predict academy soccer players' use of music to aid psychological preparation (see Figure 2.22). An iterative process of data collection and analysis was employed by the researchers and data was gathered from a variety of sources (e.g., individual- and group-based interviews, reflective journals). The resultant grounded theory model supports the notion that music components (e.g., lyrics, tempo) and extramusical associations (e.g., identification with the artist) are moderated and affected by group factors (e.g., team atmosphere), personal factors (e.g., listening habits) and task-related factors (e.g., when music is played). The interaction between such factors subsequently influences the impact of the music in terms of its positive physical and/or psychological benefits.

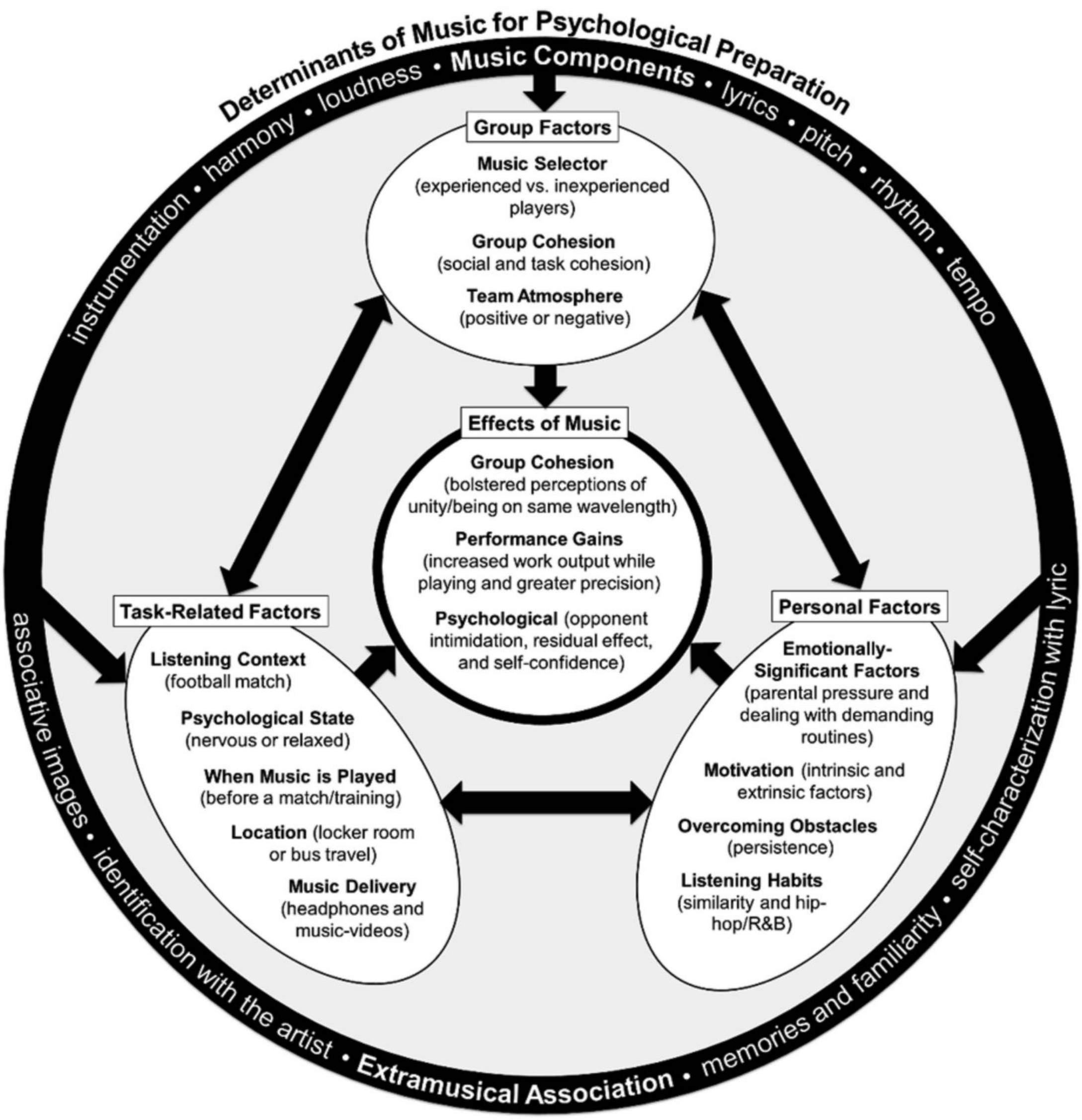

Figure 2.22. A grounded theory model of young soccer players' use of music in psychological preparation. Reprinted from "A Grounded Theory of Music Use in the Psychological Preparation of Academy Soccer Players," by C. I. Karageorghis, M. Bigliassi, K. Tayara, D.-L. Priest, and J. M. Bird, 2018, *Sport, Exercise, and Performance Psychology, 7,* p. 117. Copyright 2017 by the American Psychological Association.

2.3.6 Motivational properties of music. As a means by which to measure the motivational qualities of music within exercise and sport domains, Karageorghis et al. (1999) developed the Brunel Music Rating Inventory (BMRI), which was based upon the researcher's second conceptual framework. Users of the BMRI are required to rate 13 items that evaluate the subscales of rhythm response (4 items), musicality (2 items), cultural impact (4 items), and extra-musical association (3 items), which are suggested to contribute to the motivational qualities of a given track. Each of the 13 items is rated on a 10-point scale anchored by 1 (*not at all motivating*) and 10 (*extremely motivating*).

The BMRI has been employed in investigations that have demonstrated music's ability to produce an ergogenic effect (Crust & Clough, 2006), enhance affective states (Elliott, Carr, & Savage, 2004), and reduce RPE (Karageorghis & Jones, 2000). However, the BMRI was not without a number of limitations. Foremost among these were instability evident in the rhythm response factor following a multi-sample confirmatory factor analysis, low internal consistency for items that tapped cultural impact, and a weak relationship between the familiarity item and cultural impact (Karageorghis et al., 1999). Moreover, the BMRI was validated using a panel of aerobics instructors, who were deemed to be experts in music selection. Hence, the validation process reflected what aerobics instructors perceived would be motivating for exercise participants, rather than incorporating the views of exercise participants themselves (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006).

The BMRI (Karageorghis et al., 1999) was later revised to account for its predecessor's limitations. The BMRI-2 (Karageorghis, Priest, et al., 2006) and BMRI-3 (Karageorghis, 2008) are both six-item measures and are therefore particularly useful for rating a large number of musical selections. In addition, both instruments have demonstrated stronger psychometric properties when compared to the original measure and have been employed in a number of studies within exercise and sport settings (Clark, Baker, Peiris, Shoebridge, & Taylor, 2016; Crust, 2008; Karageorghis et al., 2009). Despite possessing solid psychometric properties, it is important to note that there are limitations in rating the motivational qualities of music purely on the basis of psychometric instruments. In order to derive the greatest benefits of music within exercise and sport contexts, the BMRI-3 should be complemented by a qualitative approach, which allows for the consideration of additional grounds such as extra-musical associations and preferred lyrical content (Karageorghis, 2008).

2.3.7 The application of music. Within the exercise domain, music can be applied in three primary ways: pre-task, in-task, and post-task (Karageorghis, Bigliassi, Guérin, et al., 2018). The application of *pre-task music* is focused towards preparation and is traditionally employed for music's use as a stimulant or sedative, or to enhance an individual's affective state (Bishop et al., 2007; Karageorghis & Priest, 2012a, 2012b). Music used pre-task often contains inspirational or motivational lyrics and is generally at a moderate tempo (Karageorghis, 2017; Karageorghis & Bird, 2016).

In-task music has attracted the most research attention and can be applied *synchronously* or *asynchronously*. Synchronous music entails a process of auditory-motor synchronisation and when an individual or group is consciously aware of such synchronisation, the author refers to this as *active synchronisation* (Karageorghis, Bigliassi, Guérin, et al., 2018). Alternatively, *passive synchronisation* refers to a motor process wherein a digital interface adapts the tempo of the music in real-time to match the movement rate of an individual or group (Karageorghis, Bigliassi, Guérin, et al., 2018). The in-task application of *asynchronous music* entails the absence of auditory-motor synchronisation. Hence, asynchronous music is used as background or ambient music to accompany exercise (Karageorghis, 2017).

The final application concerns *post-task music* and similarly to synchronous music, researchers have recently delineated two main forms (Karageorghis, Bigliassi, Guérin, et al., 2018). *Recuperative music* is used immediately after an exercise task and can be used to supplement *active* (i.e., movement-based) and *passive* (i.e., static) recovery (Terry & Karageorghis, 2011). Alternatively, *respite music* entails the use of music during periods of recovery within an exercise session to help assuage negative affective states that typically accompany such exercise (Jones et al., 2017). Herein, the reader is provided with a review of the extant literature pertaining to each application of music within the exercise domain.

2.3.7.1 Pre-task music. Relatively few attempts have been made to investigate the use of pre-task music in an exercise setting (Smirmaul, 2017). Moreover, the extant literature has focused predominantly on the propensity of pre-task music to elicit an ergogenic effect. For example, Karageorghis et al. (1996) examined the effects of stimulating and sedative music on grip strength in an attempt to overcome several methodological shortcomings that were evident in a previous study (Pearce, 1981). The researchers reported that listening to high-tempo stimulative music (134 bpm) yielded significantly higher grip strength than listening to slow-tempo sedative music (90 bmp) or a white noise control condition (Karageorghis et al., 1996). Limitations of the study include varying durations of musical selections (e.g., 230 s for stimulative music, 190 s for sedative music, 210 s for white noise), which might have compromised the internal validity. Furthermore, measures of arousal were not obtained by the investigators. Hence, it is difficult to ascertain whether the resultant changes in grip strength performance were due to changes in arousal, or other factors, such as state motivation.

Recently, Karageorghis, Cheek, Simpson, and Bigliassi (2018) continued this line of study by examining the interactive effects of music tempi and intensity on grip strength. The researchers employed five conditions: fast/loud (126 bpm/80 dBA), fast quiet (126 bpm/70 dBA), slow/loud (87 bpm/80 dBA), slow/quiet (87 bpm/70 dBA), and a no music control. Results indicated that the fast/loud condition led to the highest grip strength. Addressing the aforementioned limitations (cf. Karageorghis et al., 1996), the researchers included measures of affective responses and found that the fast/loud condition prompted the most positive affective valence. Moreover, music played at a high intensity yielded greater scores for affective arousal when compared to quiet music.

The majority of studies that have examined pre-task music have incorporated music prescribed by investigators (Bishop et al., 2009, 2014; Eliakim, Meckel, Nemet, & Eliakim, 2007; Tounsi, Jaafar, Aloui, Tabka, & Trabelsi, 2019). This has been raised as a possible cause for concern, as music of this type might prompt an external locus of control (Chanda & Levitin, 2013). An alternative approach affords participants the opportunity to self-select music for pre-task application (Pain, Harwood, & Anderson, 2011; Smirmaul, Dos Santos, & Da Silva Neto, 2015). Findings from such studies indicate that self-selected music can facilitate flow states (Pain et al., 2011), as well as enhance physical (Smirmaul et al., 2015) and perceived (Pain et al., 2011) performance across a range of exercise/sport modalities.

Researchers have often sought to apply music prior to the performance of maximal cycle ergometry tests (Chtourou, Jarraya, Aloui, Hammouda, & Souissi, 2012; Eliakim et al., 2007; Jarraya et al., 2012). For example, Yamamoto et al. (2003) investigated the effects of listening to either fast- or slow-tempo music for 20 min prior to a 45-s supramaximal cycling test. Neither condition produced significant changes in power output. Nonetheless, the researchers reported that the fast-tempo music facilitated circulation of norepinephrine, a physiological indicator of arousal, whereas the slow-tempo music had the opposite effect (Yamamoto et al., 2003). The slow-tempo music condition consisted of classical music (i.e., Chopin), whereas the fast-tempo music condition included music from popular American films (i.e., Top Gun, Rocky). Accordingly, the musical selections might not have been culturally appropriate for the Japanese undergraduate students who took part in the study.

Eliakim et al. (2007) extended this line of scientific inquiry using a sample of elite volleyball players. Participants were required to warm-up for 10 min with and without music and subsequently take part in a Wingate Anaerobic Test. The findings indicated that participants’ mean HR was significantly higher when warming-up with music and all participants recorded significantly greater peak anaerobic power during the ergometer test. Collectively, these studies support the notion that listening to music prior to completing a physical task might produce an ergogenic effect that is underpinned by neurophysiological mechanisms (Bishop et al., 2014; Karageorghis, Cheek, et al., 2018).

Pre-task music has also been employed prior to choice-reaction tasks. In one such study, Bishop et al. (2009) modified the tempo and intensity of a prescribed piece of music and compared it to white noise and silence conditions. The researchers reported that loud music resulted in the fastest choice-reaction task performance. This study is notable for employing a suitable measurement tool for the study of affective responses to pre-task music (i.e., the Affect Grid; Russell et al., 1989). The findings indicated that fast-tempo music elicited the most pleasant affective valence and highest ratings of arousal (Bishop et al., 2009).

2.3.7.2 In-task synchronous music. The idea of synchronising movement patterns to the rhythmic qualities of music is not a recent development. Indeed, classes (e.g., spin and aerobics) that revolve around applying music synchronously within exercise contexts are commonplace. Numerous teams of researchers have demonstrated the effectiveness of synchronous music in promoting psychological, psychophysical, ergogenic, and psychophysiological outcomes during exercise (Bacon, Myers, & Karageorghis, 2012; Fritz et al., 2013; Nikol, Kuan, Ong, Chang, & Terry, 2018).

Physical tasks that involve repetitive movements, such as walking or running, are often favoured by investigators when examining the effects of synchronous music (Mendonça, Oliveira, Fontes, & Santos, 2014; Ready, McGarry, Rinchon, Holmes, & Grahn, 2019; Van Dyck et al., 2015). For example, a study by Styns, van Noorden, Moelants, and Leman (2007) reveals how participants walked faster when they synchronised their walking cadence with the tempo of music compared to a metronome control condition. The researchers explained that participants could synchronise their walking movements with music over a range of tempi, but that synchronisation was optimal around 120 bpm. This finding demonstrates that the speed of movements required for walking is characterised by a similar resonance phenomenon observed in hand tapping-experiments (van Noorden & Moelants, 1999).

In a follow-up study, Leman et al. (2013) standardised all music with regards to duration (30 s) and tempo (130 bpm), which was slightly above the suggested resonance frequency in human movement (i.e., 2 Hz; MacDougall & Moore, 2005; van Noorden & Moelants, 1999). The researchers theorised that differences in walking speed could only be resultant of music-induced differences in stride length. Findings indicated that entrainment of music and movement involved (a) a timing component related to the movement response, and (b) a vigour component, whereby participants took larger or smaller steps in response to activating and relaxing music. It has been suggested that bodily pules such as respiration rate and motor patterns entrain to musical rhythms even in the absence of conscious effort (Thaut, 2008). This is evident in an exercise context, wherein the application of asynchronous music unintentionally led to a degree of auditory-motor synchronisation (Hutchinson & Karageorghis, 2013; Karageorghis et al., 2013). For example, a participant who had completed a treadmill task with musical accompaniment explained “I don’t think I was trying to keep in time with the music, I think it just sort of ended up going that way” (Karageorghis & Jones, 2014, p. 306).

Another repetitive exercise modality that researchers have employed when investigating the effects of synchronous music is that of cycle ergometry (Karageorghis & Jones, 2000). Findings indicate that cycling in the presence of synchronous music can reduce $\dot{V}O_2$ and limb discomfort (Bacon et al., 2012; Lim, Karageorghis, Romer, & Bishop, 2014), while prompting more positive affective valence and arousal when compared to control conditions (Lim et al., 2014). Collectively, these findings lend support to the idea that synchronous music can reduce the metabolic cost of exercise by facilitating greater neuromuscular or metabolic efficiency (Smoll & Schutz, 1978).

The majority of research that has applied synchronous music within exercise and sport settings has employed protocols that involve time to voluntary exhaustion (Bood, Nijssen, van der Kamp, & Roerdink, 2013; Karageorghis et al., 2009). For example, Terry et al. (2012) reported a number of benefits when elite triathletes synchronised their movements to music during a treadmill protocol. Participants reported more positive affective valence, reduced RPE, greater time-to-exhaustion, lower blood lactate concentrations, less $\dot{V}O_2$, and enhanced running economy when compared to a no-music control condition. The study was conducted within a laboratory setting, which hindered ecological validity. Nonetheless, this was the first music-related study to employ a sample of elite athletes and demonstrated the positive influence of music across varying levels of expertise.

As a means of enhancing the ecological validity of previous findings, Nikol et al. (2018) examined the influence of synchronous music on psychophysiological parameters and running performance in hot and humid conditions. The researchers heated a laboratory to 31° C using halogen lamps and 70% humidity using a water-bath. Thereafter, participants were required to run for 60 min at 60% $\dot{V}O_{2max}$ and continued to volitional exhaustion at 80% $\dot{V}O_{2max}$. Findings revealed that a synchronous music condition elicited greater time-to-exhaustion and lower RPE when compared to a no music control condition.

In addition to studies that include time-to-exhaustion protocols, researchers have examined the degree to which synchronous music can facilitate exercise of a fixed workload. For example, Simpson and Karageorghis (2006) reported significant improvements in 400-m sprint performance during synchronous music conditions compared to a no-music control. A minor limitation of the study was that participants' 400-m times were recorded using hand-held stopwatches. Although trained timekeepers operated these, using electronic timing could have enhanced the reliability of the performance data. Moreover, the intensity of the music was reported in relation to the equipment used (i.e., Level 16) as opposed to being measured in dBA, which slightly hinders the potential to replicate the study. Nonetheless, the results provide support for the notion that music can aid physical tasks performed at differing exercise intensities (Karageorghis & Priest, 2012a, 2012b).

The findings concerning the synchronous application of music in exercise contexts are not entirely conclusive. For example, Karageorghis et al. (2010) reported that circuit training accompanied by synchronous music did not elicit any significant psychological or ergogenic (number of repetitions performed) effects, which contradicted the findings of previous research (Hayakawa, Takada, Miki, & Tanaka, 2000). However, a significant Gender × Condition interaction did emerge for both dependent variables. Both genders performed worse when exercising with oudeterous music compared to motivational music, but only women performed worse in a control condition compared to oudeterous music. Conversely, men performed equally well during the control and motivational music conditions. Additionally, women reported more positive affective states than men in both the music conditions but not the control. These findings indicate that women were more able to coordinate their movements with musical tempo then men and this might help explain the popularity of exercise-to-music classes among women (Karageorghis & Priest, 2012b, 2012a).

Karageorghis et al. (2010) suggested that the tasks chosen in their study were more demanding in terms of physical load and more reliant on motor skills than those of previous research (e.g., Karageorghis et al., 2009). The *time form printing* phenomenon, which relates to the execution of repetitive patterns of movement (e.g., walking) following only an initial command requiring attention (Clynes & Walker, 1982), may more readily explain the ergogenic effects of synchronous music in endurance-based activities. Conversely, the movements that are necessary to perform circuit-training might have required an additional conscious effort, thereby reducing potential gains in efficiently resulting from auditory-motor synchronisation.

A innovative proof-of-concept study conducted by Alter et al. (2015) sought to examine the potential for synchronised personalised music to enhance physical activity adherence among cardiovascular disease patients participating in a cardiac rehabilitation programme. The authors employed a two-step randomisation process whereby participants were firstly randomised into synchronous music vs. no music condition. Thereafter, those in the synchronous music condition were subject to additional randomisation in which half the participants were exposed to music with additional rhythmic sonic enhancements.

The results of the study indicated that patients in the synchronous music conditions achieved higher volumes of physical activity over a 3-month period when compared to a no-music control condition (Alter et al., 2015). Moreover, patients exposed to synchronous music with additional rhythmic sonic enhancements attained almost twice the volume of physical activity when compared to synchronous music without enhancement and control. It is notable that the researchers employed accelerometer data as a means of providing an objective measure of physical activity. Accordingly, the findings add weight to the notion that music can facilitate physical activity adherence.

Principles of entrainment have also been integrated in the development of technology, facilitating passive synchronisation (Karageorghis, Bigliassi, Guérin, et al., 2018). For example, D-Jogger is a musical interface that detects body movements to dynamically select music and adapt its tempo to the user's pace for walking or running (Moens et al., 2014). A number of smartphone applications (e.g., *Spotify Running, RockMyRun*) can also adjust audio playback to ensure synchronisation with a user's walking or running cadence. Such applications ensure that individuals can employ the principles of musical entrainment in any exercise environment that permits access to a smartphone.

2.3.7.3 In-task asynchronous music. The vast majority of researchers who have examined the effects of in-task music have chosen to apply music asynchronously (Gabana, Van Raalte, Hutchinson, Brewer, & Petitpas, 2015; Pates, Karageorghis, Fryer, & Maynard, 2003). There is evidence to suggest that asynchronous music can engender positive affective responses to exercise. For example, Elliott, Carr, and Orme (2005) required participants to complete a 20-min submaximal cycle ergometry task while exposed to motivational music, oudeterous music, and a no music control. The researchers measured affective valence at five points throughout the exercise bout using the FS (Hardy & Rejeski, 1989). Subsequently, the findings indicated that the motivational and oudeterous music conditions prompted more positive affective valence when compared to the control condition.

Hutchinson et al. (2018) furthered this line of scientific inquiry by examining the effects of self-selected music during treadmill running. Instead of employing a fixed exercise intensity, participants were instructed to self-select an intensity that felt "good" according to the FS (i.e., corresponding to a value of +3; Hardy & Rejeski, 1989). Participants exercised for 20 min and completed a music and no music control condition separated by a period of 48 hr. Results revealed that participants chose an exercise intensity that exceeded their VT during both trials. However, the music condition prompted more positive affective valence throughout the exercise bout (M = 3.38, SD = 0.67) when compared to a no-music control condition (M = 2.79, SD = 0.81).

In addition to studying affective responses to asynchronous music during exercise, researchers often examine the psychological and psychophysical effects of such music in tandem. For example, an ambitious study conducted by Hutchinson and Karageorghis (2013) required participants to take part in a series of 7-min treadmill runs at three exercise intensities (i.e., low [45% HRR], moderate [65% HRR], and high [85% HRR]) crossed with three music listening conditions (i.e., motivational, oudeterous, and a no music control). The findings revealed that participants' state attention shifted from dissociation to association with increasing exercise intensity. Moreover, both music conditions led to a reduction in RPE during high-intensity exercise among participants with an associative dominant attentional style.

Fritz et al. (2013) sought to investigate the assertion that music lowers RPE by diverting attention away from unpleasant proprioceptive sensations associated with fatigue. The researchers employed a physical task that intentionally relied on the experience of body proprioception, rather than diverting attention away from it. Fritz et al. adapted three fitness machines so that participants either created musical sounds while exercising or passively listened to similar music produced by other individuals. The term *jymmin* (a mixture of *jamming* and *gym*) was given to this type of music feedback technology, which was engineered so that the sounds of the machines combined into a musical piece with a constant tempo of 130 bpm.

The findings revealed that participants experienced significantly lower RPE when making music with their movements (musical agency) when compared to passive listening (Fritz et al., 2013). However, there were some limitations associated with the study. For example, RPE scores were reported as a ratio between how participants felt while jymmin vs. passive listening. An alternative approach would have been to report participants' raw scores, as this would have allowed for greater interpretation of the results. Nonetheless, the aforementioned findings support the notion that the influence of music on RPE cannot always be attributed to a diversion from proprioceptive feedback (Fritz et al., 2013; Hutchinson & Karageorghis, 2013).

Researchers have reported an ergogenic effect of asynchronous music across a range of exercise modalities performed anaerobically such as rowing sprints (Rendi, Szabo, & Szabó, 2008), swimming time trials (Karageorghis et al., 2013; Tate, Gennings, Hoffman, Strittmatter, & Retchin, 2012), Wingate Anaerobic Tests (Stork, Kwan, Gibala, & Martin Ginis, 2015), and bench-press exercises (Bartolomei, Michele, & Merni, 2015). A study by

Crust (2004) investigated the effects of asynchronous music during an isometric strength task. The results revealed that participants held a weight suspended for the longest period of time during exposure to music compared to a white-noise control condition. Crust and Clough (2006) extended this line of scientific research by comparing motivational music, a rhythm condition, and a no-music control. The rhythm condition was extracted from the motivational piece of music and contained no melody, harmonies, or lyrics. Participants held the weight significantly longer during the motivational music condition. Accordingly, it appears music loses some of its potency when various constituents (e.g., lyrical content) are removed (Sloboda, 2008).

Another large body of research has explored the impact of asynchronous music during aerobic exercise modalities (Atkinson, Wilson, & Eubank, 2004; Bigliassi, León-Domínguez, Buzzachera, Barreto-Silva, & Altimari, 2015; Ghaderi, Rahimi, & Azarbayjani, 2009). For example, a novel study conducted by Lim, Atkinson, Karageorghis, and Eubank (2009) introduced and removed asynchronous music at various points during a 10-km cycle time trial. Exposure to music was controlled so that the experiment consisted of three conditions: music introduced at 0–5 km; music introduced at 5–10 km; and a no-music control. Although no significant differences in performance were found across conditions, participants recorded the fastest 10-km times when they anticipated the introduction of music from 5–10 km.

Sanchez, Moss, Twist, and Karageorghis (2014) modified asynchronous music in order to explore the effects of lyrical content during submaximal cycle ergometry. The findings revealed that participants achieved a higher cycling cadence when listening to music with lyrics when compared to an instrumental version of the same track, providing support for previous finings (Crust & Clough, 2006). However, the inclusion of lyrics did not influence measures of affect, RPE, or HR. The finding of increased pedal cadence without a corresponding increase in HR has been observed in prior research (Bacon et al., 2012; Terry et al., 2012), and might be attributed to enhanced neuromuscular efficiency resulting from participants' unconscious entrainment to the rhythmic qualities of the music (Thaut, 2008).

Researchers have also manipulated the tempo of asynchronous music to accompany aerobic exercise (Dyer & McKune, 2013). For example, Waterhouse, Hudson, and Edwards (2010) found that speeding up a music programme by 10% enhanced distance covered, power, and pedal cadence during cycle ergometry, whereas the same music slowed down by 10% had the converse effect. However, it should be noted that altering the tempo of the 6-track music programme caused the duration of the exercise protocol to vary between the experimental conditions (i.e., those exercising to slow music exercised for the greatest amount of time). An alternative approach is to limit the amount of exercise to a predetermined period of time or volume, as this allows for greater validity when comparing the results of experimental conditions (Edworthy & Waring, 2006; Szabo, Balogh, Gáspár, Váczi, & Bösze, 2009). For example, Rendi et al. (2008) examined the effects of fast and slow music during a 500-m rowing task. The researchers found that participants exposed to fast music performed significantly more strokes per min than they did in both a slow music and control condition; this led to the shortest completion times.

2.3.7.4 Post-task music. This type of music application is employed following the cessation of an exercise task and represents an emerging area of research, reflected by the paucity of empirical studies aimed at determining its efficacy (Karageorghis, Bigliassi, Guérin, et al., 2018). Post-task music can be employed in a recuperative manner, to facilitate either a passive or active recovery from exercise (Karageorghis, 2017). There is evidence to suggest that post-task music can engender positive psychophysical and psychophysiological effects in the exercise domain. For example, Jing and Xudong (2008) examined the effectiveness of sedative music to encourage passive recovery from cycle ergometry. Participants were required to cycle at a pedal cadence of 50 revolutions per minute (rpm) until the point of voluntary exhaustion. Upon completion, participants were assigned to either a music group, who listened to 15 min of sedative music, or a no-music control condition. The results showed that participants' HR, urinary protein, and RPE decreased significantly in the music condition and that such decreases were greater than those reported in the no-music control (Jing & Xudong, 2008).

Researchers have also employed motivational music in an attempt to promote an active recovery from intense exercise. For example, Eliakim, Bodner, Eliakim, Nemet, and Meckel (2012) required participants to run on a treadmill for 6 min at an intensity that corresponded with their $\dot{V}O_{2peak}$. Thereafter, participants were encouraged to walk around the laboratory under conditions of experimenter-selected motivational music and a no-music control. The researchers reported that the music condition engendered significantly greater voluntary activity, as measured by the number of steps taken by participants. Moreover, participants' blood lactate concentration levels were significantly lower in the motivational music condition when compared to the no-music control.

Eliakim, Bodner, Meckel, Nemet, and Eliakim (2013) extended this line of inquiry by investigating the effects of rhythm on active recovery from intense exercise, using the same treadmill protocol from their previous study (Eliakim et al., 2012). The researchers suggested that listening to rhythmic beats derived from motivational music was associated with a significantly greater number of steps and lower absolute lactate levels when compared to a no-music control. These findings shone a light on the importance of musical rhythm during recovery. Accordingly, it appears that motivational music used post-task might enable individuals to push through physiological and psychological barriers in order to facilitate an active recovery from intense exercise.

Interestingly, it was reported that the motivational music was more effective during the latter stages of the active recoveries (Eliakim et al., 2012, 2013). A possible explanation for this finding might relate to attentional processing; it is well documented that during high-intensity exercise, attentional capacity narrows and it becomes increasingly difficult to ignore the physiological sensations associated with fatigue (Rejeski, 1985; Tenenbaum, 2001). During recovery, as the intensity of physiological sensations decline, it is plausible that attentional capacity is restored as individuals are more readily able to focus on external cues (e.g., music). Considered in this way, attentional capacity depicts an hourglass shape, with cessation of exercise at the waist.

Recent attempts to examine the effects of recuperative music have grown in sophistication and incorporated measures of affective response, possibly owing to the recent suggestion that *recalled* or *remembered* pleasure is an important factor in determining future exercise behaviour (Zenko, Ekkekakis, & Ariely, 2016). To illustrate, a study by Karageorghis, Bruce, Pottratz, et al. (2018) not only included passive and active recoveries within their protocol, the researchers incorporated a broad variety of experimental conditions and dependent variables. Specifically, measures of affect, salivary cortisol, HR, and blood pressure were recorded in response to three conditions: Sedative music, stimulative music, and a no music control. The findings indicated that stimulative music was the most beneficial during active recovery, reflected by heightened cortisol levels. Conversely, sedative music was found to promote the most positive affective valence, least affective arousal and lowest HR during passive recovery, thus providing support for previous research (Jing & Xudong, 2008; Savitha, Mallikarjuna, & Rao, 2010).

The term *respite music* was recently proposed by Jones et al. (2017) to describe the application of music during periods of recovery within an exercise session. This novel study involved the completion of 5 × 5-min bouts of high-intensity treadmill running interspersed with 3-min of passive recovery under conditions of slow music (55–65 bpm), fast music (125–135 bpm), and a no music control. Although the researchers reported limited evidence that music could engender a more efficient physiological recovery, the findings indicated that the fast-music condition yielded more positive affective valence when compared to the no music control (Jones et al., 2017).

Collectively, the studies critically reviewed indicate that music can be used as a tool to enhance affective responses to exercise (Hutchinson, Jones, et al., 2018; Lim et al., 2014), as well as prompting a range of psychophysical (Nikol et al., 2018), ergogenic (Stork et al., 2015) and psychophysiological effects (Terry et al., 2012). It is not only what one *hears* during exercise that can bear influence upon affective responses to exercise, but also what one *sees* (Bird, Hall, Arnold, Karageorghis, & Hussein, 2016). Accordingly, the following section introduces the visual system before providing a critical review of the use of audio-visual stimuli within exercise contexts.

2.3.8 The visual system. The retina is the surface of the eyes that comprise photoreceptors that transduce light into neural signals (Ward, 2015). The photoreceptors consist of rod cells, which respond extremely well to dim light, and cone cells, which are more active during daytime (Snowden, Thompson, & Troscianko, 2012). A number of pathways exist from the retina to the brain (see Stoerig & Cowey, 1997 for a review), but the most dominant pathway travels to the primary visual cortex via the lateral geniculate nucleus, which is part of the thalamus. It is a common misconception that the retina of the left eye represents just the left side of space and vice versa. As depicted in Figure 2.23, objects in the right-hand side of space fall on the left side of the retina in both eyes and project to the left lateral geniculate nucleus. Accordingly, the representation in the lateral geniculate nucleus contains information from both eyes (Snowden et al., 2012). This information is then separated into six neural layers. The upper four layers comprise parvocellular cells which respond to detail and colour whereas the lower two layers comprise magnocellular cells, which respond to larger surface areas and movement (Ward, 2015). The visual brain is a vastly complex system that is able to identify brightness, colour, edges, shapes, movements, and depth.

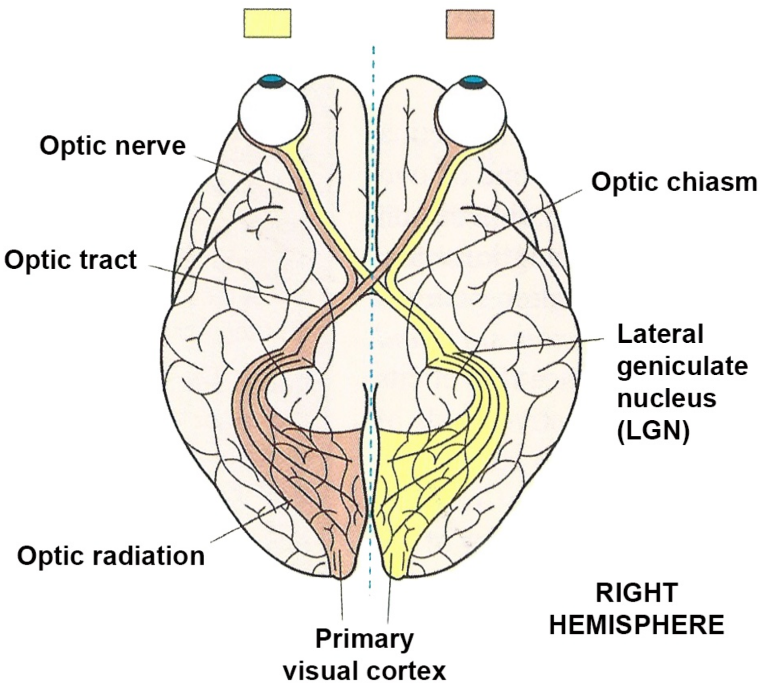

Figure 2.23. Connections from the retina to the primary visual cortex – the geniculostriate pathway. Adapted from *The Student's Guide to Cognitive Neuroscience* (3th ed., p. 110), by J. Ward, 2015, London, UK: Psychology Press. Copyright 2015 by Jamie Ward.

2.3.9 Audio-visual stimuli. Given the topic of the current programme of research, it is particularly apposite that the earliest example of audio-visual stimuli, termed a *sound film,* was entitled *The Jazz Singer* (Bullerjahn, 2017). Produced by The Warner Brothers in 1927 using the Vitaphone sound system, the fictional film depicts the story of Jakie Rabinowitz (played by Al Jolson) who runs away from home to pursue a career as a musician. The film boasted a synchronised musical score and its release signalled a transition from the silent film era to one in which sounds accompanied the projected images (Dancyger, 2019).

In the decades that followed the release of *The Jazz Singer,* a string of technological improvements in recording (e.g., magnetic film) and editing (e.g., Moviola) considerably sped up the production of audio-visual stimuli (Dancyger, 2019). That said, if an individual wanted to view audio-visual stimuli on demand during the late 1970s, their options would be fairly limited to viewing videotape-based cassettes on a Video Home System (VHS) or Sony Betamax in the comfort of their home. Conversely, 78% of adults in the UK presently carry a smartphone on their person (Ofcom, 2018). Such devices provide a host of audio-visual viewing options that are accessible while individuals are on the move. Coupled with the increasing ownership of additional portable (e.g., tablets) and stationary (e.g., television) devices, it is little wonder that we have been referred to as a society that is "digitally connected" (Kushlev, Proulx, & Dunn, 2017).

The assortment of devices that are on offer to individuals have considerably transformed the consumer landscape. Recent statistics reveal that the average adult in the UK watches 88 min of non-broadcast content on their television each day (Ofcom, 2018). This largely consists of a subscription-based services such as Netflix and Amazon Prime Video, as well as additional online platforms such as *YouTube* (Jenner, 2016). Unquestionably, audio-visual stimuli are ubiquitous within modern-day society.

2.3.10 Audio-visual stimuli and exercise. The prevalence of audio-visual stimuli is evident within contemporary exercise contexts (Frith & Loprinzi, 2018). Television screens are often placed in communal areas of exercise facilities as a means by which to advertise classes and membership packages. Furthermore, it is common for exercise facilities to attach large television screens to their walls as a means by which to distract individuals from the sensations of fatigue that accompany strenuous workouts. Moreover, manufacturers of fitness equipment, such as Life Fitness, offer exercisers what they term a "consistently captivating experience" (Life Fitness, 2018, p. 11) with the addition of a digital display integrated within their cardio equipment. Not only does the device facilitate video-streaming services such as Netflix and Hulu, but it also allows exercisers to access their own videos via Bluetooth, affording a sense of autonomy.

Beyond the context of contemporary exercise facilities, audio-visual stimuli are employed in many innovative ways to promote exercise. For example, *Change 4 Life* is a public health programme administered by Public Health England that aims to encourage families to adopt key behaviours required for a healthy lifestyle, one of which promotes physical activity. Change 4 Life launched the *10 Minute Shake Up* campaign in partnership with global brand Disney as a means by which to promote physical activity levels amongst children. The campaign grants users the opportunity to browse a collection of *10 Minute Shake Up* videos, which feature popular Disney characters from films such as *The Incredibles* and *Finding Nemo*. Given that Disney films represent an important aspect of children's media (Padilla-Walker, Coyne, Fraser, & Stockdale, 2013), using Disney characters to promote physical activity is clearly a powerful motivator. Similar to the notion of associative coding (Juslin, 2013b), the onscreen characters trigger the recollection of positive memories experienced when viewing Disney films.

Albeit researchers have devoted significant effort towards furthering understanding of the effects of motivational music in an exercise context, the same cannot be claimed for the effects of audio-visual stimuli. A possible explanation for this is that video represents a more recent modality to that of music within these settings (Karageorghis & Priest, 2012a, 2012b). Given its prominence in society and exercise settings, it is imperative that researchers strive to broaden their understanding of the combined effects of these stimuli.

2.3.11 The application of audio-visual stimuli. Audio-visual stimuli can be applied in one of three primary ways: pre-task, in-task, and post-task. Herein, the author critically analyses the extant literature pertaining to the scientific application of audio-visual stimuli pre- and in-task. Despite the intuitive appeal of using audio-visual stimuli to facilitate recovery from exercise, there is presently a distinct paucity of research focused on its application.

2.3.11.1 Pre-task audio-visual stimuli. A modest amount of research attention has focused on the application of audio-visual stimuli pre-task. Such research has typically focused on personal motivational videos (PMV; Forzoni, 2006). PMVs are recommended as a means by which to enhance performance, are usually 2–4 min in length, and typically comprise a combination of video footage, photos, and music (Tracey, 2011). The visual stimuli offer an opportunity to reinforce previous performance accomplishments and task-relevant cues. Moreover, an individual can draw upon several forms of audio stimuli such as music, speeches, or recordings from significant others as a means by which to evoke a desired response to the PMV (Forzoni, 2006).

Templin and Vernacchia (1995) conducted one of the first investigations into the effectiveness of PMVs. The researchers instructed participants to watch an individualised PMV prior to basketball training and competitive matches over the course of an entire season. The researchers reported mixed findings, whereby three players demonstrated gains in free-throw performance while two players displayed performance detriments. Accordingly, a causal relationship between the PMV and improved performance could not be established. However, the study could have been enhanced with the measurement of additional psychological variables, such as affective responses or state motivation.

Tracey (2011) extended this line of scientific inquiry by developing a PMV for a professional mountain biker. The researcher interviewed the athlete, who had regularly watched the PMV over the course of a 7-month season. Findings indicated that the PMV facilitated the athlete's perceptions of motivation, mental imagery, confidence, emotional regulation, and concentration when used prior to competition. It is noteworthy that both of the aforementioned studies employed the use of PMV over an extended period of time (Templin & Vernacchia, 1995; Tracey, 2011). Researchers have suggested that music programmes should be regularly updated in order to reduce the likelihood of desensitisation (Karageorghis, 2017). It is plausible that this notion applies to audio-visual stimuli in equal measure. Hence, it is possible that participants might have become overly familiar with the PMV, limiting its potential effectiveness over time. Nonetheless, the findings of Tracey (2011) provide initial support that pre-task audio-visual stimuli can engender a superior psychological state that is similar to those elicited by pre-task music (Karageorghis, Bigliassi, Tayara, et al., 2018).

An innovative study conducted by Loizou, Karageorghis, and Bishop (2014) sought to investigate the impact of audio-visual stimuli and primes on affective responses and the needs underlying intrinsic motivation. The video footage depicted clips from the Olympic Games and the researchers inserted the Olympic motto (i.e., "*Faster, Higher, Stronger*") into the footage at different time intervals for a period of 40 ms. The findings revealed that participants derived the greatest liking scores in the video-music-primes condition when compared to music, video, music-video, and video-primes conditions. Although Loizou et al. (2014) measured individuals' responses to audio-visual stimuli, the participants were not required to take part in an exercise protocol thereafter, making it difficult to ascertain the influence of the audio-visual stimuli on exercise.

A follow-up study was conducted in order to ascertain the effects of pre-task audio-visual stimuli and priming on anaerobic exercise performance (Loizou & Karageorghis, 2015). Participants were exposed to music, music-video, music-video-primes, and a no-music-video-primes control before completing the Wingate Anaerobic Test. The researchers reported that the music-video-primes condition prompted the most positive affective valence, greatest perceived activation, and highest liking scores. Moreover, participants displayed greater peak and mean power in the music-video-primes condition, indicating that pre-task audio-visual stimuli can engender an ergogenic effect.

2.3.11.1 In-task audio-visual stimuli. Scholars are demonstrating a growing interest for the in-task application of audio-visual stimuli. A range of visual stimuli have been employed by researchers, including music-videos (Bird et al., 2016), movie footage (Bigliassi, Silva, et al., 2016), television shows (Privitera, Antonelli, & Szal, 2014), sporting highlights (Barwood, Weston, Thelwell, & Page, 2009), and even circus performances (Chow & Etnier, 2017). Given that participants are required to remain in a relatively stationary position in order to watch the audio-visual stimuli, investigators have typically employed repetitive exercise protocols such as isometric strength endurance tasks (Bigliassi et al., 2014), cycle ergometry (Jones, Karageorghis, & Ekkekakis, 2014), and treadmill walking/running (Frith & Loprinzi, 2018; Rider et al., 2016).

This line of scientific inquiry was initiated by Annesi (2001), who examined the effects of self-selected music, television, and a combination of music and television on participants' measures of distraction, exercise adherence, and physical output at a private health club in the USA. Participants who were exposed to the combined audio-visual intervention experienced lower dropout and higher attendance over a 14-week programme, when compared to those in the music, television, or control conditions. Participants were new members of the facility and were paid $75 to participate, which might have accounted for their "unusually high" (Annesi, 2001, p. 200) Self-Motivation Inventory scores. Nonetheless, this study provided initial support for the notion that audio-visual stimuli can bear positive influence on repeated bouts of exercise.

Bigliassi et al. (2014) sought to investigate the effects of music-videos during a muscular endurance task. Participants were instructed to maintain dominant arm abduction until exhaustion, while exposed to music-video, sensory deprivation, and control conditions. Participants reported the lowest RPE scores in the music-video condition. Nonetheless, no significant differences were found across conditions in terms of overall performance. Bigliassi et al. (2014) allowed participants to self-select the audio-visual stimuli. Nonetheless, a limitation of the study was that the motivational qualities of each piece of music were not recorded.

Researchers have frequently employed cycle ergometry exercise protocols when examining the effects of audio-visual stimuli. For example, Lin and Lu (2013) reported that participants were able to cycle further and with lower RPE, when exposed to popular Chinese music-videos compared to a control condition. It is noteworthy that the control condition in Lin and Lu's (2013) study involved a state of sensory deprivation. However, there was no indication that participants were afforded an opportunity to familiarise themselves with this prior to the trial (c.f. Bigliassi et al., 2014). Bird et al. (2016) furthered this line of scientific inquiry by investigating the impact of music-videos on exercise at the lactate threshold. Participants were required to cycle for 20 min while exposed to music-video, music, and no-music-video control conditions while verbally indicating their affective responses using the FS (Hardy & Rejeski, 1989) and FAS (Svebak & Murgatroyd, 1985). Findings revealed that the music-video condition prompted the greatest affective valence, followed by the music and control conditions, respectively.

Similar results have been obtained when audio-visual stimuli have been used to accompany treadmill running. For example, Barwood et al. (2009) found that participants ran significantly further when exposed to motivational audio-visual stimuli when compared to amotivational audio-visual stimuli (i.e., footage from a political trial) and a control. It is noteworthy that participants' RPE responses remained similar across experimental conditions, implying that participants did not perceive any changes in physiological load despite' running further. Using Rejeski's (1985) parallel information processing theory as a lodestar, the researchers theorised that the video element of the motivational intervention might have competed with physiological cues for attentional resources during the exercise bout (Barwood et al., 2009). However, a limitation of the study was that participants' attentional focus was not examined. To address this shortfall, Hutchinson, Karageorghis, and Jones (2015) investigated the effects of music-videos on a range of psychological and psychophysical variables during a treadmill running task. Participants recorded the highest levels of dissociation, most positive affective responses, and lowest RPE during exposure to a music-video condition. These findings were evident not only during moderate-intensity exercise below VT but also during exercise that exceeded the VT, which is characterised by a near universal decline in affect (Ekkekakis, 2003).

The extant literature reviewed above contained audio-visual stimuli that might be considered incongruent with the exercise protocol that was administered to participants. An alternative line of scientific inquiry has seen investigators employ audio-visual stimuli that can be considered congruent with their associated exercise protocols. For example, Jones et al. (2014) used rural parkland footage to accompany indoor cycle ergometry. The video footage was filmed from the perspective of a cyclist and altered to correspond with participants' pedal cadence. The researchers reported that the audio-visual stimuli enhanced participants' affective responses and enjoyment scores when compared to video and control conditions. Similarly, Barreto-Silva, Bigliassi, Chierotti, and Altimari (2018) administered pleasant, unpleasant, and neutral road-based footage while participants cycled at 5% above VT. The pleasant condition depicted a cyclist on a descending course with an easy pedal cadence and normal breathing, whereas the unpleasant condition depicted the opposite (i.e., an ascending course with a challenging pedal cadence and laboured breathing). The researchers reported that the pleasant audio-visual stimuli elicited significantly lower RPE when compared to the unpleasant condition.

It is noteworthy that both teams of researchers predicated their audio-visual intervention on the concept of "immersive environments" (Barreto-Silva et al., 2018, p. 561; Jones et al., 2014, p. 538) as a means by which to promote attentional dissociation. It was theorised that the greater the level of immersion, the greater the likelihood that participants would focus their attention away from interoceptive cues associated with fatigue. Immersive experiences were partially accomplished through the use of video projection (Jones et al., 2014) and a large television screen placed directly in front of participants (Barreto-Silva et al., 2018). However, recent advances in technology have ensured alternative modes of delivery that are capable of achieving far superior levels of immersion.

2.3.11.1.1 Virtual reality. Despite increased media attention in the present decade, VR HMDs are not a recent technological development, they have existed since the late 1960s. The first device of its kind was developed by Ivan Sutherland and nicknamed the *Sword of Damocles,* owing to the way that it was suspended from the ceiling and precariously hungover users as they interacted with it (Cummings & Bailenson, 2016). A resurgence of interest in VR HMDs was sparked by Palmer Luckey in 2012, who used the crowd-funding platform Kickstarter to attain the financial backing he required to develop the Oculus Rift. Palmer raised over $2.4 million, almost 10 times his original funding goal, and sold his company 2 years later to Facebook for the sum of $2 billion (Gleasure & Feller, 2016).

The year 2016 saw the release of multiple consumer-ready VR HMDs from companies including Oculus, HTC, Sony, Google, and Samsung. Such devices contain two screens that are presented in front of the user's eyes. Digital images are delivered to each screen and rendered to account for the position of each eye (Slater & Sanchez-Vives, 2016). The screens are housed within a case that contain sensors that constantly track head movements so that the visual display can be updated accordingly.

Opportunities to engage with content using VR HMDs have grown exponentially in recent years, supporting the notion that mainstream VR has finally arrived (Lin, 2017). A popular use of VR HMDs today is for home entertainment (Bailenson, 2018). For example, the VR channel on *YouTube* is dedicated to 360-degree videos and currently boasts over 2.5 million subscribers, all of whom can immersive themselves into myriad scenarios ranging from hot-air balloon rides to deep-sea diving expeditions. The rate at which individuals are consuming VR content doesn't appear to be slowing down, with recent estimates suggesting that the VR market will be worth over $33 billion by the year 2022 (MarketWatch, 2018).

Researchers have employed consumer-ready VR technology in several domains such as education (Alhalabi, 2016; Jensen & Konradsen, 2018), physical rehabilitation (Cano Porras, Siemonsma, Inzelberg, Zeilig, & Plotnik, 2018; Maggio et al., 2019), the military (Norr, Smolenski, & Reger, 2018; Reger, Smolenski, Norr, Katz, & Buck, 2019), and surgical training (Barré et al., 2019; Huber et al., 2017). However, there is a paucity of research examining the efficacy of this technology in the exercise context. A notable exception is a study by Zeng, Pope, and Gao (2017), who examined the physiological and psychological effects of exercising on a VR-enabled ergometer compared to a traditional ergometer. The researchers reported that the VR-enabled condition elicited significantly lower RPE along with higher scores for self-efficacy and enjoyment. However, there were several limitations associated with this study. For example, the intensity of exercise was not defined according to a fixed metabolic indicator, such as VT (Ekkekakis, 2003). Moreover, participants were allowed to watch video and listen to music in the control condition, both of which have been found to influence affective responses and RPE during exercise (Barreto-Silva et al., 2018). Accordingly, there appears to be considerable scope to investigate the effects of exercising in VR while accounting for the aforementioned limitations.

2.4 Proposed Mechanisms Underlying the Effects of Audio-Visual Stimuli

An overview of the mechanisms that are suggested to underpin the effects of audio-visual stimuli in an exercise context is provided here.

2.4.1 Music and emotions. Of all the problems confronting musicologists, apparently none is more important than explaining listeners' emotional reactions to music (see Juslin, Liljeström, Västfjäll, Barradas, & Silva, 2008). Many researchers have suggested that the most frequently cited goal of music is to influence emotions (Laukka & Quick, 2013). For example, Juslin and Laukka (2004) asked music listeners ($N = 141$) to specify what, if anything, music expresses? Participants were required to tick items from a list of options and the results revealed that emotion, unlike any other option available, was selected by *every single* participant. The importance of emotional expression should not be understated given the increasing research pertaining to a relationship between emotional expression and physical health (Giese-Davis & Spiegel, 2003).

The study of musical emotion, like all affective phenomena, has suffered from terminological confusion (Juslin & Laukka, 2004). However, systematic efforts to understand emotional responses to music are growing (Juslin, 2016). Perhaps this is due to the increasing number of applications within modern-day society that presume music's effectiveness in inducing emotions, such as therapy (Fujioka et al., 2018) and film music (Cohen, 2015). A distinction can be made between the *expression and perception* of emotions in music and the emotions *felt* by an individual in response to music (Juslin, 2013b). This distinction is important because each process might entail different emotions as expounded herein (Juslin & Laukka, 2004).

2.4.1.1 Expression and perception of emotions in music. Emotional expression refers to instances where a listener perceives emotional meaning in music and has been described as one of the most important criteria for the aesthetic value of music (Juslin, 2013a). The emotional content of music can be limited to three types of coding that might be considered as separate layers of musical expression: (a) iconic, (b) intrinsic, and (c) associative (Juslin, 2013b; Sloboda & Juslin, 2001). Iconic coding is based upon the premise that musical structure demonstrates formal similarities to the structures of expressed emotions (Juslin & Västfjäll, 2008). Iconic coding only applies to the acoustic features of the music that the performer can control during her/his performance (e.g., tempo, intensity, timbre; Juslin & Laukka, 2003). Nonetheless, such acoustic features serve as a catalyst for physiological changes associated with emotional reactions, which influence the degree of phonation and resonance in vocal expression (Scherer, 1989). Adopting a categorical approach to the study of emotion, Juslin (2013a) suggested that iconically coded expressions are closely related to basic emotions (e.g., happiness, sadness, anger, and love).

Intrinsic sources of musical expression originate from the structural characteristics of the music such as tempo, harmony, and intensity. Changes in any of these attributes are associated with changes in emotional interpretation (Ilie & Thompson, 2006) and affective experiences (Thompson, Schellenberg, & Husain, 2001). Moreover, such attributes contribute to an emotional code that is often employed by composers and performers to communicate emotion in music, or by speakers when communicating emotion in the tone of their voice

(Thompson & Quinto, 2011). In contrast to iconic coding, intrinsic coding may help to express more complex, time-dependent emotions such as relief or hope (Juslin, 2013b).

Hevner (1935) conducted one of the earliest examinations of intrinsic sources of emotional expression in music. Listeners were presented with multiple pieces of classical music performed at slow (63–80 bpm) and fast (102–152 bpm) tempi. Despite the music being identical, aside from the tempo, the emotions that participants perceived in the music were diverse. The slow-tempo performances were described as calm, sad, and serene. Conversely, the fast-tempo performances were described as joyous, exciting, and happy (Hevner, 1935).

The structural qualities of music can also interact to mediate a listener's perception of expressed emotions in music. A study by Webster and Weir (2005) examined the interactive influence of mode (i.e., major vs. minor), texture (i.e., harmonised vs. non-harmonised), and tempo (i.e., 72, 108, and 144 bpm) on college students' perceived emotions. Although some of the findings were influenced by gender and prior musical experience, the researchers reported that music played in major keys, non-harmonised melodies, and faster tempi were associated with happier responses. Contrastingly, music with the opposite characteristics was associated with sadder responses.

Associative coding refers to the perception of a specific emotion because something in the music (e.g., a melody or timbre) has been constantly paired with other stimuli or events in the past (Juslin, 2013b). Therefore, particular pieces of music act as triggers for the recollection of such events (Gabrielsson, 2001b). To illustrate, listeners of *God Save the Queen* might perceive a feeling of patriotism based upon its association as England's most frequently played national anthem at sporting events. Associative coding may achieve a more precise and complex perception of emotional expression when compared to iconic coding. However, its recognition will ultimately depend on a listener's prior knowledge and/or experience (Juslin, 2013b).

The three primary types of coding can be conceptualised as three distinct layers (Figure 2.24). The bottom layer consists of iconically coded basic emotions and research supports the notion that they can be recognised cross-culturally (Fritz et al., 2009). As the complexity of the perceived emotions increases, they become less cross-culturally invariant. Moreover, associative coding can be divided into two subsections. A *communal* subsection refers to common associations within a particular social group whereas a *personal* subsection refers to an idiosyncratic layer that consists of deeply personal associations (Juslin, 2013b).

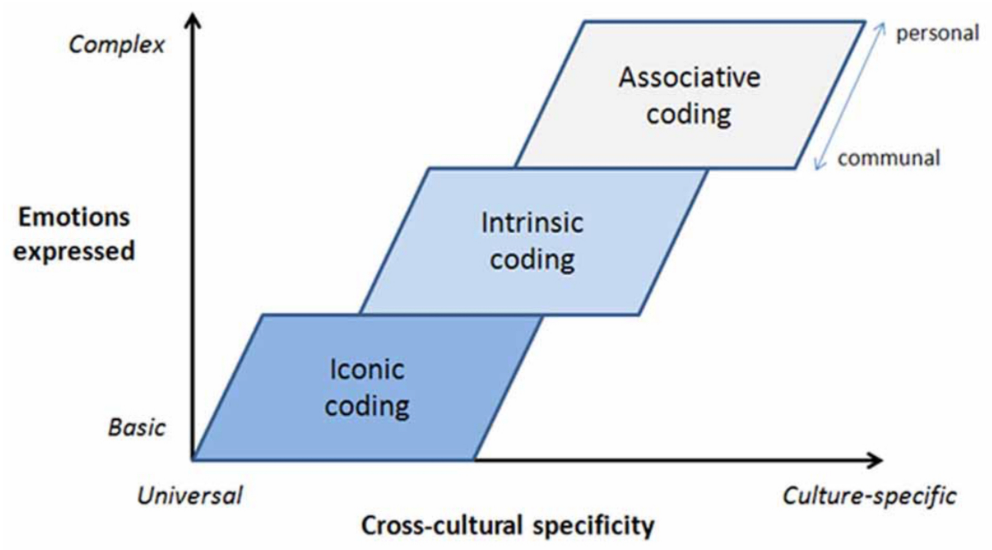

Figure 2.24. Multiple-layer conceptualisation of musical expression of emotions. Reprinted from "What Does Music Express? Basic Emotions and Beyond," by P. N. Juslin, 2013b, *Frontiers in Psychology, 4,* p. 10. Copyright 2013 by Patrik N. Juslin.

2.4.1.2 Emotions felt in response to music. In contrast to emotions that are merely perceived in a piece of music, emotions can also be felt in response to music (Gabrielsson, 2001a). Two distinct approaches have been adopted when describing the types of emotions induced by music, (a) *aesthetic emotions,* and (b) *everyday emotions* (Juslin, 2013a). The term "aesthetic" has been used to describe emotions that are only induced when individuals are engaged with artworks, such as music. Hence, this approach supports the idea that music induces unique or music-specific emotions (Scherer & Zentner, 2008). Conversely, theorists have opposed the notion of unique emotions with the suggestion that artworks merely induce everyday emotions (Dewey, 1959). Supporters of this approach concede that the circumstances surrounding the perception of music might be unique, but the actual emotions felt in response to music is a subset of ordinary emotions experienced in everyday life such as happiness or interest (Levinson, 1997).

Emotions that are frequently cited as aesthetic (e.g., wonder, admiration, awe) can also occur in other everyday contexts where music is absent. Accordingly, the view that specific emotions can be triggered only when music is apprehended aesthetically is not supported (Juslin, 2013a). Aesthetic emotions may not involve emotional states unique to music, but their *underlying causal processes* might differ to everyday emotions. Hence, aesthetic emotions may be construed as emotions that are induced by the aesthetic properties of a piece of music (Juslin, 2013a). Juslin and Västfjäll (2008) suggested that listening to music may induce basic emotions (e.g., happiness, sadness), more complex emotions (e.g., pride, nostalgia) and even mixed emotions (e.g., bitter sweet). Aesthetic emotions, such as wonder, may result from listening to music but are far less frequent (Gabrielsson, 2010). In order to fully understand why these emotions occur when listening to music, we must consider the precise mechanisms that mediate the link between musical events and experienced emotions (Juslin, Harmat, & Eerola, 2014).

2.4.1.2.1 Mechanisms for musically-induced emotions. Scherer and Zentner (2001) proposed three central routes by which emotions are triggered via music listening. The *appraisal* route relates to a listener's assessment of the personal significance of the event for her/his wellbeing. Within the *memory* route, music serves as a trigger in bringing emotional experiences back from memory into awareness. Oftentimes, emotions are prompted by observing another person that is being affected by an event that is important to them but not necessarily to us. This forms the basis of the *empathy* route, which is more likely to occur when listening to an admired performer who is performing in a highly emotional manner.

Scherer and Zentner (2001) also noted two peripheral routes to musically-induced emotion. The first is *proprioceptive feedback,* which refers to a coupling of internal rhythms to external drivers. The second concerns *facilitating the expression of pre-existing emotions*. Emotional reactions in daily life are highly controlled or regulated, both with respect to motor expression and subjective feeling (Scherer & Zentner, 2001). This peripheral route to musically-induced emotion refers to the weakening or elimination of such emotional control imposed by cultural norms (Scherer, 2004).

Building upon previous research findings, Juslin and Västfjäll (2008) theorised that the following six psychological mechanisms (along with cognitive appraisals) underlie the musical induction of emotions: (1) brain stem reflexes, (2) evaluative conditioning, (3) emotional contagion, (4) visual imagery, (5) episodic memory, and (6) musical expectancy. Several investigators within the research community responded in surprise to the occlusion of rhythmic entrainment as a possible mechanism underlying the emotional response to music (Scherer & Zentner, 2008). Musical rhythms have the capacity to entrain internal bodily rhythms of the listener (e.g., HR, respiration rate), such that they eventually lock in to a common periodicity with the music. Consequently, one could argue that specific tempi and rhythmic structures lead to a complex interplay between entrainment and resultant emotions (Agostino, Peryer, & Meck, 2008; Juslin, 2011).

Juslin, Liljeström, Västfjäll, and Lundqvist (2010) responded to the suggestions of other researchers (e.g., Scherer & Zentner, 2008) and integrated rhythmic entrainment into their framework. The researchers argued that the seven revised mechanisms (referred to as BRECVEM), along with cognitive appraisals, could account for the majority of emotions felt in response to music in everyday life. Moreover, Juslin (2013a) proposed that the BRECVEM framework could be augmented by an eighth supplementary mechanism, *aesthetic* *judgements*, in order to account for aesthetic emotions (e.g., admiration, awe). The resultant framework, renamed BRECVEMA, has provided an important advancement in the literature with its identification and differentiation of possible mechanisms connecting music and emotion, and provided numerous avenues for how each can be investigated.

2.4.2 Exercise intensity–music tempo relationship. Tempo is considered a defining determinant of musical response (Karageorghis, Jones, & Low, 2006). Moreover, it has been suggested that an individual's preference for different tempi might be dependent on the physiological arousal of the listener and context in which the music is heard (North & Hargreaves, 1997). Therefore, when an individual's arousal is high, it is plausible that they should prefer music with a faster tempo. Furthermore, when an individual is in a situation that necessitates a high degree of arousal, such as the execution of highly motoric tasks, they are likely to prefer fast, stimulative music (Karageorghis & Jones, 2014).

Prior to the induction of conceptual frameworks (e.g., Karageorghis et al., 1999), researchers hypothesised that when individuals are given the choice, they prefer music that has a tempo within the range of a normal HR during everyday activity (i.e., 70–100 bpm; Iwanaga, 1995b). For example, Iwanaga asked participants to select their favoured tempo using a 440 Hz pure tone (1995a) and music (1995b). The researcher reported a positive and linear relationship between preferred tempo and HR (Iwanaga, 1995a, 1995b). The methodologies employed by Iwanaga (1995a, 1995b) were highly criticised for lacking external validity and researchers emphasised that under normal circumstances, individuals were not able to alter the tempo of a piece of music while listening to it (LeBlanc, 1995). On the contrary, LeBlanc (1995) asserted that judgements of music tempo preference were often made post hoc.

Addressing the suggestion that individuals' favoured tempi should be subject to further examination at differing work intensities (LeBlanc, 1995), Karageorghis et al. (2006) investigated tempo preferences for slow (80 bpm), medium (120 bpm), and fast (140 bpm) music across varying exercise intensities. The results revealed that participants preferred both medium- and fast-tempo music at low and moderate exercise intensities, and fast-tempo music at high exercise intensities. Moreover, there was a general preference for medium- and fast-tempo music over slow music at all exercise intensities. Karageorghis et al. (2006) employed musical excerpts of 90 s. Although the study provided a valuable snapshot view of individuals' tempi preferences, it did not reveal how such preferences might change over a prolonged bout of exercise. Accordingly, the researchers concluded that future work might consider the construction of entire music programmes as a means of enhancing external validity.

Karageorghis, Jones, and Stuart (2008) extended this line of scientific inquiry by examining the effects of listening to entire music programmes during exercise. A mixed-tempi music condition was also included, which arranged tracks in the order medium-fast-fast-medium-fast-fast. It was hypothesised that the participants would derive the greatest psychological benefits from the mixed-tempi condition, because sustained exposure to high-tempo music alone might result in boredom and irritation (Karageorghis, Jones, et al., 2006). In contrast to the researchers' hypotheses, a medium-tempo music condition yielded the most positive outcomes of music preference, intrinsic motivation, and global flow.

Karageorghis et al. (2008) acknowledged the varying exercise intensities adopted in their previous work (Karageorghis, Jones, et al., 2006) and hypothesised that there might be a *step change* in preference from medium to fast tempi music between 70–75% maxHRR. This is plausible given that exercisers rely more heavily on anaerobic pathways for the production of energy during high-intensity exercise as physiological sensations become increasingly difficult to ignore (Ekkekakis, 2003; Rejeski, 1985; Tenenbaum, 2001). It was suggested that the relationship between music-tempo preference and HR might be quartic, possessing a broadly linear direction that is characterised by three inflection points, resulting in two shallow steps and two steeper phases (Karageorghis & Terry, 2009; Figure 2.25).

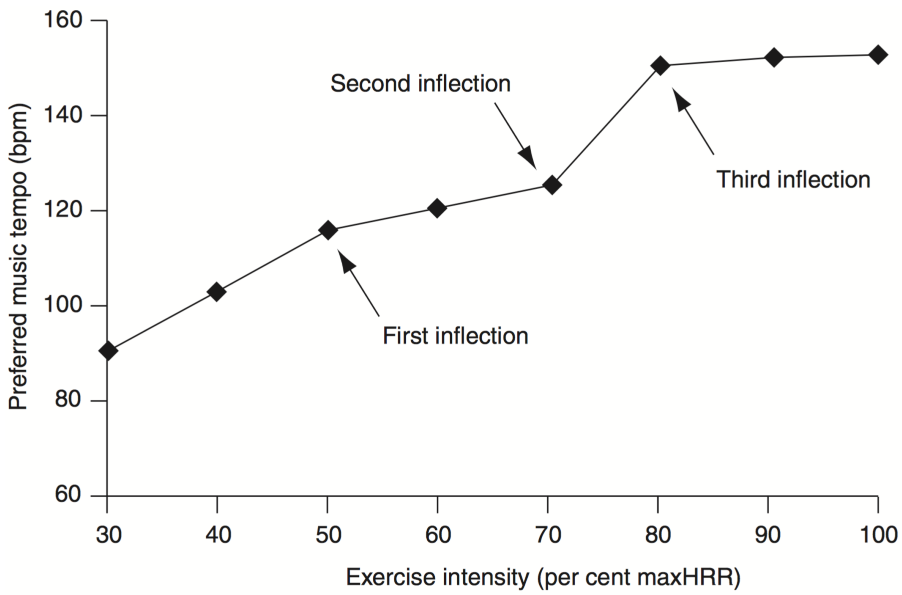

Figure 2.25. Hypothesised quartic relationship between exercise heart rate and preferred music tempo. Reprinted from "The Psychological, Psychophysical, and Ergogenic Effects of Music in Sport. A Review and Synthesis," by C. I. Karageorghis and P. C. Terry, in A. J. Bateman and J. R. Bale (Eds.), *Sporting Sounds* (p. 23), 2009, London, UK: Routledge. Copyright 2009 by Costas I. Karageorghis and Peter C. Terry.

The hypothesised relationship between music-tempo preference and exercise HR was actually cubic in nature (Figure 2.26; Karageorghis et al., 2011). A strength of a cubic relationship from an applied perspective is its relative simplicity in terms of interpretation. At low exercise intensities (40–60% maxHRR) the observed relationship is positive and linear. As the intensity of exercise increases, an inflection point is reached at 60% maxHRR, resulting in a less pronounced gradient. An additional inflection point occurs at 80% maxHRR, involving a marginally negative gradient. Accordingly, as exercise intensity increases beyond this point, there is a preference for a minor reduction in music tempo.

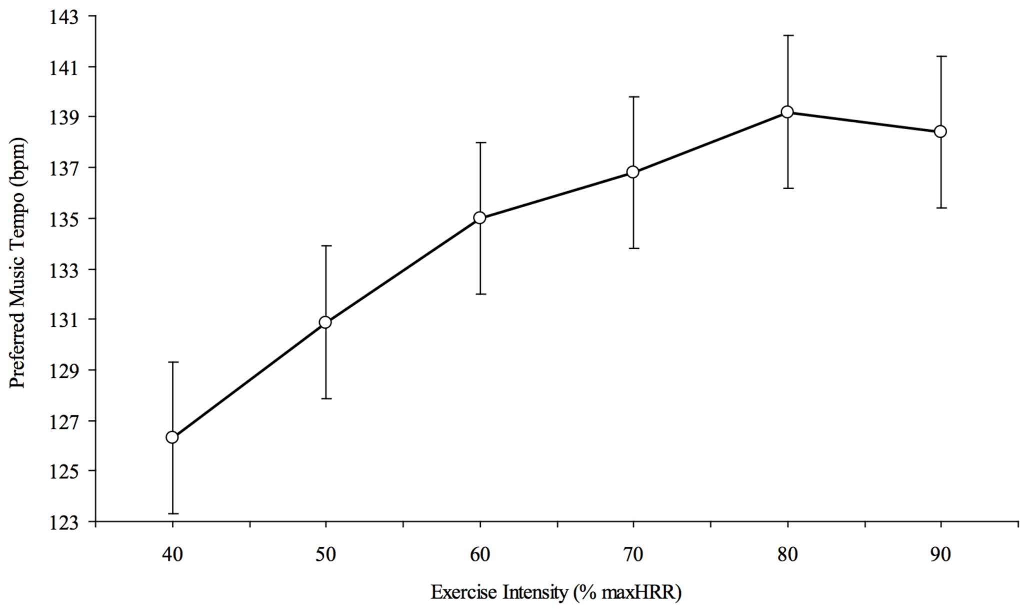

Figure 2.26. Observed cubic relationship between exercise heart rate and preferred music tempo. Reprinted from "Revisiting the Relationship Between Exercise Heart Rate and Music Tempo Preference," by C. I. Karageorghis, L. Jones, D.-L. Priest, R. I Akers, A. Clarke, J. M. Perry, B. T. Reddick, D. T. Bishop, and H. B. T. Lim, 2011, *Research Quarterly for Exercise and Sport, 82,* p. 281. Copyright 2011 by American Alliance for Health, Physical Education, Recreation and Dance.

Karageorghis and Jones (2014) examined the stability of the cubic relationship between music-tempo preference and exercise HR using a treadmill running task. Their results did not support a cubic relationship but rather a quadratic one (i.e., consisting of just one point of inflection, Figure 2.27). Specifically, the researchers reported no discernible differences in preferred music tempi at low-to-moderate exercise intensities (40–80% maxHRR), followed by a steep rise in music tempo preference from 80–90% maxHRR (Karageorghis & Jones, 2014).

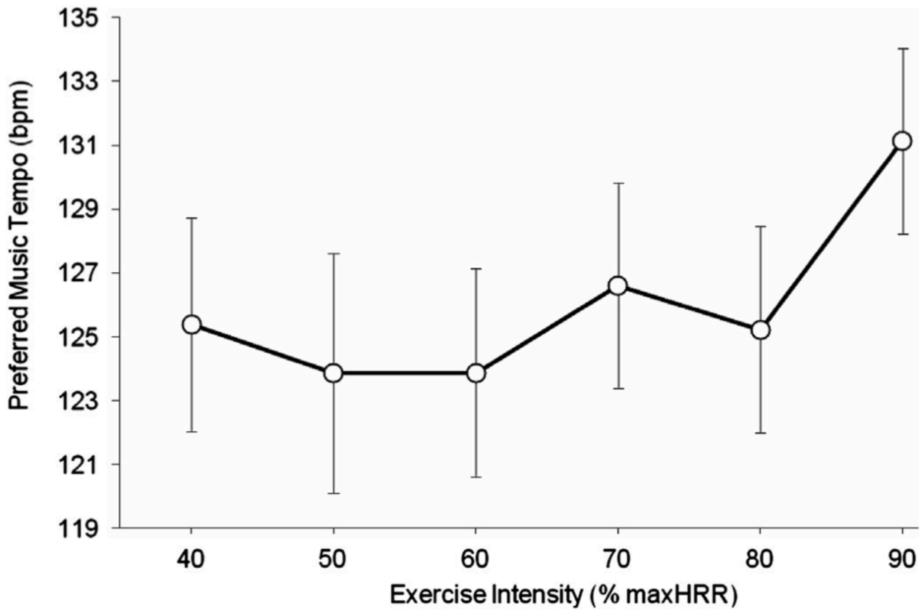

Figure 2.27. Observed quadratic relationship between exercise heart rate and preferred music tempo. Reprinted from "On the Stability and Relevance of the Exercise Heart Rate–Music-Tempo Preference Relationship," by C. I. Karageorghis and L. Jones, 2014, *Psychology of Sport and Exercise*, *15*, p. 303. Copyright 2013 by Elsevier.

Collectively, the aforementioned studies support the notion that a tempo range of 123–140 bpm should be considered as a means by which to optimise selections across a range of exercise intensities (Karageorghis & Jones, 2014; Karageorghis, Jones, et al., 2006; Karageorghis et al., 2011, 2008; Karageorghis & Terry, 2009). Practitioners are urged to avoid coupling slow selections (i.e., < 100 bpm) with high-intensity exercise. Likewise, to avoid coupling very fast selections (i.e., > 140 bpm) with low-intensity exercise. However, it should be noted that other tenets of musical selection deserve consideration, such as lyrical content, which is easier to process during low-to-moderate exercise intensities (cf. Rejeski, 1985; Tenenbaum, 2001). Accordingly, as long as the listener perceives the music as motivational, it is likely to positively influence psychological processes (Karageorghis & Jones, 2014).

2.4.3 Attentional processing. Audio-visual stimuli influence an individual's attentional processing. The afferent nervous system, which transmits sensory impulses to the central nervous system, has a limited capacity, similar to the concept of Internet bandwidth (Karageorghis & Priest, 2012a, 2012b). Relevant models of attention that have aided our understanding of audio-visual stimuli within an exercise setting will be considered herein.

2.4.3.1 Association and dissociation. Morgan and Pollock (1977) made the distinction between two broad categories of attentional focus, association and dissociation. Association was regarded as turning focus inwardly towards bodily sensations, while dissociation was regarded as turning focus outwardly and away from bodily sensations (Morgan, 1978). However, researchers suggested that this distinction was incomplete (Masters & Lambert, 1989). Accordingly, it was proposed that association should refer to the monitoring of both bodily sensations and factors that are critical to physical performance (e.g., pacing), whereas dissociation should refer to the distraction from such cues (Masters & Lambert, 1989)

Stevinson and Biddle (1998) sought to overcome the simplistic nature of previous definitions by proposing the two-dimensional classification system for attention. The first dimension considered the relevance of thoughts in relation to an exercise task. Focusing attention on task-relevant cues was considered associative whereas focussing attention on task-irrelevant cues was considered dissociative. The second dimension, *internal–external,* refers to the direction of attention in reference to the body. Accordingly, Stevinson and Biddle (1998) proposed that attentional focus could be divided into the following four categories (a) internal association (e.g., breathing cues), (b) external association (e.g., performance strategies), (c) internal dissociation (e.g., daydreaming), and (d) external dissociation (e.g., environmental stimuli). The two-dimensional classification system for attention serves as a useful tool for practitioners to comprehensively categorise the different types of cues that individuals can focus on while exercising. However, it has been suggested that only the task-relevant dimension (i.e., associative–dissociative) appears to influence RPE (Stanley, Pargman, & Tenenbaum, 2007).

Each approach to the study of attentional focus has its merits. In order to overcome confusion regarding the definition of key attentional focus terms, the present programme of research views *association* as a cognitive strategy in which an individual focuses on internal bodily sensations (e.g., muscle tension). Conversely, *dissociation* is viewed as a cognitive strategy in which an individual focuses away from bodily sensations (Morgan & Pollock, 1977). It is predicted that dissociative strategies, such as the use of audio-visual stimuli, bring relief from fatigue by occupying the limited capacity for attentional processing (Hutchinson & Tenenbaum, 2007).

2.4.3.2 Parallel processing. During the 1980s, researchers interested in the role of cognition on the perception of exertion favoured one of two models (a) sequential models or (b) parallel-processing models (Rejeski, 1985). Sequential models support the notion that individuals experience physical sensations and then respond according to past experiences and the strength of the stimulus. Rejeski (1985) theorised that sequential models were too simplistic as they characterise stimulation as a passive process. Conversely, empirical data supported the notion that sensory cues could be manipulated psychologically prior to reaching the brain (Leventhal & Everhart, 1979).

Rejeski (1985) proposed a parallel processing model that was based upon previous pain research (Leventhal & Everhart, 1979). The model organised informational and emotional components in parallel rather than in sequence (see Figure 2.28). Hence, perception was considered an active process and attention was given to the *preconscious* elaboration of sensations (Rejeski, 1985). Moreover, the model differentiated between *perception* (preconscious) and *focal awareness* (conscious). Perception concerns all possible material that can be attended to whereas focal awareness pertains to the segment that an individual does attend.

Despite researchers' interest in the potential for dissociation to alleviate discomfort associated with fatigue (e.g., Benson, Dryer, & Hartley, 1978), there was a paucity of theoretical explanations pertaining to how and why dissociation worked. Rejeski (1985) proposed that dissociative strategies occupy limited channel capacity that is critical in bringing perceptions of fatigue into focal awareness. This explanation was predicated in part upon the findings of Pennebaker and Lightner (1980), who found that participants could run faster on a cross-country course when compared to a track, despite reporting similar ratings of fatigue. The researchers suggested that participants' processing of internal cues (e.g., ventilation) was restricted when they focussed on external cues (e.g., the terrain) during the cross-country run condition, supporting the notion that external cues compete with internal cues during exercise (Pennebaker & Lightner, 1980). Rejeski (1985) theorised a point during the physical stress of exercise in which sensory cues dominate perception, due to their overwhelming strength. At this stage, mediation by psychological factors appears unlikely.

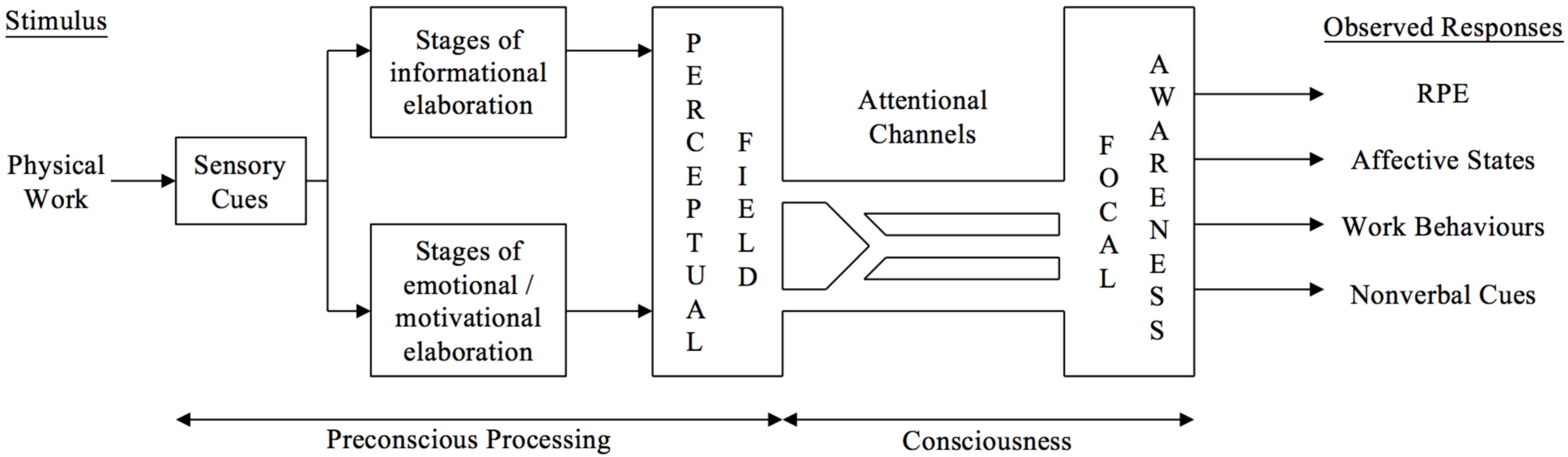

Figure 2.28. Parallel-processing model of attention. Adapted from "Perceived Exertion: An Active or Passive Process," by W. J. Rejeski, 1985, *Journal of Sport Psychology, 7,* p. 374. Copyright 1985 by Taylor & Francis.

2.4.3.3 Social cognitive model of attention. Tenenbaum (2001) introduced a conceptual framework that interrelated attentional focus, exercise intensity, and perceived exertion (Figure 2.29). Strategies for coping with physical exertion were classified as *internal* or *external* to the individual (Tenenbaum, 2001). Internal (or associative) strategies are used to cope directly with the perception of exertion by fighting against it. Conversely, external (or dissociative) strategies are used to shift attention to external events in an effort to reduce the perception of exertion.

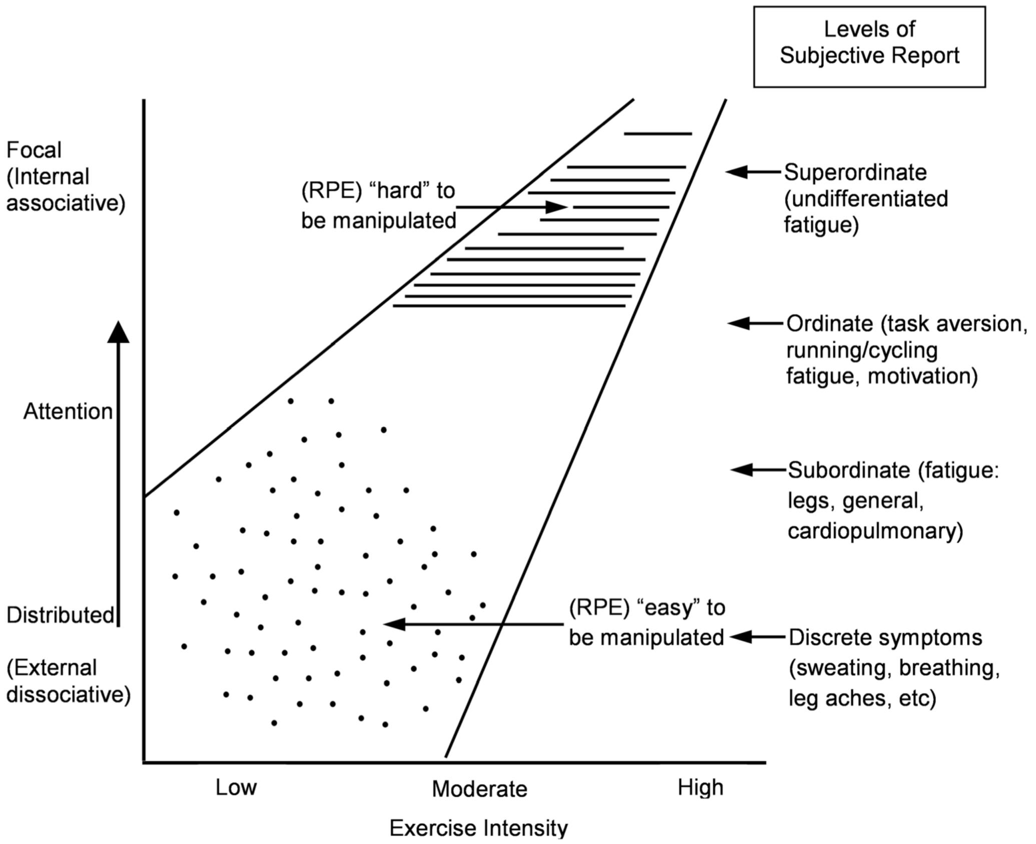

Figure 2.29. Social-cognitive model of attention. Reprinted from "A Social-Cognitive Perspective to Perceived Exertion and Exertion Tolerance," by G. Tenenbaum, in R. N. Singer, H. A. Hausenblas, and C. M. Janelle (Eds.), *Handbook of Sport Psychology* (2nd ed., p. 813), 2001, New York, NY: Wiley. Copyright 2001 by John Wiley & Sons.

The social-cognitive model of attention holds that the perception of exertion is dependent on the physical intensity of exercise and the endurance required to complete it (Tenenbaum et al., 2004). At low exercise intensities, an exerciser can voluntarily attend to external cues (e.g., audio-visual stimuli) or internal physiological processes (e.g., HR, respiration rate) and subsequently perceived exertion is generally low. As the intensity of exercise rises, it becomes increasingly difficult to divert attention away from internal physiological processes and increases in perceived exertion occur. Furthermore, Tenenbaum (2001) proposed that fatigue-inducing physiological symptoms shift from *discrete* (or distinct) at low exercise intensities, to *undifferentiated* (lacking defining features) at high exercise intensities. Consequently, it becomes extremely difficult to manipulate perceived exertion when fatigue levels are very high.

Collectively, the work of Rejeski (1985) and Tenenbaum (2001) lends support to the notion that the intensity of exercise determines the extent to which exercisers can voluntarily shift their attention to and from dissociative and associative modes. During low-to-moderate-intensity exercise (i.e., below and around the VT; Ekkekakis, 2003), attention is flexible and can voluntarily shift between modes, allowing an exerciser to process internal (e.g., physiological) and external (e.g., audio-visual) cues in parallel. During high-intensity exercise (i.e., above the VT; Ekkekakis, 2003), the capacity for attentional processing narrows and only the most salient cues are processed; such cues are often physiological owing to their overwhelming strength. Despite the suggestion that audio-visual stimuli may not alter perceptions of fatigue when individuals engage in high-intensity exercise, audio-visual stimuli have the capacity to enhance affective states at high exercise intensities (Karageorghis et al., 2009; Karageorghis & Priest, 2012b). This is plausible, given that high-intensity exercise is often associated with increased displeasure (Ekkekakis, Hall, & Petruzzello, 2004). Audio-visual stimuli can alter exercisers' perceptions of fatigue towards a more positive evaluation (Terry et al., 2012), reflecting the importance of *how* rather than *what* one feels during exercise (Hardy & Rejeski, 1989).

2.4.4 Brain mechanisms. Extremely few attempts have been made by researchers to explore the brain mechanisms that underlie the effects of audio-visual stimuli within an exercise context. Researchers have employed electroencephalography (EEG) technology in order to elucidate the electrical activity in the brain. For example, Bigliassi, Karageorghis, Nowicky, Orgs, and Wright (2016) found that asynchronous music could downregulate theta waves (4–7 Hz) in the frontal, central, parietal, and occipital regions of the brain during an isometric ankle-dorsiflexion task. Similarly, Bigliassi, Silva, et al. (2016) reported that audio-visual stimuli could downregulate theta waves (4–8 Hz) in frontal region and upregulate beta waves (12.5–30 Hz) in the central areas of the brain. More recently, researchers have employed whole-body modes of exercise (e.g., self-paced walking) and found that listening to music upregulates beta waves in the frontal and frontal-central regions of the brain when compared to podcast and control conditions (Bigliassi, Karageorghis, Hoy, & Layne, 2019).

Researchers have also used high-spatial resolution techniques, such as functional magnetic resonance imaging (*f*MRI) to help visualise the regions of the brain that activate in response to music in exercise (Karageorghis, Bigliassi, Guérin, et al., 2018). For example, Bishop et al. (2014) examined how tempo and intensity of pre-task music influenced neural activity during a choice-reaction task. The findings revealed that fast tempo, loud music activated neural structures integral to visual perception (inferior temporal gyrus), allocation of attention (cuneus, inferior parietal lobule, supramarginal gyrus), and motor control (putamen). Only one attempt to examine in-task music on exercise using *f*MRI has been made by researchers to date (Bigliassi, Karageorghis, Bishop, Nowicky, & Wright, 2018). Participants were required to engage in repetitive bouts of light-to-moderate-intensity isometric exercises using a silicone grip ring while exposed to asynchronous music and a no music control. The researchers reported that the music condition facilitated activation of the left inferior temporal gyrus, which is consistent with previous findings (Bishop et al., 2014). Collectively, the findings of the aforementioned studies lend support to the notion that audio-visual stimuli have the capacity to readjust activity in the brain, thereby reallocating attentional focus toward task-unrelated factors and reducing the physiological sensations associated with fatigue.

2.4.5 Heart rate variability. The heart is roughly the size of a closed fist and beats approximately 2.5 billion times during an average lifetime (Shaffer et al., 2014). In order to understand the cardiac cycle, researchers have sought to examine the changes in time intervals between adjacent heartbeats (i.e., HRV; Shaffer & Ginsberg, 2017). The sinoatrial (SA) node is an internal pacemaker that initiates each cardiac cycle through depolarisation of its autorhythmic fibres (Shaffer et al., 2014). The autonomic nervous system (ANS) accelerates or decelerates the function of the SA node via sympathetic and parasympathetic activity, influencing several organs including the heart (Acharya, Joseph, Kannathal, Lim, & Suri, 2006). Increased sympathetic activity results in cardio-acceleration. Conversely, increased parasympathetic activity results in cardio-deceleration.

Electrocardiographs (ECG) have been traditionally employed as a means of recording the electrical conduction system and contraction of the myocardium (Shaffer et al., 2014). However, it is now possible to capture such electrical activity by means of commercially available chest straps (e.g., Polar H7), which might be preferred to an ECG owing to its enhanced practicality and ease of use (Plews et al., 2017). The field of neurocardiology examines the connections between the heart and brain (Armour, 2003). One such connection pertains to the potential for HRV data to provide an objective measure of an individual's affective responses (Mather & Thayer, 2018). For example, HRV is significantly associated with regional cerebral blood flow in the ventromedial prefrontal cortex and the amygdala, both of which are involved in the regulation of affective states (Thayer, Åhs, Fredrikson, Sollers, & Wager, 2012).

Research examining the effects of audio-visual stimuli on HRV within an exercise context is scant. Investigations that entailed the measurement of HRV pre- and post-exercise have produced conflicting findings. For example, Urakawa and Yokoyama (2005) reported that music significantly influenced HRV during a 15 min period of rest following cycle ergometry. Conversely, Yamashita, Iwai, Akimoto, Sugawara, and Kono (2006) suggested that music had no bearing on ANS activity pre- and post-submaximal exercise. More recently, Loizou and Karageorghis (2015) found that a video-music condition could influence HRV prior to the completion of a Wingate Anaerobic Test. Concerning the measurement of HRV during exercise, it has been reported that auditory (Bigliassi, Karageorghis, Wright, Orgs, & Nowicky, 2017) and audio-visual stimuli (Bigliassi, Greca, et al., 2019) did not influence HRV when compared to control conditions, despite improvements in self-assessed affective valence (Bigliassi et al., 2017). Nonetheless, more research is required in order to confirm or refute these preliminary findings.

2.4.6 Immersion and presence. Researchers have theorised that the effects of audio-visual stimuli within an exercise context can be enhanced by providing an immersive exercise environment (Barreto-Silva et al., 2018; Jones et al., 2014). Moreover, researchers have recently sought to achieve this via the use of VR HMDs (Zeng et al., 2017). Attention is drawn between two terms that are often used synonymously within the extant literature; immersion and presence (Cummings & Bailenson, 2016). Immersion refers to the capacity of a technology to allow an individual to perceive through natural sensorimotor contingencies (Slater & Sanchez-Vives, 2016). Accordingly, immersion is entirely dependent on the technology's capacity to present a vivid virtual environment while simultaneously shutting out physical reality (Cummings & Bailenson, 2016). Slater and Wilbur (1997) suggested that immersion comprises four key components: *Inclusive* (i.e., the extent to which the physical world is occluded from the user); *extensive* (i.e., the range of senses accommodated); *surrounding* (i.e., whether the system employs panoramic virtual environments); and *vivid* (i.e., the fidelity, resolution, and quality of the displays used).

It is possible to classify technology on a continuum according to the degree of immersion that it confers (Slater & Sanchez-Vives, 2016). Specifically, a hypothetical system

x can be considered more immersive than a hypothetical system y, if system x can simulate the perception afforded by system y, but not vice versa (Slater & Sanchez-Vives, 2016). Therefore, a VR HMD can be considered more immersive than the traditional displays (e.g., television screens, projectors) employed by previous researchers from the realm of exercise sciences (Barreto-Silva et al., 2018; Jones et al., 2014), as VR HMDs continuously update the visual scene based on the participant's gaze behaviour, something which traditional displays cannot do. Hence, a virtual environment administered via a VR HMD can simulate the perception afforded by traditional television screens, but not vice versa.

A subjective correlate of immersion is presence, which refers to the psychological illusion of being inside the virtual environment (Slater, 2018). If sensory perceptions are effectively substituted by technology, then consciousness automatically shifts from physical reality to the virtual environment, despite the knowledge that the virtual environment is not real (Slater & Sanchez-Vives, 2016). Participants who are highly present behave in VR as they would in physical reality. For example, individuals have been observed dropping to their knees to find cover when participating in VR experiences that depict the occurrence of natural disasters (Bailenson, 2018). It has been suggested that the degree of immersion afforded by a technology facilitates the level of psychological presence felt by the participant (Cummings & Bailenson, 2016). The factors that are crucial for engendering feelings of presence have been known for several years and include enhanced user tracking, stereoscopic visuals, and wide fields of view (Cummings & Bailenson, 2016; Slater & Sanchez-Vives, 2016).

One of the defining characteristics of VR HMDs is the ability to track users' movements. To this end, VR HMDs draw upon two forms of tracking: orientation and position (Bird, 2019). Orientation is tracked by means of accelerometers, which provide feedback concerning the pitch (i.e., nodding), yaw (i.e., turns), and roll (i.e., lateral inclinations) of the participant's head movements (Fox, Arena, & Bailenson, 2009).

Orientation tracking provides the user with an opportunity to freely look around their virtual environment. More powerful VR HMDs have the capacity for positional tracking, which is achieved by placing external sensors within the users' physical environment (Bird, 2019). Accordingly, the sensors record the position of the HMD and additional accessories, such as hand trackers (Won et al., 2017). When using VR HMDs that are capable of positional tracking, if the user walks forwards in physical space, the movement is translated in their virtual environment.

2.5 Rationale for the Present Research Programme

The underlying rationale for this programme of research has emerged from the theoretical and empirical work presented throughout this review of the extant literature. Engagement in regular exercise is paramount to the prevention of numerous chronic diseases and psychological disorders (Rhodes et al., 2018). Nonetheless, a large proportion of the adult population fails to meet the recommended amounts of physical activity per week (Sallis et al., 2016). Given the lack of progress towards promoting physical activity at the societal level, exercise psychologists are currently experiencing a paradigmatic shift that places emphasis on the role of dual-process models, supporting the notion that individuals do not always make fully rational decisions (Ekkekakis, Zenko, et al., 2018). Rather, the affect heuristic purports that individuals are likely to participate in behaviours that engender pleasure while avoiding behaviours that engender displeasure (Kahneman, 1999). Accordingly, there is an urgent need for exercise psychologists to devise innovative solutions that seek to enhance affective responses to exercise.

One way in which exercise psychologists have enhanced affective responses to exercise is with the addition of music in the exercise environment (Karageorghis, 2017). Although early findings produced largely equivocal results (e.g., Boutcher & Trenske, 1990; White & Potteiger, 1996), this line of scientific inquiry has flourished over the past 20 years with the introduction of conceptual models to guide research efforts (Clark, Baker, & Taylor, 2016b; Karageorghis, 2016; Karageorghis et al., 1999). Where music might have been used as a sole stimulus in the past, developments in technology have ensured that audio-visual stimuli are now the most frequently implemented methods of distraction used in exercise facilities (Karageorghis & Priest, 2012a, 2012b). However, there is a paucity of frameworks that address audio-visual stimuli within the exercise context. This has important implications for the subsequent development of audio-visual interventions. Researchers can justify the selection of motivational music using conceptual models (e.g., Karageorghis, 2017) and rating inventories such as the BMRI-3 (Karageorghis, 2008), but there is a lack of sufficient theory to justify the selection of audio-visual stimuli. If this area of research is to grow out of its infancy, a fuller understanding of how audio-visual stimuli are experienced by exercisers is warranted, in order to direct future research and guide exercisers' audio-visual selections.

Given the increasing amount of research linking psychological hedonism to repeated exercise behaviour (Ladwig, Hartman, & Ekkekakis, 2017; Williams, 2018), it is necessary to examine the influence of audio-visual stimuli on affective responses to exercise. Moreover, the mechanisms that underlie such responses warrants further investigation. It is plausible that audio-visual stimuli entail greater attentional processing capacity when compared to music alone. However, more research is required to examine this while accounting for limitations in the extant literature. It has been theorised that immersive technology, such as VR HMDs, might offer an effective means by which to deliver audio-visual stimuli during exercise, owing to the capacity of such technology to induce the psychological perception of presence (Barreto-Silva et al., 2018; Jones et al., 2014; Slater, 2018). Albeit several companies are presently developing and refining VR products for use within an exercise context, research aimed at determining its effectiveness is scant. Indeed, the rate at which technology is evolving means that it is difficult for the research community to follow its effects before it is widely adopted by modern consumers (LeBlanc & Chaput, 2017).

Accordingly, the examination of the efficacy of recent immersive technology appears to be timely.

Study 1 sought to explain and predict the social process of exercising in the presence of a music-video channel. Study 2 examined the influence of a range of audio-visual stimuli on cycle ergometer exercise at the VT. Finally, Study 3 sought to enhance ecological validity with the inclusion of a commercially available VR-enabled cycle ergometer. An investigation was undertaken to further understanding of the affective, perceptual, and cardiac effects of using such technology within an exercise context. The three studies that comprise this programme of research present separate hypotheses (where relevant) and are prefaced with a specific introduction and rationale.

Chapter 3: A Grounded Theory of Music-Video Use in an Exercise Facility

3.1 Introduction

Regular engagement in physical activity can help in the prevention and management of heart disease, type 2 diabetes, some cancers, depression, and dementia (World Health Organization, 2016). Despite such benefits, physical inactivity remains a global risk factor, accounting for over 5 million deaths annually (Lee et al., 2012; D. Riebe et al., 2015). Physical inactivity has been recognised as the fourth most important risk factor in the UK and activity levels have been shown to decrease with age for both genders (Townsend, Wickramasinghe, Williams, Bhatnagar, & Rayner, 2015). In addition to posing a significant health risk to the population, the financial burden of physical inactivity on healthcare in the UK is substantial, estimated to cost as much as £1.2 billion annually (British Heart Foundation, 2017). Accordingly, there is a compelling case for interventions that focus on the enhancement of physical activity behaviours. Such interventions can be administered to individual exercisers (e.g., advice from health practitioners) or implemented at the population level (e.g., through making environmental changes; Morgan et al., 2016).

3.1.1 Music in the exercise context. One such environmental change in the exercise context is the addition of music. Digitalisation has ensured that music is more readily available today than ever before (Krause & North, 2016). Consequently, music has become an almost ubiquitous stimulus in exercise contexts; it is played over public address systems, can be enjoyed via personal listening devices, and is a key element of group exercise classes such as BODYPUMP and Zumba (Karageorghis, 2017). Such widespread use of music in the exercise context has led to an expansion in the research base addressing the effects of music on the human organism and the mechanisms that underlie its effects (Hallett & Lamont, 2015; Karageorghis & Priest, 2012a, 2012b).

3.1.2 Conceptual frameworks. A number of conceptual frameworks that are grounded in psychology have been proposed to account for the contingencies and effects of music use in exercise settings. For example, Karageorghis (2016) developed a framework that emphasised the relationship between the music, listener, and the context in which the individual is engaged. A range of musical factors were identified as antecedents and were presented in a hierarchy of intrinsic (e.g., tempo, melody) and extrinsic (e.g., iconic cues, cultural associations) factors. Moreover, the consequences of music use in exercise settings were highlighted (e.g., positive affective states, reduced RPE) and were ranked in an order that is consistent with their prevalence in the research literature. Several personal (e.g., personality, hearing acuity) and situational (e.g., sound source, intensity of exercise) factors were proposed to moderate the relationship between the music stimulus and the consequences. Additionally, the model has a reciprocal structure given that feedback loops run from the consequences, through the moderators, and back to the antecedents; meaning that the consequences of music use have a bearing on future selection decisions.

Following a systematic review and narrative synthesis of 23 theories, Clark, Baker, and Taylor (2016b) proposed a meta-theory that sought to explain the effects of listening to music during health-related exercise. The researchers explained that music listening influences cortical and subcortical responses during exercise. Consequently, such responses were theorised to facilitate physiological arousal and subjective experience, which were suggested to promote positive behavioural responses to exercise that included increased participation and adherence. The aforementioned frameworks provide a template that exercise professionals can use to inform musical selection and interventions (Karageorghis, 2017). Moreover, such frameworks can be used by researchers to inform future scientific inquiry.

3.1.3 Audio-visual stimuli in the exercise context. Twenty-first century technologies have not only ensured that music is more accessible, the capabilities of modern-day devices such as smartphones and multichannel digital televisions mean that the combination of audio and visual stimuli are increasingly prevalent in exercise facilities.

Researchers have made the distinction between music-and-video and music-video in the realm of exercise (Bird et al., 2016). The former was considered an umbrella term for all instances in which auditory and visual stimuli are experienced in tandem. Conversely, music-video was used with reference to official videos that accompanied individual pieces of music. Considered in this manner, music-videos were described as mostly “congruent”, in that there is usually some compatibility between the auditory and visual stimuli.

The aforementioned distinction offered a useful means by which to classify audio-visual interventions in an exercise context. Nonetheless, a limitation lies in the failure to acknowledge that not all auditory stimuli constitute *music*. To illustrate, researchers have examined the effects of exercising in the presence of popular television shows (e.g., Hall, Baird, Gilbert, Miller, & Bixby, 2011; Privitera et al., 2014). Accordingly, a more accurate hierarchy would consider official music-videos to be a distinct type of music-and-video, which, in turn, comprise a specific form of audio-visual stimulus.

Research examining the effects of audio-visual stimuli during exercise is still at a nascent stage, with fewer than 30 published articles to date. A small range of exercise modalities have been chosen for experimentation in a laboratory setting such as treadmill running (Barwood et al., 2009), cycle ergometry (Chow & Etnier, 2017; Jones et al., 2014), and muscular strength tasks (Bigliassi, Silva, et al., 2016). Collectively, the findings indicate that audio-visual stimuli can enhance work output (Barwood et al., 2009; Bigliassi, Silva, et al., 2016), promote greater situational motivation (Bigliassi, Silva, et al., 2016), facilitate positive affective responses (Jones et al., 2014), prompt a more dissociative attentional focus (Chow & Etnier, 2017), and reduce RPE (Chow & Etnier, 2017). A closer examination of the interventions used in the aforementioned studies reveal that a range of visual stimuli have been employed by researchers such as rural parkland based footage from a cyclist’s point of view (Jones et al., 2014), a circus performance (Chow & Etnier, 2017), movie footage (Bigliassi, Silva, et al., 2016), and sporting highlights (Barwood et al., 2009).

3.1.4 Music-videos in the exercise context. Researchers have also sought to understand the effects of exercising with music-video accompaniment, using quantitative approaches. This line of scientific inquiry was initiated by Lin and Lu (2013), who asked participants to engage in a maximal cycle test while exposed to popular Chinese music-videos. The authors found that participants cycled further and reported lower RPE when exercising with music-videos compared to video only, music only, and control conditions. Lin and Lu's (2013) findings were partially supported by Bigliassi et al. (2014), who indicated that participants reported lower RPE while performing a muscular endurance task with music-video accompaniment compared to sensory deprivation and control conditions. Music-videos have also been shown to reduce RPE, enhance affective responses, and promote a more dissociative attentional focus, while participants cycled at exercise intensities proximal to or directly at VT (i.e., the point during exercise at which breathing becomes laboured; see Operational Definitions) when compared to music and/or control conditions (Bird et al., 2016; Hutchinson et al., 2015).

Despite some initial findings purporting the benefits of exercise with music-video, there are several gaps in the knowledge base that need to be addressed for this line of scientific inquiry to flourish. For example, the vast majority of research has taken place within controlled laboratories (e.g., Hutchinson et al., 2015; Lin & Lu, 2013). Studies of this nature typically require participants to exercise in a sterile environment consisting of not much more than the equipment required for the exercise intervention. While this approach has been useful to establish causality when examining the impact of music-videos on physical and psychological outcomes (e.g., time to exhaustion; Bigliassi et al., 2014), we do not yet understand the impact that music-video channels have on the social process of exercising in a real-world context. Moreover, researchers have typically employed samples of university students in their late teens/early twenties, often from a sports science background (Bigliassi et al., 2014; Bird et al., 2016). Selecting participants with such a narrow age range does not reflect the reality of exercise facilities, which often accommodate members from across the lifespan (Hallett & Lamont, 2015).

Another limitation concerns the paucity of conceptual frameworks to inform the selection of suitable music-videos in the exercise context. Researchers, exercisers, and practitioners can use conceptual models (Clark, Baker, & Taylor, 2016b; Karageorghis, 2016) and rating inventories (Karageorghis, 2017) to help guide musical selections, but the same does not apply to the accompanying visual stimuli, owing to a lack of theory. It appears that researchers are cognisant of the motivational properties of music and often choose the accompanying video without any indication that it is suitable for exercise (e.g., Lin & Lu, 2013). A notable exception is the study of Hutchinson et al. (2015), who used a panel to evaluate the affective qualities of the music-videos used in their study. Nonetheless, this demonstrates consideration that the music-videos could elicit a particular *response* from the listener and not the specific components that constitute an effective stimulus for exercise contexts. Careful consideration towards this pervasive audio-visual stimulus is warranted if this line of scientific inquiry is to flourish.

3.1.5 Rationale for the present study. A considerable amount of research has been conducted in order to examine the scientific application of music in exercise contexts (Clark, Baker, & Taylor, 2016b; Hallett & Lamont, 2015; Karageorghis & Priest, 2012a, 2012b). This has led to the construction of conceptual frameworks (Karageorghis, 2016) and rating inventories such as the BMRI-3 (Karageorghis & Terry, 2011) that can optimise the music selection process. Audio-visual stimuli, such as music-videos, have become increasingly prevalent in exercise settings, to the point that they are now the most frequently found form of dissociative technique in exercise facilities. Accordingly, researchers have begun to investigate the effects of such stimuli using quantitative approaches (Bigliassi et al., 2014; Lin & Lu, 2013). Nonetheless, little is known about the impact of a music-video channel outside of a laboratory setting and there is a dearth of conceptual frameworks to assist with the selection of music-videos in exercise contexts. It is acknowledged that television screens are considered less immersive when compared to other technologies available to modern consumers (e.g., VR HMDs). However, given that music-video channels are ubiquitous within contemporary exercise facilities, the examination of such technology provides an ecologically valid point of origin for the present programme of research.

3.1.6 Aim of the present study. The aforementioned shortcomings in the literature provided the basis for the initial research question: How does the presence of a music-video channel influence the social dynamics of exercising in a real-world context? The aim of Study 1 was to develop a substantive theory that explained and predicted the social process of exercising in the presence of a music-video channel. The construction of such a theory would inform health practitioners' use of music-video interventions, guide exercisers' music-video selections, and advance this nascent line of scientific inquiry.

3.2 Methodology

This study was approved by the Brunel University London Ethics Committee (see Appendix A) and all participants provided written informed consent (see Appendix B).

3.2.1 Qualitative research. Researchers in the realm of exercise psychology are increasingly using qualitative methodologies to explore phenomena in their natural settings and to make sense of the meanings that individuals ascribe to them (Smith & Sparkes, 2016b). However, no qualitative research to date has addressed the impact of a music-video channel within a social setting such as an exercise facility. This is surprising given that researchers have conducted numerous studies to shed light on how exercisers use music as a sole stimulus (Hallett & Lamont, 2015; Priest & Karageorghis, 2008). When a research question aims to explain phenomena within specific contextual conditions, upon which a sufficient pre-existing theory has not yet been developed, an insightful approach is grounded theory (Corbin & Strauss, 2015; Weed, 2017).

3.2.2 Grounded theory methodology. The use of grounded theory is becoming increasingly common within exercise psychology research (Weed, 2009). Nonetheless, it has been suggested that researchers have seldom demonstrated adequate understanding of grounded theory and/or fail to present a comprehensive account of the research process (Holt, 2016; Hutchison, Johnston, & Breckon, 2011). Researchers conducting grounded theory studies should strive towards "methodological coherence" (Holt & Tamminen, 2010b, p. 419) by displaying consistency in terms of their philosophical orientation, research question, participants, and methods. Moreover, grounded theory can be considered a total methodology that provides a set of principles for the entire research process, from start (e.g., conceptualisation of the research) to finish (e.g., the outcome or product of the research; Weed, 2009).

Previous research that has employed grounded theory to investigate the effects of music within sport (i.e., Bishop, Karageorghis, & Loizou, 2007) has received criticism for not meeting the sufficient conditions for grounded theory research. Accordingly, researchers have emphasised that grounded theory methodology is not a "pick and mix" box (Weed, 2009, p. 504), whereby some of the principles are employed and others discarded, as this would result in researchers unwittingly creating their own unproven methodologies (Holt & Tamminen, 2010a). In contrast, grounded theory is a "complete research process" (Hutchison et al., 2011, p. 270). Researchers have suggested that the following eight key elements collectively represent sufficient conditions for grounded theory research at the micro-level: (a) an iterative process; (b) theoretical sampling; (c) theoretical sensitivity; (d) codes, memos, and concepts; (e) constant comparative method; (f) theoretical saturation; (g) fit, work, relevance, and modifiability; and (h) substantive theory (Holt, 2016; Weed, 2017). Study 1 advances previous music-related research within exercise and sport contexts (i.e., Bishop et al., 2007) by fully demonstrating the sufficient conditions required for grounded theory.

3.2.3 Ontology and epistemology. At the macro-level, ontological and epistemological assumptions underpinning grounded theory research should be considered by the researcher (Weed, 2017). According to Blaikie (2010), ontological claims are made regarding the nature of social reality; what can exist, what it looks like, what units comprise it, and how these interact with one another. Accordingly, an individual's ontological position lies within the answers to the questions: What is the nature of the social reality to be investigated? Is there a singular objective reality or is reality a subjective interpretation? Only after these questions have been answered can one discuss what might be known about the social reality that is thought to exist (Bryman, 2016). Epistemology concerns the theory of knowledge, particularly with regards to its methods, validation, and the possible ways of gaining knowledge of social reality (Blaikie, 2010). Hence, epistemological claims seek to answer the questions: How is knowledge of the social world possible? Can a phenomenon be directly observed and known, or can it only be indirectly understood? Having answered such questions, attention can turn towards appropriate methodologies (Holt, 2016; Weed, 2017).

Although debates concerning ontology and epistemology were not prominent when Glaser and Strauss (1967) published their original monograph on grounded theory, it is vital that researchers acknowledge the variants of grounded theory, as well as the ontological and epistemological differences that underlie them (Holt, 2016; Weed, 2017). Holt and Tamminen (2010b) suggested that this is important for the following reasons: (a) different variants of grounded theory are associated with different philosophical underpinnings; (b) a researcher's philosophical stance may influence the type of issues that he or she wants to research, which subsequently influences the research decision-making process, and the manner in which the final grounded theory is created; and (c) philosophical underpinnings have implications for how the reader can evaluate the research in an informed manner. Despite the importance of explaining the epistemological and ontological underpinnings of research, this has seldom been demonstrated in the exercise and sport psychology grounded theory literature (e.g., Bishop et al., 2007; Holt, Tamminen, Black, Sehn, & Wall, 2008; Pummell, Harwood, & Lavallee, 2008).

Several variants of grounded theory have been developed under different philosophical positions, including Glaserian (Glaser, 1978), Straussian (Strauss & Corbin, 1998), and constructivist (Charmaz, 2006). The author employed Corbin and Strauss's (2015) variant of grounded theory in this study, which is philosophically underpinned by symbolic interactionism and pragmatism. Such a position directs scholars' attention toward research questions and methodologies that can make the greatest applied impact to the individuals and groups that they examine (Corbin & Strauss, 2015; Cruickshank, Collins, & Minten, 2014; Morgan, 2014). Hence, pragmatism does not prioritise metaphysical concerns such as the nature of reality and the possibility of an objective truth (Morgan, 2014). However, the pragmatist position discards the assumptions of an objective reality and that one interpretation can more accurately represent the truth than another. Pragmatists view all knowledge as provisional and believe that knowledge should be judged in accord with its usefulness in a given context (Bryant, 2009).

Corbin and Strauss's (2015) variant of grounded theory was considered appropriate for the present study given the author's desire to construct a substantive theory that would hold practical utility for researchers and practitioners working in real-life settings. Moreover, the associated principles and procedures outlined by Corbin and Strauss (2015) align with the author's beliefs. For example, it was recognised that it was difficult to approach the research site without any preconceptions or biases regarding music-videos in an exercise context (Holt, 2016). However, it was precisely this prior knowledge that allowed for innovative theorising (Bryant, 2009). By taking an active role in the research process, knowledge concerning the social process of exercising in the presence of a music-video channel was co-constructed between participants and researchers (Corbin & Strauss, 2015).

3.2.4 Research site. The nature of the main research question helped determine the site to study and the people to speak with in order to get the best answers (Holt & Tamminen, 2010b). Considering such sampling matters from the outset of the study provided the author with a clear sense of direction from which to begin gathering data (Corbin & Strauss, 2015). An exercise facility located in Cheltenham, Gloucestershire, was chosen as a suitable site for data collection. The exercise facility employed 25 members of staff and accommodated ~1750 exercisers per week ($M_{\text{age}} = 40.0$ years; equal female–male distribution; predominantly White British ethnicity). Moreover, the facility comprised two primary exercise environments that were situated on two separate floors plus a free weights room. Both primary exercise environments contained wall-mounted televisions that displayed a variety of channels (e.g., news, radio, music-video). The choice of which channels were played was determined by members of staff. Initial access to the site was gained by the author who had frequently exercised at the facility but was unconnected to the staff and clientele (see Appendix C). This working knowledge of the site helped the author become more habituated with the meanings embedded in the data collected and thus enhanced theoretical sensitivity (Corbin & Strauss, 2015).

3.2.5 Sampling and participants. Study recruitment was conducted through word-of-mouth and aided by means of promotional posters at the exercise facility (see Appendix D). Sampling and data collection processes occurred over five phases (see Figure 3.1). Initially, participants were purposively sampled (i.e., sampling driven by the nature of the research question). Given the need to consider diverse perspectives, there were no restrictions concerning the personal characteristics or audio-visual preferences of participants. Rather, it was the author's intention to recruit a sample that were familiar with exercising in the presence of the audio-visual stimuli used in the exercise facility. Hence, inclusion criteria specified that individuals used the facility a minimum of two times per week and that they had been members of the facility for at least 2 months.

One of the core components of grounded theory is that the researcher is involved in an iterative process between data collection and analysis, a notion that echoes the symbolic interactionist concept of action and interaction (Corbin & Strauss, 2015; Holt, 2016; Weed, 2017). Theoretical sampling facilitated this process, wherein participants were selected for phases 2–5 on the basis of refining concepts and developing ideas (see Figure 3.1). This has been overlooked in previous grounded theory research that investigated the use of music in sport (e.g., Bishop et al., 2007). The author followed the trail of emergent concepts, by searching for participants who could provide rich information pertaining to such concepts until an adequate level of saturation was attained (Corbin & Strauss, 2015; Holt, 2016; Weed, 2017). Striving for theoretical saturation ensured congruence between the resultant substantive theory and relevant music-video channel-related phenomena (i.e., "fit"; Weed, 2017).

To illustrate the author's approach to sampling by way of an analogy, consider the shape of an hourglass (Bruce, 2007). The early stages of data collection and analysis revolved around the impact of a music-video channel on the social process of exercising in a public exercise facility. Accordingly, a broad selection of participants' experiences was sought. However, as the analysis progressed, the author focused on key participants and concepts until saturation was reached. Simultaneously, the author began to realise that the impact of the music-video channel of facility staff was an equally important avenue to explore and thus sampling was broadened. The overall sample consisted of 13 exercisers (6 females, 7 males; M_{age} = 42.7 years, SD = 6.7 years, age range: 25–49 years) as well as two female and two male members of staff (M_{age} = 36.8 years, SD = 12.3 years, age range: 28–55 years). The ethnicities represented by the overall sample were White/British (n = 14), White Other (n = 2), and Indian (n = 1).

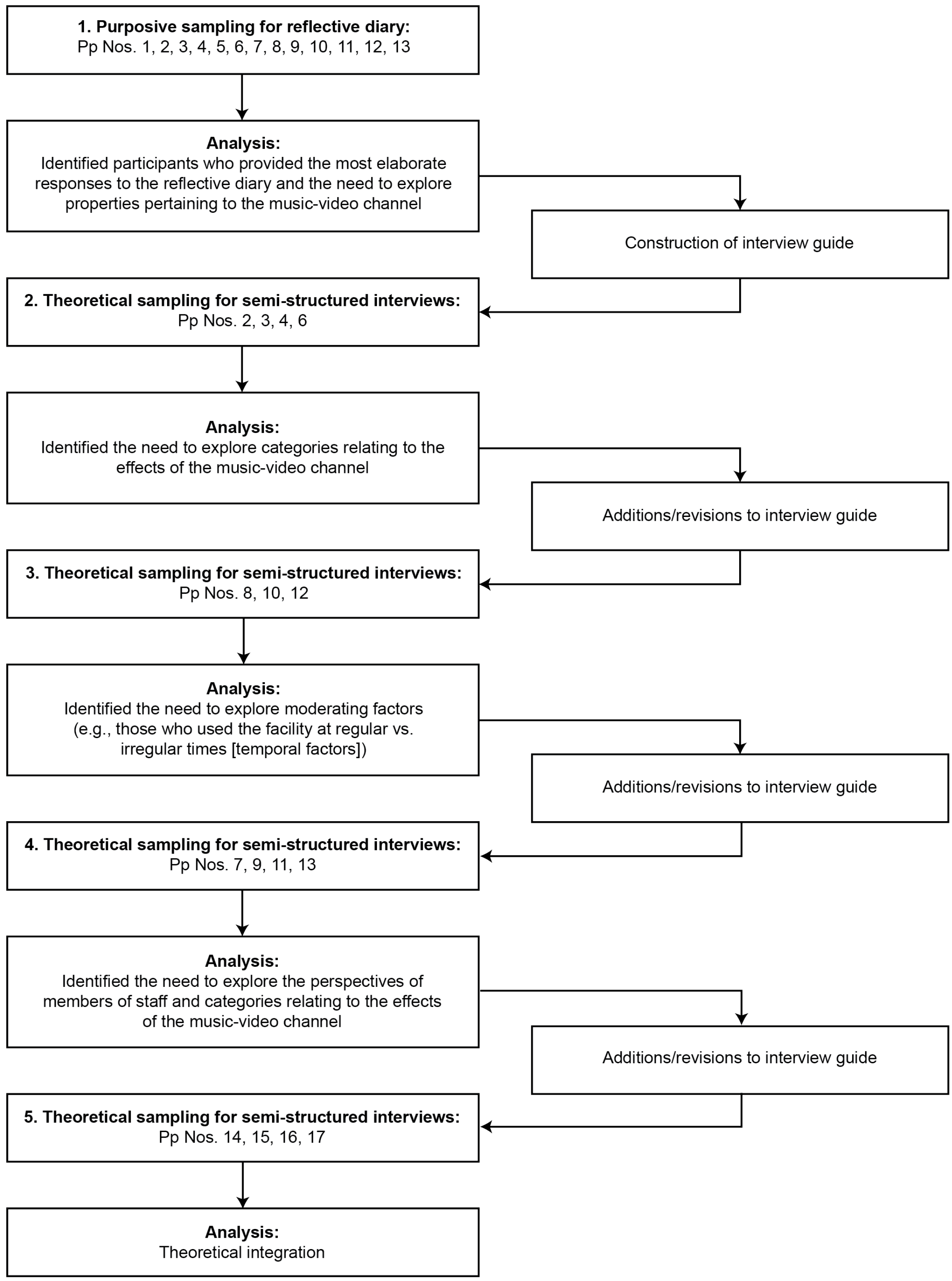

Figure 3.1. Forms of data collection, rationale for inclusion of participants, and participants sampled for each iteration of data collection during Study 1. *Note.* Pp Nos. = participant numbers.

3.2.6 Procedure.

3.2.6.1 Initial meeting. Those who expressed an interest in participating in the study were contacted by email or telephone. An initial informal meeting took place and participants read an information sheet (see Appendix E), provided informed consent (see Appendix B), and completed a demographic questionnaire (see Appendix F) as well as the Attentional Focus Questionnaire (Brewer, Van Raalte, & Linder, 1996; see Appendix G).

3.2.6.2 Music-video channel. In order to adequately address the research question, it was agreed with the facility manager that one of the primary exercise environments would display a music-video channel for a period of 6 weeks, at a standardised sound intensity (~75 dBA). The exercise facility had access to Freeview, which contains two music-video channels, *4Music*, and *Viva*. The channel chosen for the present study was *4Music*. The other primary exercise environment remained unaffected for those members that did not want to exercise in the presence of a music-video channel. The inclusion criteria served to ensure that participants were familiar with exercising in the presence of a variety of audio-visual stimuli. However, it was hoped that exposure to a *music-video* channel during exercise would enrich participants' experiences during the first phase of data collection (Corbin & Strauss, 2015).

3.2.6.3 Reflective diaries. The author chose to employ reflective diaries because they facilitate the recording of data that are temporally ordered, which allowed the author to gauge the impact of the music-video channel over a prolonged period. In addition, reflective diaries circumvent the pitfalls associated with retrospective reporting and participants are more likely to disclose sensitive information in a diary when compared to a face-to-face interview (Corbin & Strauss, 2015; Day, 2016). Prior to the data collection process, a thorough review of literature was conducted in order to identify a number of sensitising concepts that informed the construction of a one-page diary (Clark, Baker, & Taylor, 2016b; Hutchinson et al., 2015). Such concepts have been described as "points of departure" (Holt & Tamminen, 2010a, p. 410), because they represent open-ended ideas to pursue and act as a place to start, rather than end (Weed, 2009).

Thirteen exercisers completed a handwritten diary entry over a 4-week period during each occasion they visited the facility and produced a total of 91 diary sheets. The diary sheet questions were purposely minimal so as to influence participant responses (e.g., What effect did the music-video channel have on your feelings, if any? see Appendix H). Reiterating the idea that the diary questions served as points of departure, participants were encouraged to complete an additional comments section upon each diary entry and to specify up to three memorable music-videos. Following the 4-week diary period, participants selected two memorable music-videos.

3.2.6.4 Pilot testing. Additional phases of data collection were to comprise (a) an observation of participants viewing the two memorable music-videos specified within the four-week diary, (b) psychometric testing, and (c) a semi-structured interview to investigate the impact of the music-video channel on the social process of exercising at the facility. During the observation, participant's changes in facial expressions, behaviours, and somatic responses were to be recorded, with notes indicating the timings of such responses. A music-video form of the BMRI-3 (Karageorghis & Terry, 2011) was developed for Study 1 entitled the Brunel Music-Video Rating Inventory (BMVRI; see Appendix I). Upon completion of an expert validation process, it was recommended that the inventory be administered while participants were viewing each music-video, as opposed to afterwards, owing to the difficulty associated with completing some of the items retrospectively (e.g., the lighting in this video would facilitate my exercise session). Participants were to complete the Affect Grid (Russell, Weiss, & Mendelsohn, 1989; see Appendix J) immediately following the cessation of each music-video. The responses from participants' diary sheets helped in identifying several concepts and categories that informed the development of a semi-structured interview guide.

The questions were open-ended and initially focused on the music-video channel (e.g., "What does an effective music-video mean to you in a social exercise context?").

Two pilot observations and interviews were conducted with a convenience sample (M_{age} = 27.0 years), to familiarise the author with the procedure and to make any necessary changes to the interview guide. The pilot observations revealed a methodological problem in that very little meaningful data were collected with regard to participants' changes in facial expressions and behaviours. Furthermore, this was exacerbated with the completion of the BMVRI during the music-video. Accordingly, the author did not incorporate any observational notes or results from psychometric testing into the formal analysis. Rather, these were used to help direct the content of the semi-structured interview that followed.

3.2.6.5 Semi-structured interviews. The author chose to conduct semi-structured interviews on the basis that they provide an opportunity to gain rich knowledge about social and personal aspects of individuals' lives (Smith & Sparkes, 2016a). Additionally, semi-structured interviews are an effective method for understanding individual perspectives, which represents a key component of the symbolic interactionist approach underlying Corbin and Strauss's (2015) variant of grounded theory.

The two music-videos that each participant considered memorable from the reflective diaries were legally downloaded from Apple iTunes (Apple Inc., California). When participants failed to specify two memorable music-videos, the author selected the most frequently cited music-videos across all selections of remaining participants. The author contacted each participant via telephone in order to arrange a suitable date and time to meet at the exercise facility, wherein data collection took place within a quiet room. The music-videos were played at a standardised intensity on a laptop (MacBook Pro, Apple Inc., California) and the author prompted participants to complete the BMVRI after exactly 2 min. Thereafter, participants viewed the remainder of the music-video, before completing the

Affect Grid (Russell et al., 1989). Subsequently, participants were interviewed with reference to the impact the music-video channel had on the social process of exercising at the facility.

As the iterative process of data collection and analysis continued, the interview guide was updated to reflect additional concepts and categories that emerged, and participants were theoretically sampled in accordance with this (see Figure 3.1). While the content of the music-video channel and their effects on exercisers were of interest in the early stages of data collection, latter interviews were orientated more towards the factors that influenced such effects. Participants who provided the greatest detail within the first phase of data collection were contacted first and data collection continued until theoretical saturation was attained. Eleven exercisers took part in this phase of data collection.

Research questions within grounded theory studies can transform in light of emerging categories (Corbin & Strauss, 2015). The perspectives of *staff members* were also deemed important after the ongoing analysis revealed that the environment was a key category and that, ultimately, staff were responsible for how the facility, as a social space, was constructed. Accordingly, the research question changed to accommodate this development (i.e., How does the presence of a music-video channel influence the social dynamics of running an exercise facility?). Staff members were theoretically sampled, and the interview guide was updated in order to explore their perspectives (e.g., "What is the decision-making process that underlies the selection of audio-visual material at the facility?). The theoretical sampling of staff members enhanced the "relevance" (Weed, 2017) of the resultant substantive theory by accommodating both populations that characterised the social environment (i.e., exercisers and staff). Participants read an information sheet (see Appendix K), provided informed consent (see Appendix B), and completed a demographic questionnaire (see Appendix F). Four members of staff took part in this phase of data collection until theoretical saturation was attained. Semi-structured interviews lasted 20–65 min (M_{duration} = 40:11 min, *SD* = 12:59

min), were digitally recorded (iPhone 6S, Apple Inc., California) and transcribed verbatim to yield 173 pages of single-spaced text.

3.2.7 Data analysis. Diary and interview data were organised using qualitative analysis software (NVivo for Mac v.10) and analysed in accordance with the coding recommendations of Corbin and Strauss (2015). This process was predicated on the interaction between data collection and analysis (Holt, 2016). Thus, the analysis commenced with participant diary sheets, the content of which informed the direction of the first semi-structured interview. Subsequently, this informed the direction of the next semi-structured interview and so forth.

The constant comparative method was employed. As the researcher moved along the analysis, each incident (i.e., the words of a participant) was compared with other incidents for similarities and differences (Corbin & Strauss, 2015; Holt, 2016). Incidents that were found to be conceptually similar were placed together under a higher-level descriptive concept (e.g., audio-visual preferences, audio-visual accessibility). Subsequently, comparisons were made across incidents and developing concepts, among concepts, and finally, between categories (e.g., exercise factors) and existing theory (e.g., Clark, Baker, & Taylor, 2016b; Karageorghis, 2016). The constant comparative method ensures that researchers remain close to their studied worlds without "taking off on theoretical flights of fantasy" (Sparkes & Smith, 2014, p. 119). Other analytical tools were drawn upon to facilitate the coding process such as the asking of questions (e.g., sensitising, theoretical), using the "flip-flop" technique, and considering the various meanings of words used by participants (Corbin & Strauss, 2015). Such tools promoted the interaction between the researcher and the data, stimulated conceptual thinking, and enhanced the author's ability to negotiate the participants' perspectives (Corbin & Strauss, 2015; Mead, 2002).

Initially, each transcript was read in its entirety in order to gain a sense of the overall context of the data and to enter vicariously into the life of participants (Corbin & Strauss, 2015). Open coding took place that sought to "fracture" the data by breaking it into manageable sections and exploring the ideas contained within. Several concepts were identified within the data and were examined with regard to their properties and dimensions (Corbin & Strauss, 2015). Axial coding was then used to reconstruct data that were fractured during open coding. Concepts were assembled into categories, which were then examined in order to identify higher-order categories and subcategories, and to refine and make connections between them. This process served to promote theoretical sampling with the identification of categories that required further saturation (Holt, 2016).

The data were subsequently analysed using selective coding, whereby categories were integrated to form a larger theoretical model. Theoretical integration was achieved by developing relationships among categories and contrasting them with the extant literature (e.g., Clark, Baker, & Taylor, 2016b; Karageorghis, 2016). An essential consideration at this stage of analysis was that the resultant substantive theory could explain, interpret, and predict the social process of exercising in the presence of a music-video channel (i.e., "work" Weed, 2017). Additionally, the author strived to ensure that the structure of the theory could accommodate future research (i.e., "modifiability" Weed, 2017). The author conducted all coding procedures independently. Thereafter, the author explored the meaning ascribed to the codes with his principal supervisor.

The process of moving from description to conceptualisation was aided by the use of memos, which enabled the recording of ideas, insights, and questions while the theory evolved within the iterative process (Corbin & Strauss, 2015). This is an effective means by which to reflect upon the research process, facilitating an awareness in what symbolic interactionists refer to as "self" (Mead, 2002). A possible version of the grounded theory was diagrammed during the planning stages of Study 1 to facilitate theoretical thinking, as opposed to descriptive thinking (Holt, 2016). Data collection and analysis ceased when an adequate level of theoretical saturation was attained (Corbin & Strauss, 2015; Holt, 2016). At this point, the collection of new data seemed counterproductive, because it failed to generate additional insights related to how a music-video channel influenced the social process of those using and working in an exercise facility.

The resultant substantive theory was evaluated using the quality criteria of “fit” (i.e., do the concepts and theory resemble the music-video channel-related phenomena?), “work” (i.e., does it provide an appropriate analytical explanation for how music-videos are interpreted?), “relevance” (i.e., does it account for each population present within the environment [i.e., exercisers and staff members]?), and “modifiability” (i.e., can it be developed further to accommodate the insights derived from future research? [Weed, 2017]).

3.3 Results

The diary sheets and interviews provided rich and thick data pertaining to the social process of exercising in the presence of a music-video channel and managing a facility that displays such a channel (see Figure 3.2). When viewed from top to bottom, the model depicts a three-stage process commencing with the content of the music-video channel. A series of moderators are proposed, which contribute toward the core category of the model, an appraisal of music-video appropriateness. Thereafter, a range of effects caused by the music-video channel are presented. Such effects have the potential to cause conflict within the facility and such conflict is ultimately resolved via accommodation. The study took place in a context that consisted of two populations that interact socially with one another; exercisers and staff. Accordingly, the left side of the model represents the perspective of individual exercisers and the right represents the perspective of facility staff.

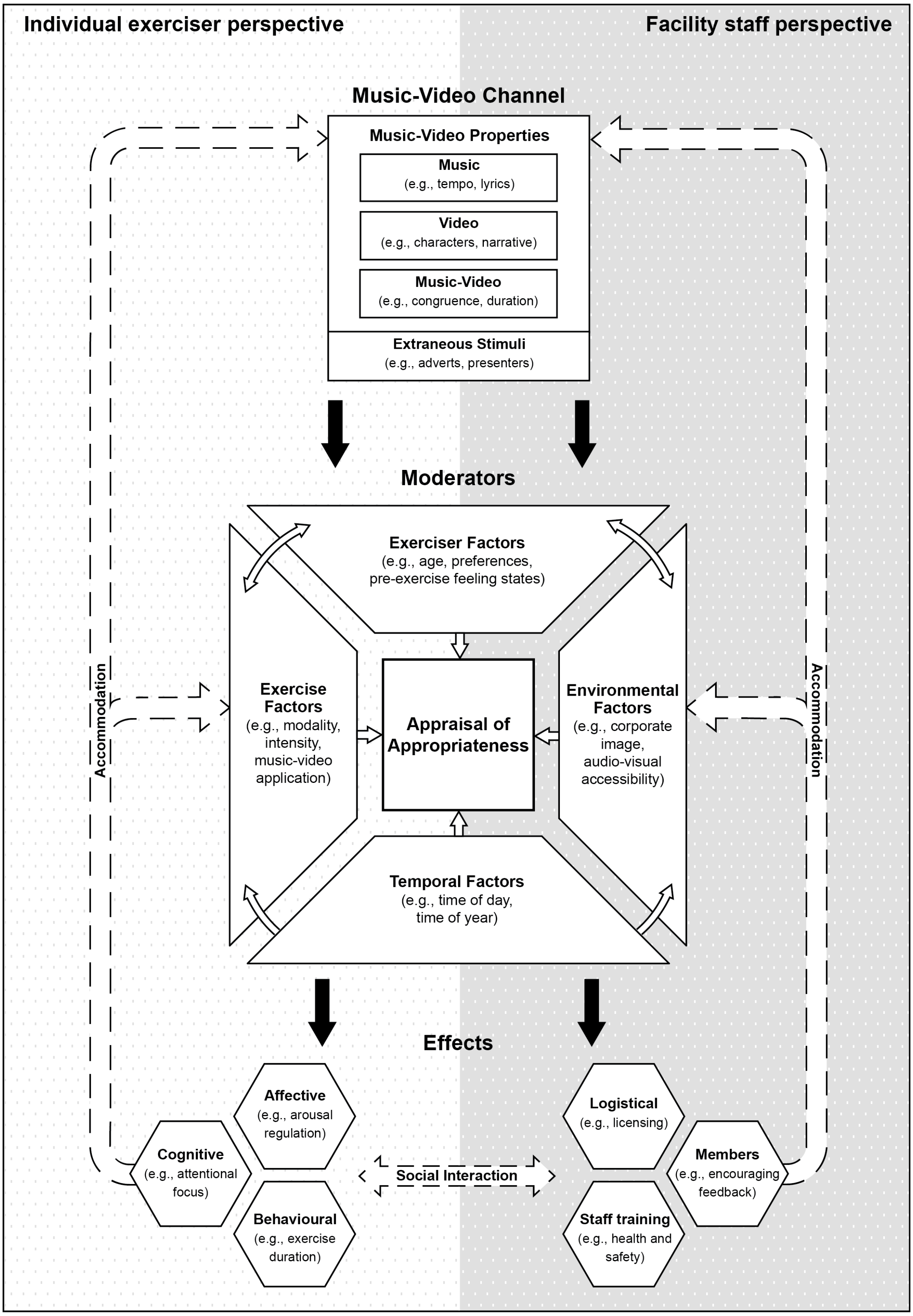

Figure 3.2. A grounded theory of exercising with output from a music-video channel.

3.3.1 Music-video channel. The music-video channel represents the first stage of the model and can be likened to the first domino that initiates a chain reaction. Moreover, the channel is located equally between the individual exerciser and facility staff, given its equal importance to the two populations that coexist within the social context. Exercisers are subjected to such stimuli and yet the staff are ultimately responsible for the nature of the stimuli. The channel was selected to enable participants to exercise in the presence of music-videos. Nonetheless, interviewees indicated that the channel presented two main forms of stimuli, music-videos and extraneous stimuli.

3.3.1.1 Music-video properties. Participants described a variety of properties relating to the music, video, and music-video collectively. Regarding the musical components, all participants had expectations that the music should "have the right tempo for a gym" (Participant 3; interview). Although this expectation is moderated by a range of factors that are discussed herein, it appears that the "right" tempo in this context is fast (e.g., ≥ 120 bpm). Otherwise, the music-videos were described as "too slow to help [facilitate exercise]" (Participant 6; reflective diary). Furthermore, participants identified a range of additional musical components that were deemed important in exercise contexts such as the rhythm, harmony, and lyrical content.

An original contribution of the substantive theory pertains to the identification of the video and music-video properties that are considered salient in an exercise context. Regarding the video properties, components such as the colour, lighting, narrative, characters, and location depicted in the video appeared to be important:

> Happy, uplifting, brightly coloured videos made me workout quickly . . . If there was a sense of being drawn into the movement, all the better. That is, if the video was shot as if you were on the bike too . . . Anything expansive, such as cityscapes and landscapes, skies and sea, made me feel transported elsewhere and gave me a sense of happiness and energy that translated into working out that bit harder . . . videos with a

> narrative arc . . . were good at keeping me interested and going until I, too, reached the conclusion of that section of my workout. (Participant 12; reflective diary)

Participants suggested that the video properties could make the audio seem "more positive or negative . . . the audio alone is a happy medium . . . it [the video] has the potential to be beneficial . . . it also has the potential to really tick me off" (Participant 8; interview). Hence, consideration should be given to the audio *and* visual components that comprise audio-visual stimuli if we are to fully harness the associated benefits in an exercise context.

Components unique to music-videos collectively, such as the release date, the duration, and variation of music-videos played on the channel were also identified. Furthermore, participants provided support for the idea that the congruence between the audio and the visual content influenced how they responded:

> If the images on the screen are not associated with what I'm listening to, I can completely tune it out, but when it's a music-video and its associated, you're drawn to it, because everything's in rhythm, everything's connected, it's a lot harder to ignore it. (Participant 8; interview)

Thus, it appears that music-videos may represent a more potent form of distraction than other forms of audio-visual stimuli, which present audio and visual stimuli that are incongruent in nature (e.g., television programs with musical accompaniment).

3.3.1.2 Extraneous stimuli. Music-videos represented the majority of the channel's content. Nevertheless, broadcasters supplement such channels with additional content that might be considered extraneous or irrelevant. To illustrate, exercisers frequently cited that presenters, other programs and adverts could prompt undesirable outcomes:

> Updates on what Kim Kardashian is doing this week, or Rita Ora spent a lot of time hanging around on a boat not wearing very much . . . and then adverts, and

> particularly adverts for things like chocolate and McDonald's and Burger King, which I just thought was totally and utterly inappropriate in a gym. (Participant 3; interview)

It appears that the source of the participants' frustration is not completely attributed to the *presence* of extraneous stimuli, but the fact that they "interrupt the flow of the tracks" (Participant 7; reflective diary). Hence, extraneous stimuli can be viewed as a form of disruption to both the audio and visual stimulation provided by a steady stream of music-videos on the channel.

3.3.2 Moderators. The second stage of the model depicts the categories that are proposed to influence the effects of a music-video channel in an exercise facility.

3.3.2.1 Appraisal of appropriateness. The core category of the developed model is an appraisal of appropriateness pertaining to the music-video channel: "I just think that you need to consider that the channel you're listening to is appropriate" (Participant 16; interview). But what concepts make a music-video channel appropriate vs. inappropriate? Data from reflective diaries identified many instances in which the content was deemed appropriate:

> I watched a [music-] video that contained long stretches of a cyclist going along different roads, with scenery changing around him. It was filmed so that you felt you were riding the bike. It made for a really good and uplifting 4 minutes on the bike; like I had travelled that journey. (Participant 12; reflective diary)

Music-videos depicting exercise were welcomed by participants and this offered a useful starting point to help the author understand how such videos were appraised to be "appropriate". The ongoing collection and analysis of interview data revealed that the ways in which participants made sense of and ascribed meaning to the content of the music-video channel involved several additional concepts beyond those directly related to exercise. Participant 3, who disliked music-videos, hinted at the factors that led to an appraisal of inappropriateness:

> I didn't think it [music-video] was particularly appropriate. Particularly as I normally exercise in the morning . . . the clientele that is here, I'm probably the youngest . . . and you can imagine that some of the people here found it distinctly uncomfortable . . . alongside that I thought that people running around with no clothes on at kind of half-eight in the morning was a little bit too much to take. (interview)

The analysis revealed that participants' appraisal of appropriateness was influenced by a range of factors that included the exerciser and exercise mode as well as the social environmental and temporal factors; such factors are expounded herein.

3.3.2.2 Exerciser factors. The appropriateness of the music-video channel appeared to be moderated by a range of exerciser factors such as age, gender, audio-visual preferences, and cultural upbringing: "I think all preferences have to have some wider cultural influence on you as to what you've been exposed to, and what you're familiar with, and what your friends are familiar with" (Participant 13; interview). Female participants were more likely than their male counterparts to appraise the content of the music-video channel as inappropriate. While watching music-videos, females often wondered "why are women portrayed like this?" (Participant 6; interview). Further probing suggested that the unequal portrayal of the genders was a major concern: "there were just continuously people running around with no clothes on – women. And if there had been men running around with no clothes on as well that would have been fine, but there wasn't an equal balance". (Participant 4; interview).

Participants' feeling states prior to exercising influenced how they appraised the music-video channel. Specifically, exercisers described that feeling states (e.g., mood) lowered the threshold for related feeling states (e.g., emotions) to occur:

> We all have good days and bad days . . . on a good day, if I came in and Paloma [Faith] was on there belting it out and I was already in a good mood, actually I might go "cor, yeah, I do feel properly happy now!" Whereas, if I was late and in a

> miserable mood and Madonna came on . . . I'd go "for God's sake" (Participant 4; interview)

As an illustration of the social processes at play, members of staff took an active interest in exercisers' audio-visual preferences, stating that "it's about kind of appeasing everybody, obviously, we've got so many different age ranges here, we don't want to discriminate against anybody" (Participant 14; interview). Accordingly, exerciser factors bear relevance not only to the individual but also the considerations of facility staff and are thus positioned centrally in the proposed model (see Figure 3.2).

3.3.2.3 Exercise factors. Over the course of the study, exercisers were instructed to not deviate from their typical regime. The decision to engage in exercise is ultimately under the control of the individual and thus the exercise factors are situated on the left of the model (see Figure 3.2). The analysis revealed several exercise factors that would alter participant's perception of how appropriate music-videos were, including the duration and intensity of exercise:

> If I was doing . . . an intense kind of session, I would rather watch a [music-] video that was probably more aligned with some kind of intense activity, Insanity or something like that . . . If I was on the running machine for an hour . . . probably for the first few minutes I would like to have something intense but then the whole kind of getting your mind off it would probably be something that I would prefer . . . not something so intense and so action packed. (Participant 10; interview)

How participants chose to apply music-video to their exercise regimes was also a seminal factor. Interviewees explained that they exercised in synchrony with music-videos: "there was a song that came on and it was perfect for the movement of my legs and after a bit, it was almost as if the song was doing the work" (Participant 4; interview). Equally, they used music in the asynchronous mode: "the [music-] video is in the background providing some sort of distraction from the hideous thing that I am doing" (Participant 3; interview).

Regardless of whether exercisers used the music-videos synchronously or asynchronously, participants suggested that the specific time at which they viewed the music-video, in relation to their workout, influenced their response:

> I think the music has less influence at the start . . . there's a focus on what am I here to achieve today . . . also I don't need any help at that point because I'm hopefully feeling quite energised . . . The further through it I get, the more ragged it becomes and the more I feel the need to borrow "oh someone give me some energy" . . . the influence of the music and the video . . . would go up as the row went along. (Participant 4; interview)

Hence, it appears that music-videos might be most potent when the physiological sensations associated with fatigue become increasingly difficult to ignore.

3.3.2.4 Environmental factors. In contrast to the exercise factors, the environmental factors are primarily governed by the facility staff and are therefore situated on the right-hand side of the model (see Figure 3.2). Environmental factors concern the physical (e.g., size of the facility) and perceived (e.g., corporate image) components of the exercise location and how the music-video channel is set up. Several factors emerged that warrant consideration when displaying a music-video channel in an exercise context. Prominent among these was the notion of accessibility:

> I think there's a lot of places where you can't see anything . . . sometimes you can see okay, sometimes you're either a bit too close or just looking at the side of the screen, and that's not great (Participant 11; interview).

In stark contrast to related studies conducted in a laboratory setting, which often entail contributions from one experimenter and one participant, the exercise facility was replete with opportunities for social interaction with other exercisers:

> If I was doing a 10 km and I was 7 km into it and someone came and sat down next to me, looked over like they do, and started rowing a bit quicker, I would think right,

stuff it, you don't know I've been sat here for half an hour already, watch this and they [the exercise facility] could have been playing anything and I wouldn't have known what it was. (Participant 4; interview)

Accordingly, the findings provided support for the notion that others within the environment have the potential to alter one's perceptions of a music-video channel.

The messages conveyed by a piece of music are perhaps reinforced with the addition of visual stimuli. Therefore, music-videos are a powerful form of media with the potential to influence viewers' beliefs and attitudes. Participant 8 revealed how the notion of body image was important in an exercise context:

Here it's a lot more laid back . . . so something [a music-video] like *Happy*, which isn't preaching a particular body image, there's a huge variety in that, I think it's quite positive for that, and again it goes back to . . . these over-sexualised images on, it's not just music videos, it's everywhere, which I think are quite unhealthy for young people to a certain extent, to say "that's the way you have to be" . . . I don't think just putting out pictures of one particular body shape in that context is particularly healthy because actually you want to get people in the gym who aren't the shape you'd expect to see in a gym, and they would probably get better health benefits than somebody who would go anyway. (interview)

Consequently, it appears that the content of a music-video channel should be congruent with the corporate image of the exercise facility.

3.3.2.5 Temporal factors. The analysis revealed that temporal factors such as the time of day were influential in determining how participants made sense of the music-video channel:

I don't know if there are music-videos without this excessive amount of flesh on show, but I do think the sexism and the nudism was quite inappropriate, now whether that is more appropriate at six at night when people come out from work and it's a different clientele… it probably is. (Participant 3; interview)

Although the content of the channel varied throughout the day, participants indicated that they quickly grew bored of the music-videos if they used the exercise facility at the same time of day throughout the week: "I train at about the same time when I visit the gym. [The exercise facility] just repeats the Top 20 so we see the same videos – it gets boring" (Participant 13, reflective diary). Hence, it appears that facility staff should be mindful to regularly update and refresh the audio-visual stimuli.

3.3.2.6 Relationships between moderators. There are bidirectional relationships among the exerciser, exercise, and environmental moderators. Thus, participants suggested that exercise factors (e.g., modality and intensity) influenced environmental factors (e.g., audio-visual accessibility):

> One [screen] is to your left and you have to sort of look to your left and up and if you're doing the crosstrainer and working hard, particularly in the latter stages, of what is, for me at least, quite a hard exercise programme, if you're yanking your head up and to the left, it's actually really difficult . . . when you're tired, you don't do that, your head tends to drop slightly . . . (Participant 13; interview)

The temporal factors maintain a unidirectional relationship with the exerciser, exercise, and environmental factors. For example, participants' pre-exercise feeling states (i.e., an exerciser factor) differed in accord with the time of day:

> Well considering I exercise early, for me, after the kids have gone to school, the emotional ones really tapped into that feeling of, not quite awake, and that's when you're more emotional I think . . . (Participant 12; interview)

The facility staff were also aware of the interaction among the moderators, such as the degree to which temporal factors influenced the type of exercisers in the facility:

In the mornings we tend to get the older members come in. Some early afternoons you get students, you get people on their lunch breaks and then in the evenings you get all the office workers coming in . . . depending on what you can try and perceive your clientele to be like and what they might be interested in, you can then try and figure out a channel to put on that's specific to them. (Participant 17; interview)

Participants entered the exercise setting with meaning already ascribed to music-videos; this was based on prior exposure (i.e., exerciser factors). Nonetheless, such meanings were influenced by the presence of other exercisers (i.e., environmental factors), before an interpretative process took place (i.e., appraisal of appropriateness) to evaluate the stimuli presented. This is plausible given that participants often evaluated the appropriateness of the stimuli not only in accord with their personal preferences, but also the perceived preferences of other exercisers. For example, an "extremely contentious" (Participant 8; interview) issue with music-videos is that they often contain "a lot of cheap sex . . . and people not wearing very much (Participant 7; interview). Regarding such content, Participant 3 suggested that "if somebody wanted to watch that in their own house, that's fine" (interview). Nonetheless, it appears that within a public facility, the music-video selection process should be influenced by the collective preferences of exercisers.

3.3.3 Effects. The final stage of the developed model depicts the effects that the music-video channel can have on individual exercisers and the facility staff. The analysis revealed that exercising in the presence of a music-video channel could elicit a range of affective, cognitive, and behavioural outcomes. Importantly, such outcomes can be considered to range from "desirable" to "undesirable" based on the degree to which individuals deemed the content to be appropriate. Participant 12 described how music-videos deemed to be inappropriate could elicit undesirable affective states:

What didn't work were videos of live performances, gigs, or just a video of a girl/boy band on a stage in the studio. I found these the opposite of lively, and very often they made me feel flat. I guess I wanted to feel involved physically or emotionally in the video, not as if I were just a member of an audience, be it in the studio or at a concert; this type of video made me feel excluded and deflated. (reflective diary)

Conversely, music-videos that were deemed to be appropriate often led to positive affective states. When the on-screen performers projected such affective states, they would often be reflected by participants:

> She's exuberant and happy . . . there's this sort of happy energy that comes out of her, and it almost feels as if when you're exercising you can steal or borrow some of that . . . there's bits when she's saying, "this isn't what I've signed up to" so there's a feeling that she's trying to take a thing that isn't so great and turn it into a better thing perhaps as part of the song, which is a positive emotion, so all the thing that came out of it said yes and none of them said no. (Participant 4; interview)

The analysis revealed that the music-video channel could facilitate a range of cognitive effects during exercise too, including personal associations, self-talk, and a more dissociative attentional focus. Similar to the affective states elicited by music-videos, participants deemed such cognitive effects to be desirable or undesirable. Hence, participants detailed that the music-videos were "a distraction rather than a help" (Participant 4; interview) *and* a "positive distraction to what I'm doing" (Participant 2; interview). There was evidence to suggest that this might be influenced by one's dominant attentional style:

> I've got friends that actually would find it [music-video] very good and positive, and they would get distracted and do more, some friends that come along and as soon as they start getting out of breath they just stop, but actually if they were watching that, then maybe they would just keep going without thinking. (Participant 9; interview)

Several behavioural effects were evident. Participants explained that appropriate music-videos could help to enhance work output, prolong exercise duration, and regulate the time spent on pieces of equipment: "I used them [music-videos] as a deadline for the time I spent on each area" (Participant 1; reflective diary). Conversely, music-videos that were deemed inappropriate prompted undesirable behavioural effects such as reduced work output:

> [A music-video] would come on that would help me flip into the rhythm I wanted to hit quicker, almost like I could align with it and I think that was a helpful thing. Equally, something that could come on when I got into a good rhythm, and then . . . a ballad again, there's nothing to work with there, absolutely nothing and actually I find myself going slower and slower and slower. (Participant 4; interview)

Another behavioural response to emerge from the ongoing analysis was that of behavioural transference. In response to a music-video that depicted elaborate skyscapes, Participant 12 explained: "I started doing the crosstrainer because it felt quite outdoorsy, I wanted to actually stand up more than being [stationary] on my bike" (interview). Such effects might be attributed to mirror neurons, whereby specific behaviours depicted on-screen were mirrored by exercisers in the facility (Ferrari & Rizzolatti, 2014).

The analysis revealed that the affective, cognitive, and behavioural effects of exercising in the presence of a music-video channel were interactive, whereby one effect (e.g., attentional dissociation) would readily influence another (e.g., a positive affective state):

> [Music-videos made] me feel less concentrated on myself – mentally, in that I used to work through what I had to do that day, etcetera, and physically, in that I was usually concerned with my body and the response to different bike levels. I found that I simply didn't concentrate on myself so much. I somehow felt happier leaving the gym, in that I hadn't simply worked out despite my surroundings, more that I'd worked out amongst others enjoying exercise. I started to see working out at the gym as a more all-round experience . . . it was enough for me to change what I expect to do and get out of the gym from hereon in. (Participant 12; interview)

The data indicated that displaying a music-video channel had a range of implications for the facility staff that can be categorised as logistical, staff related, or member related. Regarding the logistical implications, the facility had to comply with licensing regulations in order to publicly display the channel, which had direct implications for budgeting. Nonetheless, facility staff felt that the benefits of displaying the channel outweighed the associated costs: "It's going to cost to run them . . . but if you don't have a visual motivation in there then people are just kind of looking at themselves running in a mirror" (Participant 14; interview). The choice of digital broadcasting provider was another logistical implication that warranted attention, although having a range of channels wasn't always advantageous:

> It's quite nice to have quite a varied range of what [channels] you want to put on there. However, it then sometimes causes problems because members know what channels you've got . . . it goes back to the whole issue of, they want this and don't want that on. So, yes, it is a nice luxury, because you have that variation, however I think it cause issues sometimes, because then if you didn't have a wide range, you wouldn't have to keep changing it over. (Participant 16; interview)

In addition to the associated logistics, facility staff suggested that an active concern of theirs was staff training. Members of staff were trained in a variety of areas that aided them with the task of running the music-video channel, including establishing a daily routine, conducting a review process, and understanding how to resolve conflict. Moreover, staff members took a range of precautions to ensure the health and safety of patrons and fellow staff:

> I don't think gyms should have absolute [intensity], as if you're at a rock concert, you know, if it's a class that's different, but I think you know, it's not healthy for the trainer. I don't want to go deaf when I'm 60 [years old]. (Participant 15; interview)

The inclusion of a music-video channel also had implications for staff with regard to facility members. For example, the following participant explained that the music-video channel had the potential to enhance the gym experience:

> If I was sitting here and somebody said "well, you know, we have our own music-video channel that has been specifically researched and it has particular music for particular times of the day, so if you're here at 9.00 am it's feel-good music but if you're here at 5.00 pm it's de-wind after your stressful day at work music", I mean that actually sounds quite cool. (Participant 3; interview)

The findings pertaining to the implications for facility staff suggest that displaying a music-video channel in an exercise facility is not simply a case of switching on several television screens. There are abundant implications that require careful consideration if music-videos channels are to be used effectively within a social exercise context.

3.3.3.1 Social interaction. The effects of the music-video channel had the potential to prompt social interaction between individual exercisers and facility staff. When exercisers appraised the content of the music-video channel as inappropriate and experienced undesirable effects (e.g., negative affective states), social interaction would follow: "Oh, they [exercisers] would tell us [staff members] if there was something [music-video] on which they didn't approve" (Participant 15; interview).

Given the number of factors that are proposed to contribute toward an appraisal of appropriateness (i.e., exerciser, exercise, environmental and temporal), ensuring that every member is always satisfied appeared to be an unrealistic expectation: "I think it's impossible to cater for everyone, you just try and cater for the majority I think, you're never going to please everyone . . . that was the hardest thing I found, moving into my current position" (Participant 14; interview). Bearing this into consideration, some conflict might be *inevitable* in settings where communal television screens are used.

Conversely, when exercisers appraised the content of the music-video channel as appropriate and experienced desirable effects (e.g., attentional dissociation), there was evidence to suggest that participants became more amenable to social interaction:

> I don't really pay much attention to other people and what they're doing, but I became more aware of other gym members simply because we were watching and listening to the same thing . . . I then began to see that there may be other benefits, like treating a gym visit as more of a social event. You could say that it made me feel happier in that regard, and, if a sense of overall wellbeing is tied to what you want from a workout, you could say that was a productive side-effect. (Participant 12; reflective diary)

Participant 12 typically exercised with a personal listening device. Accordingly, it appears that an appropriate music-video channel might prompt individuals to burst their personal "listening bubbles" in order to enjoy exercise alongside others in a social context. This is important, as staff members intonated that the increasing rate at which individuals were engaging with personal technology served to undermine social interaction at the facility:

> I think that we've lost this homely effect, it's like people rather than talk to another person will look at their phone . . . so before it used to be, you know, a bit of a face-to-face chat and a bit of banter, nowadays I notice when someone leaves the gym or even in the gym, they're glued to their phone. (Participant 15; interview)

3.3.3.2 Accommodation. When exercisers experienced undesirable effects in the presence of the music-video channel, they would employ a range of strategies that could facilitate accommodation. The social process of accommodation entails individuals or groups making adjustments to a new situation in order to resolve conflict and promote equilibrium. The strategies that exercisers employed were targeted towards exercise factors, or the music-video channel (see Figure 3.2). With regards to the former, participants indicated that they would change components of their exercise session (e.g., modality, intensity), as expounded by Participant 12:

> The slower ones [music-videos] that were outdoors, made me feel as though I was walking, so that's when I did the crosstrainer, if they were really slow, and yet there was a throbbing kind of beat, I would actually do my weights, and I would do more. (interview)

Exercisers also articulated a range of strategies that enabled them to limit their exposure to the music-video channel, one such strategy being attentional diversion:

> I probably just looked more at what's going on with the machine itself in terms of the speed, the rate, the distance, those sorts of bits I guess . . . sometimes I would just shut my eyes and concentrate more on the breathing . . . just switching off, going into another place in my mind. (Participant 11; interview)

Facility staff employed several accommodation strategies in response to undesirable effects concerning the music-video channel. These strategies were focused on environmental factors or the music-video channel (see Figure 3.2). For example, staff explained that despite having limited space, they used a novel approach to ensure that exercisers could access the music-video channel (i.e., an environmental factor) from most viewing angles:

> . . . it's a quite a long narrow room . . . what we've done there is use mirrors in front of them [pieces of equipment] . . . so that wherever you are, you can see the TV but you're not directly looking at it. (Participant 14; interview)

Equally, members of staff described that they would change the music-video channel if they felt that this would be appreciated by the majority of exercisers present within the facility:

> . . . if someone's gone in there and said "I would like this [channel] changed over" then we would be there while they asked everyone, or we would ask everyone and make sure that they were happy before turning it over. Obviously, if the majority wanted it, then we would go with it, if not, we wouldn't. (Participant 16; interview)

Following the social process of accommodation, exercisers and facility staff would engage in another appraisal of appropriateness with respect to the music-video channel, reflecting the notion that meanings are not permanent; rather, they are subjected to a process of modification and reappraisal (Blumer, 1969).

3.4 Discussion

This study developed a substantive theory that explained and predicted the social process of exercising in the presence of a music-video channel and, allied to this, managing a facility that displays a music-video channel. When viewed through the prism of the extant literature, the present model shares some similarities with conceptual frameworks that delineate the music listening process in exercise contexts (Clark, Baker, & Taylor, 2016b; Karageorghis, 2016). For example, the author found support for a three-stage process that commences with the qualities of the stimuli that are moderated by a range of factors in eliciting a variety of effects. Nonetheless, the substantive theory advances extant literature by offering numerous unique insights at each stage of the model and depicting relevant social processes.

Current conceptual frameworks that address the music listening experience in exercise contexts focus almost exclusively on the exerciser (Clark, Baker, & Taylor, 2016b; Hallett & Lamont, 2015; Karageorghis, 2016). In contrast, the proposed substantive theory advances extant literature by presenting a dual perspective from individual exercisers *and* facility staff. The inclusion of facility staff was not an initial aim of the author's, but a serendipitous addition that occurred while following the trail of emerging concepts within the iterative grounded theory process (Corbin & Strauss, 2015). Theoretically sampling members of staff greatly increased the practical utility of the model (Bryant, 2009) and can be applied by health psychologists as well as exercisers and facility staff.

The substantive theory provides the first exploration into the video and music-video components that are deemed important in an exercise context. Accordingly, researchers are urged to consider properties such as the characters, location, colours, lighting and narrative depicted in the video when selecting music-videos for experimental studies. This would allow researchers to fully justify their selections, as opposed to relying solely on the motivational qualities of music (e.g., Lin & Lu, 2013). It is noteworthy that exercisers reported desirable effects when the visual content enabled them to feel part of the action depicted on-screen. This frequently occurred when the video was shot from a first-person perspective. Although there are more immersive forms of technology available than those used by the exercise facility, the present findings support the notion that exercisers enjoyed music-videos that engendered psychological presence (i.e., the illusion that the audio-visual content represented their primary reality; Bailenson, 2018). Future research might investigate other technologies that are considered more immersive than traditional television screens, such as VR HMDs, to explore the optimal degree of presence in an exercise context.

Visuals depicting movement and characters promoting positive affective states were generally appraised by participants to be appropriate for exercise settings. This could be attributed to a mechanism termed "emotional contagion" (Hatfield, Cacioppo, & Rapson, 1994), wherein individuals "catch" the affective states of others unconsciously and unintentionally. The vocal *and* facial expressions of performers have been theorised as seminal factors in emotional contagion (Juslin, 2013b; Juslin & Västfjäll, 2008). Nonetheless, the substantive theory does not advocate a "one size fits all" approach, whereby one type of video will elicit a similar response for every type of viewer in every context. Rather, this is influenced by a combination of exerciser, exercise, environmental, and temporal factors that are delineated as moderators in the proposed theory. Additional research is required to examine the components that are preferred and under what circumstances, if this line of scientific investigation is to flourish.

Given the predominance of research into the enabling qualities of music, it has been suggested that researchers should consider the degree to which music (and by extension, music-video) can have a deleterious effect (Dibben, 2017). To this end, the proposed model extends our understanding of audio-visual applications in an exercise context by shedding light on the undesirable effects that a music-video channel might elicit when applied in a real-world context. For example, negative affective states were experienced by women owing to the gender inequality evident in some music-videos. In accordance with social comparison theory (Festinger, 1954), it is possible that such affective states were facilitated by upward comparisons to the thin body-type models frequently employed in music-videos (Bell, Lawton, & Dittmar, 2007). Affective responses have been recognised as an important driver of physical activity behaviour (Ekkekakis, Zenko, et al., 2018). Hence, it is imperative that we understand how audio-visual stimuli might contribute toward feelings of pleasure and displeasure if we are to combat the global physical inactivity pandemic.

The present theory offers a fulsome representation of the data that were collected from a specific group and setting (Corbin & Strauss, 2015). Hence, the findings should be interpreted with reference to physically active people. Furthermore, the findings are confined to those exercise facilities that display music-video channels using communal televisions that are managed by members of staff. Future research might seek to examine the experiences of engaging with music-video channels among other populations (e.g., previously inactive people). In addition, more research is needed to examine the range of audio-visual stimuli that is typically on offer within exercise facilities, in order to determine which are the most appropriate. Given that pieces of gym equipment often contain personalised screens with a multitude of channels on offer, this represents a viable and pragmatic direction for future inquiry, which might involve the linking of substantive theories into a more formal grounded theory (Corbin & Strauss, 2015; Weed, 2017).

3.4.1 Practical implications. Perhaps the most significant practical implication to stem from the study concerns the core category of the proposed model. Hence, music-video channels should be chosen according to the degree that they are *appropriate* with respect to exerciser, exercise, environmental, and temporal factors. When the content of a music-video channel is deemed appropriate, the substantive theory predicts that desirable effects will ensue. Conversely, when the content is considered inappropriate, undesirable effects are predicted, leading to the social processes of conflict and accommodation. Hence, facility staff are advised to question whether their environment is conducive to the watching of a music-video channel, seek the audio-visual preferences of their members and be conscious that the collective preferences of their members are likely to change over time (i.e., throughout a single day and over an extended period; Krause & North, 2018). Likewise, exercisers are advised to appreciate that suitable content will vary depending on the components of their exercise (e.g., intensity) and their individual responses (e.g., feeling states), which again, are subject to change over time.

The model can be used to identify the components of a music-video channel that are deemed salient in order to enhance selections in exercise contexts. Exercisers and facility staff are urged to recognise that broadcasters often supplement music-video channels with additional audio-visual stimuli (e.g., celebrity news, adverts), that can be considered superfluous in an exercise context. Moreover, staff members can draw upon the effects depicted by the substantive theory (e.g., logistical) to ensure that they are adequately prepared for the consequences of displaying a music-video channel within their facility.

Algorithms developed by music streaming companies can create personalised playlists for subscribers. However, this has not been attempted within group exercise contexts. In the near future, it is plausible that algorithms will be capable of ingesting music-video metadata and weighing each of the proposed moderators in order to optimise the selection process. In practice, this might result in automatic volume control during peak times to counter the noise of equipment, tailoring selections to match exercise modalities, and accommodating for the exercisers' seasonal preferences (Krause & North, 2018). Automating the selection process might lead to a reduction in potential conflict and thus enhance the exercise experience.

3.4.2 Strengths and limitations. This is the first study in the exercise sciences literature to examine how music-videos are presented to exercisers outside of a laboratory setting. Moreover, the author sought to recruit participants from across the lifespan (cf. Chow & Etnier, 2017). Indeed, the posters used at the facility and inclusion criteria also resulted in the recruitment of participants with varying opinions regarding music-video channels (i.e., some liked them while others disliked them). Accordingly, a strength of Study 1 pertains to the high degree of external validity when compared to previous research that has investigated the effects of music-videos in an exercise context (Bird et al., 2016; Lin & Lu, 2013). Finally, the authors strived to demonstrate "methodological coherence" (Holt & Tamminen, 2010b) in terms of their philosophical orientation, research question, participants, and methods; something that has been rarely achieved in this literature (Weed, 2017).

In terms of limitations, it could be argued that asking a range of exercisers to complete diary sheets over a 4-week period at once does not adhere strictly adhere to theoretical sampling. However, it is important to note that theoretical sampling involves collecting data, raising questions about concepts, and using such questions as a guide for what incidents to look out for within the next set of data, as opposed to simply recruiting new participants (Corbin & Strauss, 2015). The facility reverted back to their original audio-visual selections after the 6-week period of displaying the music-video channel. Hence, the retrospective nature of the interviews might have impacted upon the quality of the findings. In an attempt to mitigate this, participants were shown their selected music-videos prior to interview and had their diary sheets in order to facilitate information recall. The facility had a small selection of music-video channels from which staff members could choose, none of which were curated specifically for the exercise context. Nonetheless, this limitation applies to every current digital broadcasting provider in the UK, none of which showcase a music-video channel dedicated to the exercise context.

The reader can apply the concepts of fit, work, relevance, and modifiability when evaluating the quality of the present findings (Weed, 2017). Moreover, they can draw upon the criterion postulated by Corbin and Strauss (e.g., evidence of context and process; 2015). In accordance with the pragmatist notion that all knowledge is provisional, the reader is also encouraged to apply the "difference principle" (Bryant, 2009). That is, to consider the extent to which the substantive theory functions as a useful tool and offers practical solutions relating to the use of music-video channels in an exercise context.

3.5 Conclusions

The objective of this study was to develop a substantive theory that explained and predicted the social process of exercising in the presence of a music-video channel and managing an exercise facility that displays such a channel. Data derived from reflective diaries and semi-structured interviews were analysed and integrated to construct a substantive theory of the studied phenomena (see Figure 3.2). The findings suggest that the role of a music-video channel in an exercise context is more complex than previously thought and one that has the potential to cause conflict if implemented inappropriately. Accordingly, music-video channels can be likened to a swinging pendulum that has the potential to facilitate a range of both desirable and undesirable outcomes for those in the social environment (i.e., exercisers and facility staff). In order to maximise the likelihood of desirable effects, careful consideration should be given to the specific components of music-video channels and the degree to which they are appropriate to relevant exerciser, exercise, environmental, and temporal factors. Given the increasing prevalence of music-video channels in exercise settings as well as a conspicuous lack of conceptual frameworks, the substantive theory provides a useful reference point.

Chapter 4: Effects of Music, Video, and 360-Degree Video on Cycle Ergometer Exercise at the Ventilatory Threshold

Study 2 has been accepted for publication in the *Scandinavian Journal of Medicine & Science in Sports* (see section titled Publications by the Author During the PhD Programme)

4.1 Introduction

Engagement in physical activity is fundamental to the prevention of numerous chronic diseases, such as heart disease, type 2 diabetes, and some cancers (American College of Sports Medicine, 2018). The benefits of physical activity are so widely documented that the WHO's Global Action Plan for the Prevention and Control of Non-Communicable Diseases includes the target to reduce physical inactivity by 10% by 2025 (World Health Organization, 2013). Unfortunately, progress toward this goal appears to be significantly off track (Foster, Shilton, Westerman, Varney, & Bull, 2018). Researchers using self-report data estimate that 23.3% of the adult population fails to achieve 150 min of moderate-intensity activity or 75 min of vigorous-intensity activity per week (Sallis et al., 2016). However, the severity of physical inactivity is often underestimated when predicated on self-report data when compared to objective assessments using accelerometer data (Ekkekakis & Zenko, 2016a). Hence, there is a strong need for interventions that aim to enhance physical activity among the general population.

For the past 50 years, the dominant metatheoretical perspective within exercise psychology has been the cognitive paradigm. Theories based on this paradigm adhere to the rational-educational model wherein individuals are viewed as rational thinkers who collect, interpret, and reliably act upon information that serves their greatest self-interest (Ekkekakis, 2017). Any instances of irrational behaviour are proposed to be corrected by supplying the individual with more accurate information concerning the consequences of her/his behaviour (Ekkekakis & Zenko, 2016a). However, it appears that individuals understand the benefits associated with physical activity that are emphasised by public health campaigns and yet still choose to refrain from engagement in physical activity. Therefore, the field of exercise psychology faces a “paradigmatic crisis” wherein current theoretical models are misaligned with available data (Ekkekakis, 2017).

4.1.1 Dual-process models. Researchers are beginning to conceptualise physical activity and exercise behaviour using dual-process models. It is acknowledged that individuals often behave in ways that do not serve their self-interests (Ekkekakis & Zenko, 2016a). Dual-process models hold that behavioural decision making is founded upon two main processes. Type 2 processes reflect those that are postulated by current cognitive theories; they are slow, reflective, and require deliberate contemplation of available information. On the other hand, Type 1 processes are primitive, automatic, and intuitive. Such processes are governed by heuristics, which are simplified rules that allow individuals to make decisions quickly (i.e., bounded-rationality; Zenko, Ekkekakis, & Kavetsos, 2016).

The affect heuristic has been proposed to be an essential component of physical activity behaviour (Ekkekakis, 2017). Based on the hedonic principle (Kahneman, 1999), the affect heuristic reflects the notion that individuals are likely to gravitate toward behaviours that result in pleasure and avoid those behaviours that result in pain (Williams et al., 2016). Physical activity holds a precarious position that has the potential to cause conflict between Type 1 and Type 2 processes (Ekkekakis, 2017). Individuals are aware of the numerous health benefits associated with physical activity (via Type 2 processes). Nonetheless, many individuals’ affective reactions at the time of decision making contain a negative hedonic tone (via Type 1 processes), owing to a history of experienced discomfort associated with physical activity (e.g., muscle acidosis, laboured breathing). The automaticity of Type 1 processes has the capacity to override the more rational decision-making process that underlies Type 2 processes. This ultimately results in individuals refraining to engage in physical activity.

4.1.2 Dual-Mode Theory. Affect is defined as "a neurophysiological state consciously accessible as a simple primitive nonreflective feeling most evident in mood and emotion but always available to consciousness" (Russell & Feldman Barrett, 2009, p. 104). Moreover, affect is conceptualised as a dimensional domain, comprised of two orthogonal and bipolar dimensions, affective valence (ranging from pleasure to displeasure) and perceived activation (commonly referred to as "arousal"). Researchers have drawn upon the intensity of exercise to help explain the variance observed in affective responses across individuals. An underlying premise of the DMT (Ekkekakis, 2003) is that exercise intensity should be defined in accord with fixed metabolic markers such as the VT and RCP, both of which are associated with several physiological changes (e.g., increased respiration rate and carbon dioxide production [$\dot{V}CO_2$]).

According to the theory, affective responses below VT (i.e., low-to-moderate intensities) are primarily driven by cognitive factors and are largely pleasurable. Affective responses to exercise proximal to VT (i.e., heavy intensities) are associated with the most interindividual variability, with some individuals experiencing an increase in pleasure and others a decrease in pleasure. At intensities beyond the RCP (i.e., severe intensities), interoceptive cues gain salience and there is a near universal decline in pleasure, as a physiological steady state becomes impossible to maintain (Ekkekakis, 2003). Moreover, upon cessation of strenuous exercise that induces a decrease in pleasure, a rapid rebound toward pleasure is expected to occur (Ekkekakis, 2013a). Measuring affective responses throughout the entire exercise bout (i.e., pre-, during-, and post-exercise) is advisable given that hedonically significant experiences extend over time (Kahneman, 1999). Focusing on affective constructs when designing interventions to promote physical activity may hold promise (Rhodes & Kates, 2015), although it has been suggested that there is a paucity of information regarding how we can achieve this in practice (Zenko, Ekkekakis, & Ariely, 2016).

4.1.3 Enhancing affective responses to exercise with audio-visual stimuli. One possible strategy for enhancing affective responses concerns the addition of audio-visual stimuli within the exercise environment. A substantial body of research has demonstrated that music can facilitate positive affective responses to exercise and physical activity across several modalities including cycle ergometry (Carlier & Delevoye-Turrell, 2017), treadmill running (Hutchinson, Jones, et al., 2018) and self-paced walking (Bigliassi, Karageorghis, et al., 2019). A mechanism proposed to underlie these findings concerns attentional dissociation, which refers to the way in which music can divert attention away from the unpleasant somatic sensations associated with strenuous exercise (Karageorghis et al., 2017).

Building upon the theoretical premise that greater attentional dissociation might yield more positive affective responses to exercise, investigators have examined the influence of audio and visual stimuli in combination. This represents an ecologically valid form of scientific inquiry, as audio-visual stimuli have become almost ubiquitous within modern-day exercise facilities. A range of stimuli have been employed by researchers including music-videos (Hutchinson, Karageorghis, & Black, 2017), movie footage (Bigliassi, Silva, et al., 2016), sporting highlights (Barwood et al., 2009) and even circus performances (Chow & Etnier, 2017).

The first original study in the present programme of research (see Chapter 3) employed Corbin and Strauss's (2015) variant of grounded theory in order to explain and predict the social process of exercising in the presence of a music-video channel. A substantive theory was proposed (see Figure 3.2) that commenced with the content of the music-video channel (e.g., tempo, characters). Thereafter, a series of moderators (e.g., exercise modality, audio-visual accessibility) is depicted before a range of effects on individual exercisers and facility staff is predicted. The core category of the substantive theory pertained to an appraisal of appropriateness with respect to the content of the music-video channel. Interestingly, participants indicated that music-videos filmed from a first-person perspective were deemed particularly appropriate in an exercise context, as they facilitated the perceptual illusion that participants were part of the action depicted on-screen.

Researchers have examined the impact of immersive first-person videos on affective responses to exercise. For example, an innovative approach was adopted by Jones et al. (2014), who used rural parkland-based video footage filmed from a cyclist's point of view. The researchers found that music-only and music-video conditions could yield more positive affective responses to exercise at intensities 10% below and 5% above VT compared to video-only and control conditions. Jones et al. (2014) attempted to create an immersive environment by projecting video footage onto a large screen placed in front of participants. The researchers concluded that a fruitful direction for future research concerns the degree of immersion required to optimise the effects of audio-visual stimuli on exercise-related affect.

4.1.4 Immersion and presence. The term immersion refers to the technical capabilities of a system to afford the individual to perceive through natural sensorimotor contingencies (Slater & Sanchez-Vives, 2016). That is, to be able to perceive the stimuli in a natural way. Hence, it is possible to place systems on a continuum according to the degree of immersion that they confer. One type of system that has the potential to engender higher degrees of immersion when compared to video projection (e.g., Jones et al., 2014) is a VR HMD. This has the capacity to subject individuals to a range of audio-visual content (e.g., 360-degree videos, virtual environments). VR HMDs are considered immersive because they occlude the individual from physical reality (i.e., are inclusive), accommodate a range of senses (i.e., are extensive), offer panoramic environments (i.e., surround the participant), and comprise high-resolution displays (i.e., are vivid; Bailey & Bailenson, 2017; Slater & Wilbur, 1997). A correlate of immersion is presence, which refers to the sense of being in the virtual environment, despite the fact that you know that you are not actually there (Cummings & Bailenson, 2016; Slater & Sanchez-Vives, 2016).

4.1.5 Virtual reality empirical research. Researchers from the realm of medicine have employed VR technology to assist in the treatment of chronic and procedural pain for some time. For example, Schmitt et al. (2011) examined the effectiveness of a virtual environment depicting a wintery scene on burn outpatients' pain ratings. Participants reported significant reductions in pain of 27–44% and elevated levels of "fun" when undertaking physical therapy with VR accompaniment. Using a randomised controlled trial, Gold and Mahrer (2018) found that VR could significantly reduce procedural pain and anxiety associated with blood draw in children when compared to the standard of care. Moreover, Tashjian et al. (2017) reported that a VR experience could significantly reduce inpatients' pain ratings when compared to a 2D video control condition.

The findings above indicate that VR represents a useful technology to distract individuals from the sensation of pain. A related but distinct sensation pertains to exercise-related discomfort, which is expected to occur at most exercise intensities. Accordingly, it is plausible that the aforementioned findings could translate to an exercise context. Nonetheless, research employing VR in an exercise context is scant. A study by Zeng, Pope, and Gao (2017) provides a notable exception: They investigated the physiological and psychological effects of exercising on a VR-enabled cycle ergometer compared to a traditional cycle ergometer. The results indicated that higher self-efficacy and enjoyment scores were reported in the VR condition when compared to the traditional cycle ergometer condition. Participants also reported significantly lower RPE in the VR condition, indicating that VR-mediated exercise might offer a useful means of encouraging attentional dissociation.

There were, however, some notable limitations evident in the Zeng et al. (2017) study. Foremost among these, the researchers employed one exercise intensity in the VR condition, as opposed to defining intensity according to a fixed metabolic marker, such as VT (Ekkekakis, 2003). In addition, participants were able to listen to music or watch videos during the traditional cycle ergometer condition, although the precise nature of these stimuli was not delineated. Hence, there appears to be considerable scope to examine the effects of audio-visual stimuli delivered via VR HMDs during exercise while accounting for the aforementioned limitations.

4.1.6 Aims and hypotheses. Using the substantive theory proposed in Study 1 as a lodestar (see Figure 3.2), the present study sought to examine the effects of appropriate audio-visual stimuli delivered via immersive VR technology. The study is predicated on the notion that a dissociative manipulation of attentional focus through the application of music, video, music-video, 360-degree video, and 360-degree video with music would be reflected in participants' subjective ratings of affect (i.e., affective valence and perceived activation), attentional focus, RPE, and perceived enjoyment, all of which are concepts derived from the substantive theory proposed in Study 1 (see Figure 3.2). Accordingly, the aim was to examine the influence of a range of audio-visual stimuli on affective and perceptual responses to exercise at the VT; an intensity that is associated with the most affect-related interindividual variability (Ekkekakis, 2013a).

It was hypothesised that conditions containing 360-degree video would facilitate the most positive affective valence and highest perceived activation. Moreover, it was expected that music-video, music, and video conditions would elicit more positive affective valence and higher perceived activation when compared to the control condition (H_1). Furthermore, it was predicted that the control condition would prompt the greatest "affective rebound", owing to participants' less positive in-task affective state (H_2). It was expected that conditions containing 360-degree video to elicit the most dissociative thoughts and lowest RPE. In addition, it was hypothesised that music-video, music, and video conditions would prompt more dissociative thoughts and lower RPE when compared to the control condition (H_3). Finally, it was expected conditions containing 360-degree video to facilitate the greatest perceived enjoyment. It was also predicted that music-video, music, and video conditions would prompt greater perceived enjoyment when compared to control (H_4).

4.2 Methodology

This study was approved by the Brunel University London Ethics Committee (see Appendix L) and all participants provided written informed consent (see Appendix M). The substantive theory proposed in Study 1 predicted that a range of exerciser factors influence an individual's response to audio-visual stimuli (see Figure 3.2). Accordingly, participants were homogenous in terms of age (i.e., 18–31 years), ethnicity (i.e., White British), and sociocultural background (i.e., formative years spent in the UK) at each stage of the present study. None of the participants reported any form of hearing deficiency and/or visual impairment.

4.2.1 Music selection. A sample of 42 University of Gloucestershire and Brunel University London students (M_{age} = 21.6, SD = 1.9 years) were used to identify possible music selections that could be administered during the experimental phase of the study. Given that responses to music during exercise are influenced by situational factors (e.g., exercise/training location, mode/intensity of exercise; Karageorghis, 2017) participants were instructed to specify up to five pieces of music that they considered motivational for high-intensity, indoor cycling (i.e., the intensity and exercise modality for the experimental phase). A total of 181 tracks were ranked by tempo and 15 tracks that were at an appropriate tempo for high-intensity indoor cycling (i.e., 135–145 bpm; Karageorghis, 2017) were subjected to further testing.

The 15 appropriate tracks were legally downloaded from Apple iTunes (Apple Inc., California). A purposively selected sample of 10 exercise science undergraduates at the University of Gloucestershire (M_{age} = 19.1, SD = 0.6 years) rated the motivational qualities of each track using the BMRI-3 (Karageorghis, 2017; see Appendix N). Participants were instructed to rate the music with reference to high-intensity, indoor cycling. The rating procedure ensured that the tracks used during the experimental phase were homogenous in terms of their motivational qualities (Karageorghis, Priest, et al., 2006). The final track selection was aided by the qualitative guidelines of Karageorghis et al. (2006) and three tracks with similar motivational qualities were chosen for use during the experimental phase (see Table 4.1). GarageBand (Apple Inc., California) software was used to segue the selections into a coherent playlist that lasted for 10 min.

4.2.2 Video selection. The findings from Study 1 (see Chapter 3) indicated that participants enjoyed exercising in the presence of music-videos that depicted movement. Accordingly, video footage that depicted the exercise modality under investigation was employed (i.e., cycle ergometry). The author perused *YouTube* to source monoscopic 360-degree videos. Specifically, he searched for “Cycling 360” and filtered the search results by (a) Video Duration – Long (> 20 min) and (b) Features – 4K Resolution and 360-degree. Subsequently, the author viewed 15 videos and selected one according to (a) recording factors (e.g., camera stability) and (b) the footage characteristics (e.g., minimal changes in elevation and cornering, traffic-free roads). The selected video was shown to the aforementioned sample of 10 exercise science undergraduates at the University of Gloucestershire (M_{age} = 19.1, SD = 0.6 years). The core category of the substantive theory proposed in Study 1 served to emphasise the importance of displaying audio-visual stimuli that are deemed appropriate in an exercise context (see Figure 3.2). Hence, the sample were asked to indicate the extent of their agreement that the video was appropriate for high-intensity indoor cycling by use of a 5-point scale anchored by 1 (*strongly disagree*) and 5 (*strongly agree*; Jones et al., 2014). Nine of the ten respondents indicated that they agreed or strongly agreed that the video was appropriate for high-intensity indoor cycling.

Table 4.1

Details of the Music Selections Used in Experimental Conditions

Artist	The Killers	Paramore	Iggy Azalea
Track title	Human	Still Into You	Work
Album	Day & Age	Paramore	The New Classic
Sound Recording Copyright ℗	2008 The Island Def Jam Music Group	2013 Atlantic Recording Corporation and WEA International Inc.	2014 Virgin EMI Records, a division of Universal Music Operations Ltd.
Tempo (bpm)	135	136	140
BMRI-3 Score (*M*)	28.4	24.9	26.3

4.2.3 Experimental investigation.

4.2.3.1 Power analysis. A power analysis was conducted using the software G*Power 3 to establish a suitable sample size for a repeated-measures (RM), within-subjects, multivariate analysis of variance (MANOVA; Faul, Erdfelder, Buchner, & Lang, 2009). This analysis was predicated on a large effect size for a Condition × Time interaction for affective valence reported by Hutchinson et al. ($\eta_p^2 = .30$; 2015) and indicated that 18 participants would be required ($\alpha = .05$; $1 - \beta = .80$; Cohen, 1988).

4.2.3.2 Participants. A convenience sample of 18 adult volunteers was recruited for the experimental phase of the study (9 women and 9 men; $M_{\text{age}} = 24.17$, $SD = 4.23$ years; $M_{\text{BMI}} = 22.98$, $SD = 3.05$ kg m^{-2}; $M\dot{V}O_{2\text{peak}} = 37.07$, $SD = 6.36$ ml kg^{-1} min^{-1}). Recruitment was conducted through word-of-mouth and aided by means of promotional posters at the University of Gloucestershire (see Appendix O). Participants were deemed eligible to engage in exercise, according to the Physical Activity Readiness Questionnaire (PAR-Q; Warburton et al., 2011; see Appendix P). Participants were familiar with cycle ergometry, the selected exercise modality for Study 2.

4.2.3.3 Apparatus and measures. An electronically-braked cycle ergometer (Lode Excalibur Sport; Groningen, Netherlands) was used for the pre-test and during all experimental trials. In addition, a VR HMD (Samsung Gear VR; Suwon, the Republic of Korea), smartphone (Samsung S8; Suwon, the Republic of Korea), laptop (Apple MacBook Pro; Apple Inc., California), and wireless headphones (AfterShokz Trekz Titanium; Cheshire, UK) were used during the experimental trials to deliver the audio-visual stimuli (see Figure 4.1). Music intensity was standardised at ~70 dBA.

Figure 4.1. Experimental set-up with the VR HMD during Study 2.

On the basis that affect is conceptualised as a dimensional domain, affective valence was assessed using the FS (Hardy & Rejeski, 1989; see Appendix Q) and perceived activation was measured using the FAS (Svebak & Murgatroyd, 1985; see Appendix R). The FS is a single-item, 11-point scale anchored by -5 ([*I feel*] *very bad*) and 5 (*very good*). The FAS is a single-item, 6-point scale anchored by 1 (*low arousal*) and 6 (*high arousal*). RPE was assessed using the Borg CR10 Scale (Borg, 1998; see Appendix S), which is anchored by 0 (*nothing at all*) and 10 (*extremely strong*). Attentional focus was measured using

Tammen's (1996) Attention Scale (AS; see Appendix T), which is anchored by 0 (*Internal focus* [*bodily sensations, heart rate, breathing, etc.*] and 100 (*External focus* [*daydreaming, external environment, etc.*]. Perceived enjoyment was assessed post-exercise using the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991; see Appendix U). This scale includes 18 items attached to 7-point bipolar scales (e.g., 1 = *I enjoy it,* 7 = *I hate it* [item 1]).

4.2.3.4 Pre-test and habituation. During this session, the particulars of the study were discussed (see Appendix V), anthropometric data were collected, participants were habituated to the VR HMD, and peak aerobic capacity and VT were determined. After each participant had confirmed their eligibility for the study (see Appendix W) and provided written informed consent (see Appendix M), height, weight, and resting HR were measured. Each participant was then introduced to the psychometric scales that were to be administered during the experimental trials. Thereafter, the participant was granted an opportunity to habituate her-/himself with the VR HMD. After becoming comfortable wearing and adjusting the device, the participant was instructed to complete the experience *Introduction to Virtual Reality* (Oculus, California), which is designed to gradually acquaint users with the key concepts of VR.

The participant was then required to remove the VR HMD in order to complete a maximal exercise test on the cycle ergometer. For this purpose, s/he was fitted with a mouthpiece that was connected to a metabolic cart (Ultima Series CardiO_2, MGC Diagnostics, Minnesota). The flow sensor and gas were calibrated prior to each maximal exercise test in order to facilitate accurate measurement of $\dot{V}O_2$ and $\dot{V}CO_2$. After a 2-min warm-up (0 W), the workload was increased to 60 W and thereafter, increased by 25 W per min in a ramp fashion. Upon reaching volitional exhaustion, the mouthpiece was removed from the participant and s/he completed a 5-min warm-down (0 W). VT was later determined by use of the V-slope protocol (Beaver, Wasserman, & Whipp, 1986). This entailed plotting

$\dot{V}CO_2$ by $\dot{V}O_2$ data in Microsoft Excel and dividing it into two segments, each of which were fitted with a linear regression. The location of the intersection between the two regression lines was then calculated. Thereafter, the author identified the pair of regression lines that maximised the ratio of the distance of the intersection point from a single regression line of the data to the mean square error of regression. The solution was accepted as VT if the change in slope from the lower to the upper segment was > 0.1 (Beaver et al., 1986).

4.2.3.5 Experimental trials. A within-subjects design was adopted, and experimental testing took place at least 48 hr after the pre-test. There were five experimental conditions (music, video, music-video, 360-degree video, and 360-degree video with music) and one control condition (no music and/or video). In the music condition, participants were exposed to the 10-min playlist while in a visually sterile environment. In the video condition, participants were exposed to the cycling video by means of an Internet browser on a laptop that inhibited the function to navigate the scene in 360-degrees. In the music and video condition, participants viewed the cycling video on a laptop and listened to the 10-min music playlist via headphones. In the 360-degree video condition, participants were administered the cycling video using a smartphone-powered VR HMD. The 360-degree video with music condition entailed viewing the cycling video through the VR HMD while being exposed to the 10-min music playlist. In the control condition, participants were not exposed to music or video footage. Moreover, the participant's eyes and ears were not occluded in order to maintain ecological validity (Jones et al., 2014).

Participants were required wear a HR monitor during each testing session and participation in each condition lasted a total of 25 min. The FS and FAS were administered following a 2-min period of seated rest (i.e., 0–2 min) and subsequently used as baseline values for core affect. Thereafter, participants were required to maintain a cadence of 75 ± 3 rpm on the cycle ergometer, commencing with a 5-min warm-up (0 W; i.e., 2–7 min). The appropriate resistance was then applied to correspond with each participant's VT. The exercise bout lasted for 10 min (i.e., 7–17 min) and the FS, FAS, AS, and Borg CR10 Scale were administered after 10, 13, and 16 min of each condition.

Once the participant had completed the exercise bout, the wattage of the cycle ergometer was lowered to zero and the participant completed a 5-min warm-down (i.e., 17–22 min) before dismounting. The FS and FAS were administered post-exercise after 19, 22, and 25 min of each condition, during which time participants were required to remain in a seated position. Moreover, perceived enjoyment was assessed using the PACES upon completion of the warm-down. Participants completed two conditions separated by a rest period upon each visit to the laboratory (see Figure 4.2). Before commencing the second condition, the participant's HR was required to descend to within 10% of her/his resting value. The order of conditions was randomised to limit learning and order effects. However, it was not possible to fully counterbalance the design, owing to the number of conditions that were included (720 participants would have been required). Each participant visited the laboratory on four occasions (one pre-test/habituation session and three testing sessions). Given that temporal factors are predicted to moderate the effects of audio-visual stimuli in an exercise context (see Figure 3.2), the experimental trials were scheduled at the same time of day for each participant over a 4-week period, with a minimum of 72 hr between trials.

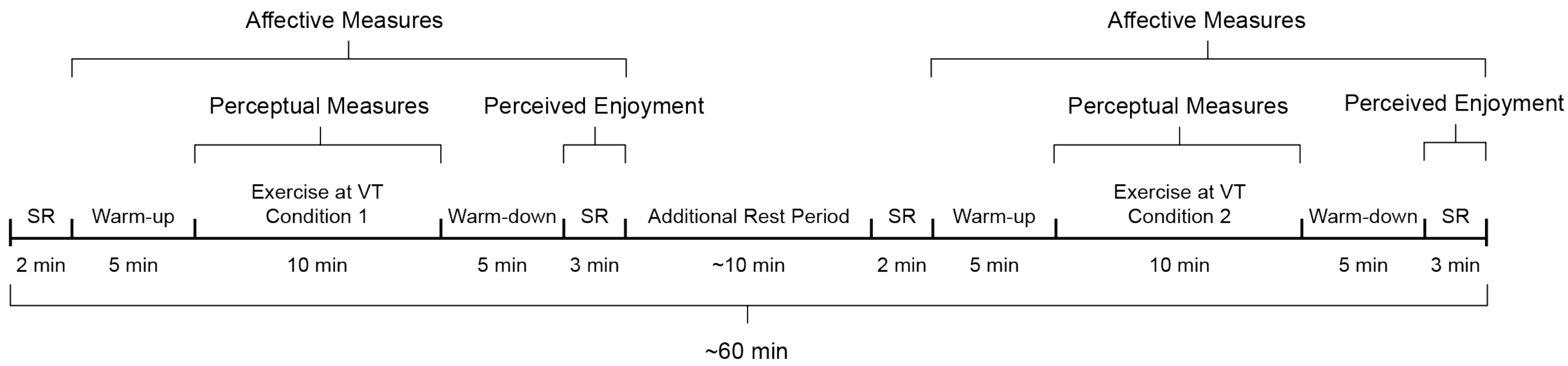

Figure 4.2. Diagrammatic representation of experimental procedures for each testing session during Study 2. *Note.* SR = seated rest; VT = ventilatory threshold. Conditions were randomised.

4.2.4 Data analysis. Data were screened for univariate outliers through use of standardised *z*-scores (i.e., $z > \pm 3.29$; Tabachnick & Fidell, 2018) and multivariate outliers using the Mahalanobis's distance test with $p < .001$. Moreover, data were examined for the parametric assumptions that underlie analysis of variance (ANOVA) and MANOVA (Tabachnick & Fidell, 2018). Where variables were theoretically linked, MANOVA were applied to reduce the influence of experimentwise error. Affective variables (affective valence and perceived activation) were assessed using a 6 (Condition) × 7 (Time) MANOVA. Perceptual variables (RPE and attentional focus) were assessed using a 6 (Condition) × 3 (Time) MANOVA. Perceived enjoyment was assessed using a oneway, RM ANOVA. An assessment of whether scores on the affective variables and perceived enjoyment varied as a consequence of exercise trial number. This was achieved through calculating the mean of each variable, regardless of condition, and running a RM MANOVA for the affective variables, and RM ANOVA for perceived enjoyment.

Greenhouse-Geisser adjustments were made to *F* tests in instances where the sphericity assumption was violated. Where the *F* ratio was significant, Bonferroni-adjusted pairwise comparisons or checks of standard errors (*SE*) were employed to determine where differences lay. Effect sizes were calculated using partial eta squared (η_p^2). Significance was accepted at $p < .05$ for all analyses and exact *p*-values are reported unless $p < .001$.

4.3 Results

Prior to the main analyses, univariate outlier tests revealed three outliers ($z > \pm 3.29$) and in all instances, the score was adjusted by assigning the outlying cases a raw score on the offending variable that was one unit larger (or smaller) than the next most extreme score in the distribution until $z < \pm 3.29$ (Tabachnick & Fidell, 2018). No multivariate outliers were identified. Tests of the distributional properties of the data in each cell of the analysis revealed violations of normality in 41 of the 126 cells (14 at $p < .05$, 11 at $p < .01$, and 16 at $p < .001$). Further testing revealed that 39 of the aforementioned violations of normality were associated with the affective variables (i.e., affective valence and perceived activation). However, the *F* test is sufficiently robust to withstand such violation (Tabachnick & Fidell, 2018). Moreover, concern has been expressed regarding transformation of subjective data derived from Likert scales (Nevill & Lane, 2007). Accordingly, it was decided not to transform these data and the results pertaining to the affective variables should be interpreted with these violations in mind. Tests of affective variables and perceived enjoyment across exercise trials indicated that there was only a difference between trial 1 and trial 5 for perceived activation (p = .020, 95% CI [0.05, 0.86]; see Table 4.2).

Table 4.2

Descriptive and Inferential Statistics for Affective Valence, Perceived Activation, and Perceived Enjoyment Across Exercise Trials

	Trial 1		Trial 2		Trial 3		Trial 4		Trial 5		Trial 6	
Dependent Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Affective Valence	3.55	0.92	3.45	1.00	3.52	0.87	3.37	0.82	3.81	0.70	3.33	0.99
Perceived Activation	2.48	0.55	2.33	0.72	2.26	0.54	2.17	0.54	2.03	0.51	2.10	0.54
Perceived Enjoyment	93.61	18.70	94.61	22.14	93.22	14.00	91.78	16.83	93.78	12.37	85.89	19.11

	Pillai's Trace	*F*	*df*	*p*	η_p^2
Affective Variables					
Trial	.310	3.12	10, 170	.001	.16
Affective Valence	–	1.49	3, 53	.227	.08
Perceived Activation	–	4.69	3, 58	.004	.22
Perceived Enjoyment					
Trial	–	1.28	5, 85	.280	.07

4.3.1 Affective variables. The omnibus analysis revealed a significant Condition × Time interaction that applied only to perceived activation (p = .019, η_p^2 = .12; see Table 4.3 and Figure 4.3a) and was associated with a moderate-to-large effect size. Conditions that contained 360-degree video (i.e., 360-degree video and 360-degree video with music) elicited significantly higher perceived activation during the exercise bout (i.e., after 10, 13, and 16 min) when compared to the control condition. Moreover, all experimental conditions elicited higher perceived activation after 13 min when compared to control. These effects did not continue beyond the exercise bout, as no significant differences were found across conditions during the warm-down and post-task phases (see Figure 4.3a).

There was a main effect of condition that applied only to perceived activation (p = .003, η_p^2 = .19; Table 4.3) and was associated with a large effect size. Pairwise comparisons indicated that perceived activation was significantly higher for 360-degree video with music when compared to control (p = .011, 95% CI [0.07, 0.78]) and music conditions (p = .048, 95% CI [0.01, 0.62]). There was a main effect of time for both affective valence (p < .001, η_p^2 = .61) and perceived activation (p < .001, η_p^2 = .82), both associated with a large effect size. Affective valence scores decreased incrementally throughout the exercise bout and then increased immediately following cessation of exercise. Pairwise comparisons revealed that affective valence was significantly higher during the warm-down (i.e., after 19 min) compared to the end of the exercise bout (p = .002, 95% CI [0.26, 1.51]). Moreover, affective valence scores were significantly higher following a 3-min period of seated rest post-exercise (i.e., after 25 min) compared to the end of the warm-down (p = .045, 95% CI [0.00, 0.57]. Perceived activation scores increased incrementally throughout the exercise bout and subsequently decreased post-exercise. Pairwise comparisons indicated that perceived activation was significantly higher during the start of the exercise bout (i.e., after 10 min) when compared to baseline (p < .001, 95% CI [0.77, 1.43]). Moreover, perceived activation was significantly lower during the warm-down when compared to the end of the exercise bout ($p < .001$, 95% CI [-1.56, -0.68]).

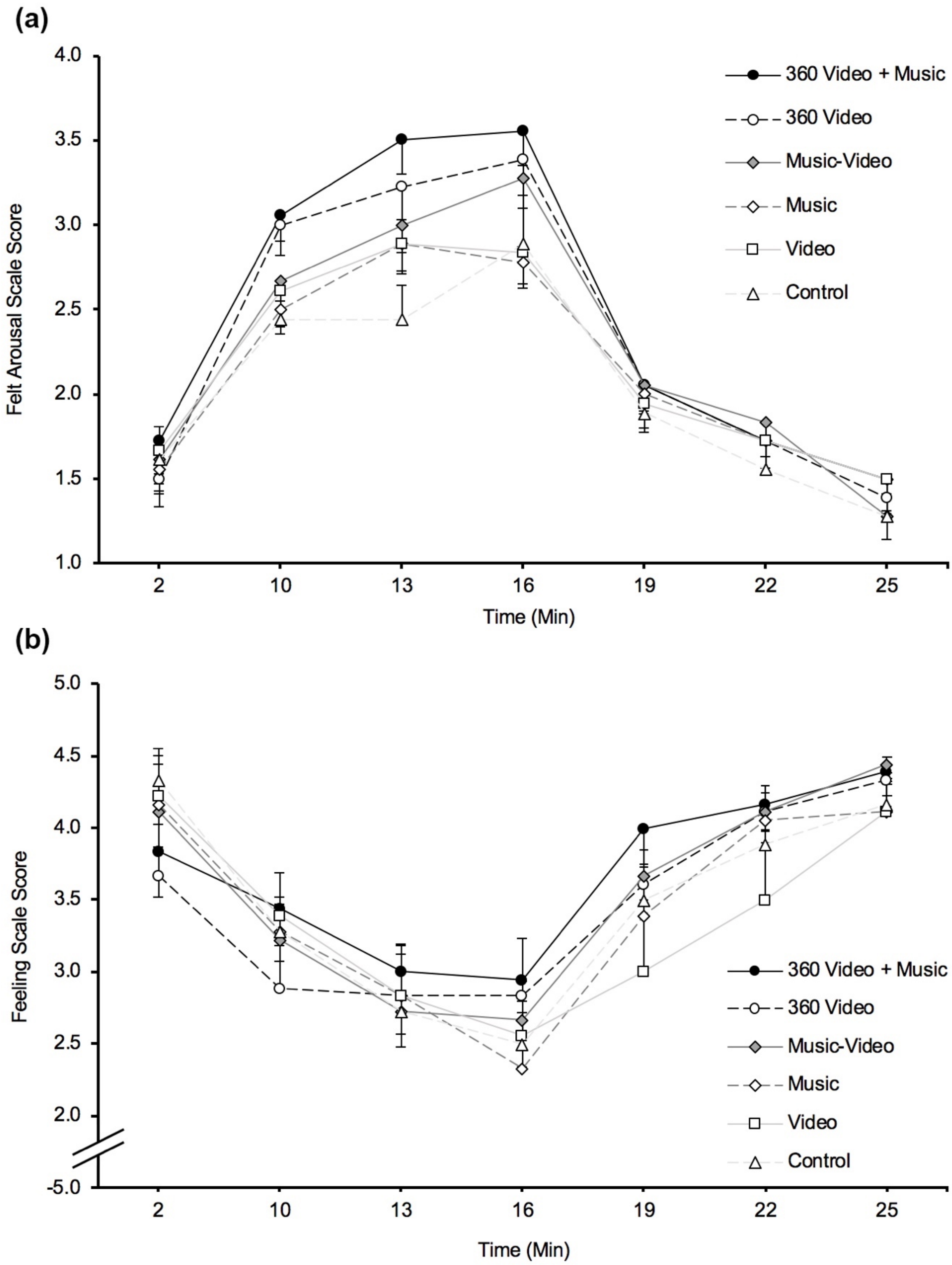

Figure 4.3. Felt Arousal Scale (a) and Feeling Scale (b) responses (*M* and *SE*) across conditions.

4.3.2 Perceptual variables. The omnibus analysis indicated that the Condition × Time interaction was nonsignificant ($p = .787$, $\eta_p^2 = .04$; Table 4.3). Nonetheless, there was a main effect of condition that applied only to state attention ($p < .001$, $\eta_p^2 = .31$) and was associated with a large effect size. Pairwise comparisons showed that 360-degree video and 360-degree video with music elicited significantly greater external focus when compared to control ($p = .041$, 95% CI [0.42, 31.80] and $p = 0.10$, 95% CI [3.72, 38.94], respectively; see Figure 4.4). Moreover, 360-degree video with music prompted a significantly greater external focus when compared to the video-only condition ($p = .015$, 95% CI [2.32, 30.54]). There was a main effect of time for perceived exertion only ($p = .004$, $\eta_p^2 = .36$) that was associated with a large effect size. Participants reported incrementally greater perceived exertion throughout the exercise bout. Pairwise comparisons revealed that perceived exertion was significantly higher after 13 min and 16 min when compared to 10 min ($p = .003$, 95% CI [0.14, 0.74] and $p = .019$, 95% CI [0.80, 1.01], respectively).

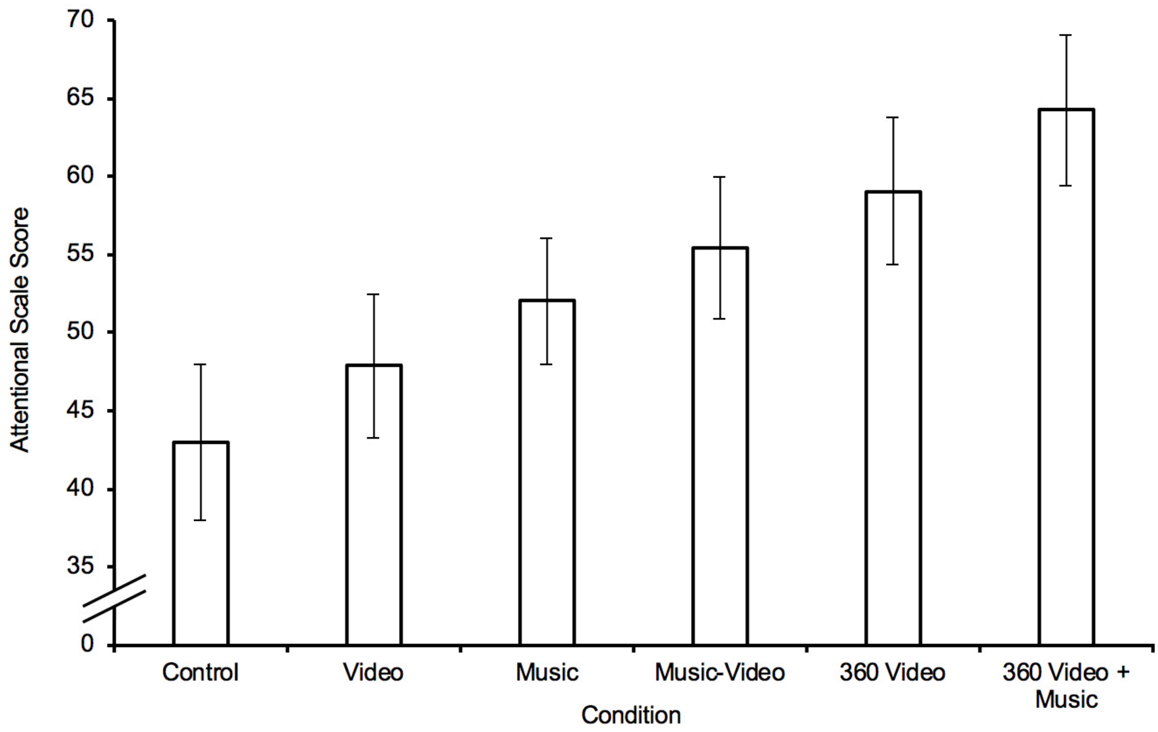

Figure 4.4. Attentional Scale responses (*M* and *SE*) across conditions.

4.3.3 Perceived enjoyment. A one-way, RM ANOVA revealed a significant effect of condition (p = .011, η_p^2 = .20; Table 4.3) that was associated with a large effect size. Pairwise comparisons indicated that the music-video condition elicited significantly greater enjoyment when compared to control (p = .008, 95% CI [2.56, 23.67]; see Figure 4.5). The difference between the 360-degree video with music condition and the control condition did not reach significance (p = .150, 95% CI [-2.34, 28.78]), although the difference between means was in the expected direction ($M_{control}$ = 84.67; $M_{360degreevideowithmusic}$ = 97.89; see Figure 4.5).

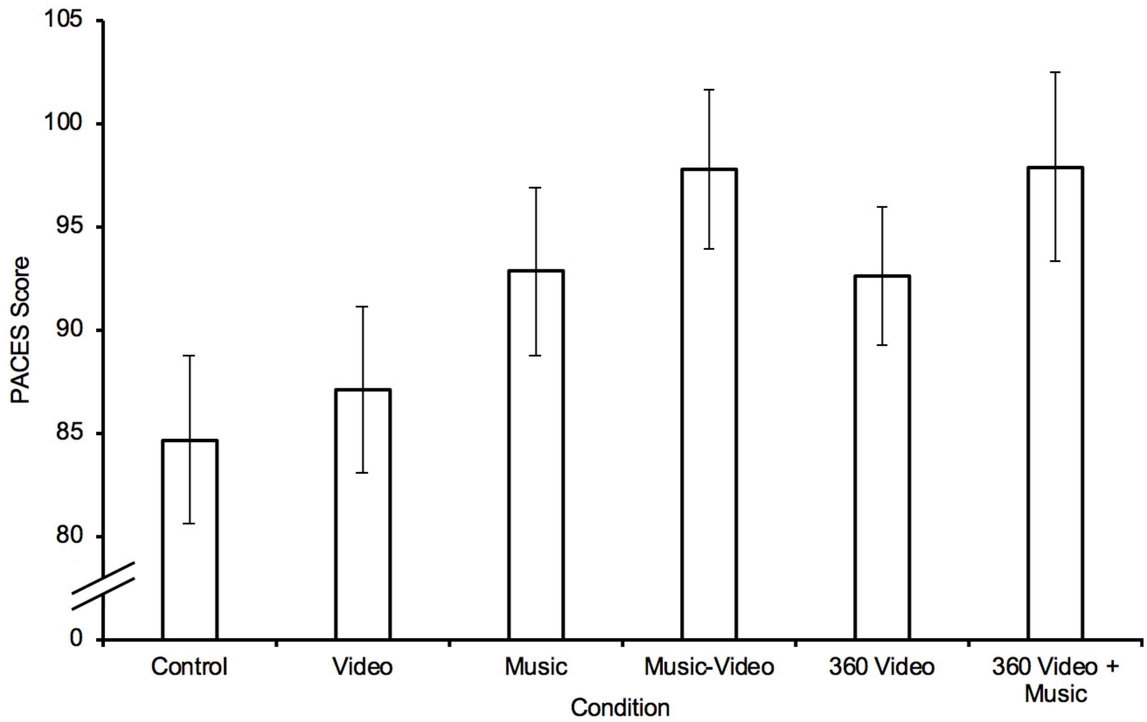

Figure 4.5. Physical Activity Enjoyment Scale responses (*M* and *SE*) across conditions.

Table 4.3

Inferential Statistics for all Dependent Variables

	Pillai's Trace	*F*	*df*	*p*	η_p^2
Affective Variables					
Condition x Time	.207	1.96	60, 1020	.000	.10
Affective Valence	–	1.61	5, 92	.160	.09
Perceived Activation	–	2.34	9, 145	.019	.12
Condition	.209	1.99	10, 170	.038	.11
Affective Valence	–	.55	3, 52	.654	.03
Perceived Activation	–	3.94	5, 85	.003	.19
Time	.899	13.88	12, 204	.000	.45
Affective Valence	–	26.88	2, 34	.000	.61
Perceived Activation	–	77.29	2, 31	.000	.82
Perceptual Variables					
Condition x Time	.083	.74	20, 340	.787	.04
Attention	–	1.10	5, 77	.365	.06
Perceived Exertion	–	.34	5, 80	.880	.02
Condition	.396	4.20	10, 170	.000	.20
Attention	–	7.73	3, 49	.000	.31
Perceived Exertion	–	1.28	5, 85	.280	.07
Time	.400	4.24	4, 68	.004	.20
Attention	–	1.36	1, 22	.266	.07
Perceived Exertion	–	9.74	1, 21	.004	.36
Perceived Enjoyment					
Condition	–	4.26	3, 47	.011	.20

4.4 Discussion

The present study extended the findings of Study 1 (see Chapter 3). Building upon the premise that exercisers experienced positive affective responses with the perceptual illusion of presence, the main purpose of this study was to investigate how participants responded to a range of audio-visual stimuli during cycle ergometer exercise. The stimuli comprised music, video, music-video, 360-degree video and 360-degree video with music. Moreover, the effects of the aforementioned audio-visual stimuli on exercise were examined at the VT, an intensity that is characterised by large affect-related interindividual variability. The dependent measures spanned affective (affective valence and perceived activation), perceptual (state attention and RPE), and enjoyment variables.

4.4.1 Affective variables. It was predicted that 360-degree video with music and 360-degree video conditions would facilitate the most positive affective valence and highest perceived activation (H_1). Furthermore, it was hypothesised that music-video, music, and video conditions would elicit more positive affective valence and higher perceived activation when compared to the control condition (H_1). This expected outcome was observed for perceived activation, providing only partial support for H_1. This finding reinforces the notion that introducing audio-visual stimuli within an exercise environment appears to enhance perceived activation when compared to control conditions (Bigliassi, Karageorghis, et al., 2019; Jones et al., 2014). An original contribution of Study 2 concerns the heightened perceived activation in conditions that included 360-degree video. It is possible that the novelty of using a VR HMD might have contributed to this finding, given that the most pronounced differences in perceived activation were observed during the exercise bout, the time during which participants experienced the experimental manipulation (see Figure 4.3a).

No statistical differences in affective valence emerged across conditions and this was an unexpected finding that precluded full acceptance of H_1 (see Figure 4.3b). Contrastingly, researchers have demonstrated that the use of auditory (Hutchinson, Jones, et al., 2018) and audio-visual (Bird et al., 2016) stimuli can positively influence exercisers' affective valence during exercise. It is noteworthy that the 360-degree video with music condition elicited the highest ratings of affective valence *and* variation during the exercise bout (i.e., from 7–17 min; $M = 3.13$, $SD = 1.53$). The observed variation in affective valence scores in this condition might have been caused, in part, by simulation sickness, which is a possible side effect of VR HMD use (Bailenson, 2018; Slater & Sanchez-Vives, 2016).

An alternative explanation for the lack of differences across all conditions pertains to the participants recruited for Study 2, the vast majority of whom were young, healthy, exercise science undergraduates or recent graduates (cf. Hutchinson et al., 2017). It is likely that these participants had a high degree of physical self-efficacy, which might have influenced their ability to tolerate or even prefer exercising at the VT, an intensity that usually elicits a range of affective responses (Ekkekakis, 2003). The characteristics of the sample employed herein might help to explain the positive affective valence scores observed in the control condition during the exercise bout (i.e., from 7–17 min; $M = 2.83$, $SD = 1.15$).

It was expected that the control condition would be associated with the most pronounced affective rebound (H_2), owing to participants' less positive in-task affective state. The greatest difference in affective valence scores from the final in-task measurement (i.e., after 16 min) to the final post-task measurement (i.e., after 25 min) was observed in the music condition ($M_{\text{diff}} = 1.78$) and therefore H_2 was not accepted. It is noteworthy that affective rebounds across conditions were of a similar magnitude (M_{diff} range = 1.45–1.78) and this was reflected in the nonsignificant Condition × Time interaction observed for affective valence (see Figure 4.3b). Despite the nonacceptance of H_2, the present findings do provide support for the notion that a robust rebound toward pleasure is expected following the cessation of exercise that has induced an affective decline (Hutchinson et al., 2017).

4.4.2 Perceptual variables. It was hypothesised that conditions containing 360-degree video would facilitate the most dissociative thoughts and lowest RPE. It was also expected that music-video, music, and video conditions would engender more dissociative thoughts and lower RPE when compared to the control condition (H_3). This predicted outcome was observed for state attention only, providing partial support for H_3. The finding that an audio-visual stimulus can prompt more dissociative thoughts than a sole stimulus (e.g., music or video) is supported by previous research (Chow & Etnier, 2017; Hutchinson et al., 2017). However, this is the first study in the exercise science literature to demonstrate that 360-degree video footage administered via a VR HMD can facilitate a greater number of dissociative thoughts when compared to audio-visual stimuli delivered via traditional displays (e.g., television screens).

For RPE, no statistical differences emerged across conditions and this was somewhat unexpected (H_3). When considered alongside the state attention data, the findings indicate that participants were dissociating more in conditions that comprised 360-degree video footage, however their psychophysical state was not modulated by the experimental manipulation. This finding stands in opposition to a growing body of literature that has demonstrated that audio-visual stimuli can alleviate perceptions of exertion during exercise (Chow & Etnier, 2017; Hutchinson et al., 2015). A plausible explanation for the unexpected RPE findings might be attributed to the type of action depicted in the video during the experimental conditions. Video footage that was congruent with the exercise modality under investigation (i.e., cycle ergometry) was chosen. Contrastingly, researchers who have reported reductions in RPE have employed video footage such as circus performances (Chow & Etnier, 2017) and music-videos (Hutchinson et al., 2015), both of which were incongruent with their associated exercise protocols. Accordingly, it is possible that using 360-degree video that is unrelated to the task at hand (e.g., 360-degree music-videos) might have reduced participants' RPE to a greater degree than reported herein. However, it should be noted that participants' RPE scores were relatively low across all conditions ($M = 3.80$, $SD = 0.18$), indicating that they perceived the exercise to be of a light-to-moderate intensity, regardless of the condition to which they were exposed.

4.4.3 Perceived enjoyment. It was predicted that participants would derive the greatest perceived enjoyment in conditions that contained 360-degree video. Furthermore, it was expected that music-video, music, and video conditions would elicit greater perceived enjoyment when compared to control (H_4). The main effect of condition revealed that the greatest perceptions of enjoyment was derived in the 360-degree video with music condition followed by the music-video condition, providing partial support for H_4. The finding that audio-visual stimuli can enhance exercise-related enjoyment is supported by previous work (Bigliassi, Karageorghis, et al., 2019; Jones et al., 2014). Nonetheless, this is the first study to demonstrate the enjoyment-inducing effects of 360-degree video footage delivered via a VR HMD during exercise. These findings are encouraging given that exercise-related enjoyment has been suggested to be a key determinant of exercise adherence (Stork et al., 2015).

4.4.4 Theoretical and practical implications. From a theoretical perspective, these results illustrate the efficacy of employing audio-visual stimuli as a means by which to enhance affective responses to exercise at the VT. This is noteworthy because exercising at the VT is associated with large interindividual variability in affect, depicted by an inflection point on the DMT of exercise-related affect (Ekkekakis, 2003). In addition to enhancing affective responses during exercise, researchers have postulated that *remembered pleasure* (i.e., how pleasant or unpleasant an exercise bout is remembered), is a key factor in determining whether a behaviour will be repeated (Zenko, Ekkekakis, & Ariely, 2016). Accordingly, the perceived enjoyment data derived from the PACES (Kendzierski & DeCarlo, 1991) supports the notion that audio-visual stimuli might be used to good effect in helping individuals adhere to exercise.

One of the mechanisms underlying the effects of audio-visual stimuli on exercise is attentional processing (Karageorghis, 2017). It has been suggested that perception is a limited-capacity process that proceeds automatically until that capacity is reached (Murphy, Groeger, & Greene, 2016). Tasks that involve high perceptual load leave little room for the processing of unattended information. Contrastingly, tasks that involve low perceptual load do not fully consume perceptual capacity, resulting in the processing of all available stimuli (i.e., attended and unattended). In an exercise context, such unattended stimuli could refer to the physiological sensations that typically accompany exercise at the VT (e.g., muscle acidosis; Hutchinson et al., 2017). It is possible that audio-visual stimuli administered via VR HMDs can induce a higher perceptual load on exercisers when compared to traditional displays (e.g., television screens). This is because modern VR HMDs are considered to be more immersive than traditional displays and can therefore facilitate greater perceptions of presence (i.e., the psychological sense of being in the virtual environment; Bailey & Bailenson, 2017; Slater & Sanchez-Vives, 2016). Accordingly, the use of VR HMDs might be particularly potent at exercise intensities proximal to VT, as the physiological sensations associated with fatigue begin to compete for attentional resources (Ekkekakis, 2003).

From a practical perspective, these results provide exercise and health practitioners with a viable solution for enhancing the affective responses of individuals who are exercising at VT. The implications of these results for public health are grounded in the emerging support pertaining to a positive relationship between affective responses and exercise adherence (Williams et al., 2016). Given the lack of progress made toward reducing physical inactivity (Foster et al., 2018), a strong case can be advanced for such interventions if we, as a society, are to derive the numerous physical and mental health benefits associated with regular engagement in exercise. Although employing audio-visual interventions via traditional displays has the advantage of cost effectiveness, the increasing rate at which VR HMDs are becoming widely accessible (e.g., via a smartphone), means that virtual experiences will be readily available to a huge consumer audience in the near future (Bailenson, 2018). Moreover, employing audio-visual stimuli in an exercise context has the advantage of requiring no previous training when compared to other psychological interventions such as cognitive reframing or imagery (Jones et al., 2014).

4.4.5 Strengths and limitations. An original contribution of this work pertains to the examination of 360-degree video footage delivered via a VR HMD during exercise. The decision to incorporate such technology was predicated on the findings of Study 1 (see Chapter 3), which illustrated the positive effects of psychological presence in an exercise context. There is substantial interest in the use of VR technology and a plethora of applications are now available for consumers to download and experience instantly. However, the chronic effects of using VR technology remain relatively unknown (Madary & Metzinger, 2016). Therefore, an examination of this technology in a controlled environment appears timely. The findings of Study 2 stand on the shoulders of an evolving corpus of literature that has employed traditional displays (e.g., television screens, projectors) as a means of investigating audio-visual stimuli in an exercise context (Hutchinson et al., 2017; Jones et al., 2014).

A rigorous music selection process was employed to ensure that the motivational qualities of the tracks used in the experimental trials were homogenous, given that a lack of homogeneity has been suggested to pose a threat to internal validity in related studies (Hutchinson et al., 2015; Jones et al., 2014). The assessment of each participant's VT prior to conducting the experimental trials represents another strength. Defining exercise intensity according to physiological markers such as VT is preferable to that of percentage of maximal heart rate (MHR), as it reduces interindividual variability in metabolic state when responding to measures of affect (Bird et al., 2016). Finally, a range of conditions were included to account for every possible eventuality that individuals might encounter in an exercise context. This allowed comparisons to be drawn between audio and visual stimuli used singularly and in combination (cf. Hutchinson et al., 2015).

In terms of limitations, a minor point of concern was the observed difference in perceived activation scores between exercise trial 1 and trial 5 (Table 4.2). It is likely that this difference was manifest as a consequence of perfect counterbalancing not being possible, owing to the complexity of the present design. Furthermore, it could have been difficult for participants to respond to the psychological scales while wearing the VR HMD. As a means of reducing the impact of this limitation, each participant was fully familiarised with the psychological scales upon entry to the laboratory and the scales were administered verbally in conditions that required the VR HMD. Moreover, the music content was delivered via bone-conducting headphones, which enabled participants to listen to the music while simultaneously listening to the vocal instructions of the experimenter.

The present sample largely comprised young adults who were either exercise science undergraduates or recent graduates, which might explain the positive affective valence scores observed across all conditions. Accordingly, the findings cannot be readily generalised to other populations without replication of Study 2 using a sample that is more representative of the wider population. Nevertheless, the study provides an initial examination into the effects of audio-visual stimuli at the VT and the findings can be used to spark research with other populations; in particular "at-risk" populations such as the obese or people with type 2 diabetes (Hutchinson et al., 2017).

4.4.6 Future directions. The present study serves as a catalyst for several lines of future research. From a practical perspective, a useful addition to this line of research would be to examine a range of 360-degree videos (e.g., music-videos, documentaries) in order to determine which has the most potent influence in terms of affective responses to exercise. Furthermore, researchers might assess individuals' perceptions of presence when exposed to 360-degree videos in an exercise context. It is plausible that incongruent video footage would represent a more potent form of dissociation technique when individuals are engaged in exercise. Given the volume of 360-degree content that is readily available from online libraries such as *YouTube Virtual Reality* and *Jaunt*, this represents a rather pragmatic extension of Study 2.

The present study sought to encourage psychological presence by employing 360-degree video footage administered via a VR HMD. However, it is acknowledged that the movements associated with the exercise modality (i.e., cycle ergometry) had no bearing on the video footage to which participants were subjected. Hence, if a participant were to alter their cycling cadence during the experimental trials, the video would not change in response to this. Accordingly, future research might seek to examine the efficacy of more immersive forms of technology, such as VR-enabled cycle ergometers (e.g., Zeng et al., 2017). It is plausible that such technology would encourage greater levels of psychological presence. From a methodological point of view, future work might include a broader range of exercise modalities than that examined here (e.g., rowing, circuit training). However, caution is urged when employing VR HMDs in an exercise context, as there is great potential for individuals to collide with objects in the physical world (Bird, 2019). Moreover, there is risk of eyestrain when using VR HMDs over prolonged periods (Bailenson, 2018). Researchers might also employ other exercise intensities, such as those predicated on ramp-down protocols (Zenko, Ekkekakis, & Ariely, 2016), or self-paced exercise (Hutchinson, Jones, et al., 2018). From a mechanistic perspective, researchers are encouraged to examine the brain mechanisms that underlie the effects of audio-visual stimuli in an exercise context. Such explorations might include non-invasive methods such as EEG that embrace active shielding technology, as a means of reducing the influence of movement artefacts (Bigliassi, Karageorghis, et al., 2019).

4.5 Conclusions

The current findings demonstrate that audio-visual stimuli delivered via a VR HMD have the capacity to positively influence the affective experience of exercise. This was evident through participants reporting greater perceived activation, more dissociative thoughts, and higher exercise enjoyment. Given the recent emphasis on affective responses to exercise as determinants of future behaviour (Hutchinson, Jones, et al., 2018), audio-visual stimuli should be considered as a valuable tool to help promote an enjoyable exercise experience.

Chapter 5: Effects of Music and Virtual Reality on Cycle Ergometer Exercise

5.1 Introduction

Regular physical activity is fundamental to the prevention of several chronic diseases such as heart disease, type 2 diabetes, and some cancers as well as psychological disorders such as depression and anxiety (Rhodes et al., 2018). Given the numerous health benefits associated with physical activity, the WHO set a global target to reduce physical inactivity by 10% by 2025 (World Health Organization, 2016). Unfortunately, recent reports indicate that "no country in the WHO European Region is on track to meet the [physical activity] target" (World Health Organization, 2018a, p. 6). Accordingly, there is an urgent need to develop evidence-based interventions that seek to promote physical activity among the general population.

Given the lack of progress made toward increasing physical activity at the population-level, researchers have questioned the efficacy of the "rational-education" approach which has predicated public health campaigns for decades (Ekkekakis, Zenko, et al., 2018). Such an approach assumes that individuals are rational and if provided with complete information pertaining to a behaviour, they are likely to change their behaviour in the desired manner (Ekkekakis, 2017). Nonetheless, it is quickly becoming evident that individuals often behave in ways that do not serve their self-interests (Ekkekakis & Zenko, 2016a). It has been postulated that a crucial factor influencing participation in physical activity is an individual's affective response to the behaviour (Dunton, Leventhal, Rothman, & Intille, 2018).

5.1.1 Affective responses to exercise. Herein, affect is conceptualised affect as a dimensional domain that is comprised of affective valence and perceived activation. Based on the principle of psychological hedonism (Kahneman, 1999), the *affect heuristic* supports the notion that individuals are likely to engage in behaviours that result in pleasure and avoid behaviours that result in displeasure (Williams, 2018). Hence, individuals who experience desirable affective states (i.e., high positive affect/low negative affect) during physical activity will be more likely to adhere to an exercise program (Dunton et al., 2018).

The DMT (Ekkekakis, 2003) explains how exercise intensity relates to the pleasure/displeasure individuals feel when engaged in exercise. Central to the DMT is that affective responses are determined by a combination of cognitive factors (e.g., physical self-efficacy) and interoceptive cues (e.g., laboured breathing). Moreover, the theory defines exercise intensity with reference to metabolic indicators such as the VT and RCP, both of which entail specific physiological changes (e.g., increased respiration, muscle acidosis; Ladwig, Hartman, & Ekkekakis, 2017).

The DMT posits that affective responses below VT are primarily influenced by cognitive factors and are pleasurable. Affective responses between the VT and the RCP are associated with the greatest interindividual variability, wherein some exercisers feel pleasure and others feel displeasure. As the intensity of exercise exceeds the RCP, affective responses are primarily influenced by interoceptive cues and there is a near universal decline in pleasure as the body enters a state of severe stress (Ladwig et al., 2017). Moreover, the term *affective rebound* refers to the rapid increase in pleasure that is expected to occur following cessation of exercise that induces displeasure (Ekkekakis et al., 2011).

Focusing on affective constructs might reduce physical inactivity, but there remains a dearth of information concerning how we can render the experience of exercise more pleasant (Zenko, Ekkekakis, & Ariely, 2016). One option that holds considerable promise concerns an attempt to create a pleasurable exercise environment, given that contextual factors have been proposed to play a seminal role in determining exercise-related affect (Dunton, Liao, Intille, Huh, & Leventhal, 2015).

5.1.2 Audio-visual stimuli within exercise contexts. An intervention that can be easily implemented within the exercise environment is the addition of audio-visual stimuli. A vast corpus of research spanning the past two decades has demonstrated that listening to music can bolster affective responses to exercise across several modalities and intensities (e.g., Bigliassi, Karageorghis, Hoy, & Layne, 2018; Edworthy & Waring, 2006). The term *attentional dissociation* is an oft-cited cognitive mechanism underlying such findings and refers to the way in which music has the capacity to guide attention outwardly (i.e., toward exteroceptive cues), alleviate fatigue, and render the exercise experience more pleasurable (Jones et al., 2014).

Researchers have also examined the effects of audio and visual stimuli in combination, including music-videos (Hutchinson et al., 2017), television shows (Privitera et al., 2014) and videos (Bigliassi, Greca, et al., 2019). For example, a grounded theory approach was employed by the researcher during Study 1 in order to explain and predict the social process of exercising in the presence of a music-video channel (see Chapter 3). The findings supported the notion that audio-visual stimuli can prompt a range of affective, cognitive, and behavioural responses in accord with the degree to which the stimuli are deemed appropriate in an exercise context. Scholars have also administered visual stimuli that are congruent with the exercise protocols that they employ. For example, Jones et al. (2014) used rural parkland footage to accompany indoor cycle ergometry. They reported that music and music-video conditions elicited more positive exercise-related affect when compared to video and control conditions. Similarly, Barreto-Silva, Bigliassi, Chierotti, and Altimari (2018) administered pleasant, unpleasant, and neutral road-based footage while participants cycled at 5% above VT. The pleasant condition depicted a cyclist on a descending course and facilitated significantly lower RPE when compared to the unpleasant condition.

Interestingly, both teams of researchers predicated their audio-visual intervention on the concept of immersion as a means by which to encourage attentional dissociation. It was postulated that the greater the level of immersion, the greater the likelihood that participants would focus their attention outwardly (i.e., away from interoceptive cues). Moreover, that an immersive environment might up-/downregulate the effects of fatigue-related symptoms through psychophysiological indices such as HRV (Barreto-Silva et al., 2018). Immersive experiences were partially accomplished through use of video projection (Jones et al., 2014) and a large television screen placed directly in front of participants (Barreto-Silva et al., 2018). Nonetheless, recent technological advances have afforded alternative modes of delivery that are capable of achieving far superior levels of immersion.

5.1.3 Virtual reality head-mounted displays. VR HMDs are highly immersive because they replace real-sense perceptions with ones that are computer generated (Bailenson, 2018). This allows the user to perceive stimuli actively through natural sensorimotor contingencies (Slater, 2018). The close-to-life experience is achieved through a combination of wide field of views, head tracking, low latency from head movements to display, high-resolution displays, and a capacity to accommodate a range of senses (Slater & Sanchez-Vives, 2016). Related to immersion, the term *presence* refers to the perceptual illusion of being inside the virtual environment despite the knowledge that one is not actually there (Slater, 2018).

Researchers have suggested that VR HMDs are efficacious in the treatment of post-traumatic stress disorder (Maples-Keller, Yasinski, Manjin, & Rothbaum, 2017) and delivery of physical rehabilitation (Howard, 2017). Nonetheless, the application of VR HMDs in the exercise context is surprisingly scant. In the present programme of research, Study 2 entailed an examination of a range of audio-visual stimuli on affective and perceptual responses to cycle ergometer exercise at the VT. The findings indicate that a 360-degree video with music condition administered via a VR HMD prompted the most positive affective valence, greatest perceived activation, most dissociative thoughts, and highest ratings of perceived enjoyment. However, it was acknowledged that a more immersive exercise environment could be achieved with the inclusion of a VR-enabled cycle ergometer as opposed to the traditional cycle ergometer that was employed.

Zeng, Pope, and Gao (2017) sought to compare the physiological and psychological effects of exercising on a VR-enabled cycle ergometer compared to a traditional ergometer. The findings from two 20-min bouts of exercise indicated that the VR condition elicited significantly lower RPE, which might be indicative of greater attentional dissociation. Moreover, the VR condition facilitated greater scores for enjoyment and self-efficacy, both of which were measured upon completion of the exercise bout.

While the Zeng et al. (2017) study represents the first exploration into the effectiveness of commercially available VR-based exercise technology, a close examination of the researchers' methodology reveals several potential shortcomings. For example, Zeng et al. (2017) allowed participants to listen to music and watch videos during the traditional exercise condition, both of which have been shown to influence RPE and affective responses to exercise (Bigliassi, Greca, et al., 2019). They employed a fixed resistance during the VR-enabled condition but varied the resistance in the traditional cycle ergometer condition. Further, the researchers used HR data to determine the resistance applied to the traditional cycle ergometer, as opposed to defining the intensity of exercise according to fixed metabolic indicators, such as VT (Ekkekakis, 2003). Finally, it was acknowledged that counterbalancing of conditions would offer a useful means by which to control for order effects. In sum, there is ample opportunity to examine the effects of exercising with VR HMDs while addressing the aforementioned limitations.

5.1.4 Aims and hypotheses. Researchers have emphasised the importance of initiating studies that enhance understanding of how technology can be used to promote physical activity (Lewis et al., 2017). Accordingly, the aim of Study 3 was to investigate the effects of music, VR, and VR with music on the affective, perceptual, enjoyment, and cardiac responses to aerobic exercise. The researcher drew upon the substantive theory proposed in Study 1 (see Figure 3.2) to facilitate the design of the present study. Hence, the music, video, and music-videos components were taken into consideration when selecting the audio-visual stimuli. In addition, the moderators (e.g., exercise factors, environmental factors) helped ensure that the experimental manipulation was appropriate for an exercise context. Moreover, the effects on individual exercisers (e.g., affective, cognitive) depicted in the substantive theory helped in justifying the choice of dependent variables for the present study.

It was hypothesised that conditions containing VR would facilitate the most positive affective valence and highest perceived activation. In addition, it was predicted that the music condition would prompt more positive affective valence and perceived activation when compared to control (H_1). It was hypothesised that the control condition would elicit the steepest "affective rebound", owing to participants' superior affective state during the experimental conditions (H_2). It was expected that conditions containing VR to prompt the most dissociative thoughts and lowest RPE, followed by the music and control conditions, respectively (H_3). It was also predicted that conditions containing VR would facilitate the greatest perceived enjoyment, followed by music and control conditions, respectively (H_4). Finally, it was expected that conditions containing VR would elicit the least global activity of the ANS and the greatest parasympathetic activity, followed by the music, and control, respectively (H_5).

5.2 Methodology

This study was approved by the Brunel University London Ethics Committee (see Appendix X) and all participants provided written informed consent (see Appendix Y).

5.2.1 Participants. A power analysis was conducted using G*Power 3 (Faul et al., 2009) in order to establish a suitable sample size. This analysis was predicated on the mean of effect sizes reported by Bigliassi, Karageorghis, Wright, Orgs, and Nowicky (2017); specifically, the main effect of Condition for affective valence ($\eta_p^2 = .33$) and the main effect of Condition for perceived activation ($\eta_p^2 = .15$). Moreover, an alpha level of .05 and power at .80 to protect beta at four times the level of alpha (Cohen, 1988). The analysis indicated that 16 participants would be required.

The substantive theory proposed in the first original study provided support for the notion that a range of exerciser factors influence an individual's response to audio-visual stimuli (see Figure 3.2). Accordingly, participants were homogenous in terms of age (i.e., 20–34 years), ethnicity (i.e., White British), and sociocultural background (i.e., had spent their formative years in the UK). An institutional e-mail was circulated to describe the nature of the study and recruitment posters were used on social media platforms (see Appendix Z). The inclusion criteria specified that participants needed to be recreationally active (according to the PAR-Q; see Appendix P), should not present any form of hearing deficiency and/or visual impairment, and be familiar with cycle ergometry. Eight additional participants were recruited to account for likely experimental dropout and to facilitate a fully counterbalanced design. Following procurement of institutional ethics committee approval and written informed consent, 24 adult volunteers were recruited (10 women and 14 men; $M_{\text{age}} = 26.67$, $SD = 4.02$ years; $M_{\text{BMI}} = 23.63$, $SD = 5.12$ kg m^{-2}).

5.2.2 Experimental procedures. Participants were administered light-to-moderate-intensity bouts of physical activity performed on a VR-enabled cycle ergometer (VirZOOM Bike Controller; Cambridge, Massachusetts). The exercise modality and equipment were chosen because they allowed participants to remain in a seated position throughout the exercise bout and there are relatively few degrees of freedom in terms of the kinematics involved (see Figure 5.1). Cycle ergometry is frequently accompanied by music in health and exercise contexts; therefore, it represented an ecologically valid form of physical activity. In addition, participants could engage in this exercise modality with and without the use of a VR HMD, thus allowing the researcher to elucidate the effects of VR on the exercise experience.

Figure 5.1. Experimental set-up with the VR HMD and VirZOOM cycle ergometer during Study 3.

5.2.2.1 Pre-experimental phase. Each participant was provided with an information sheet (see Appendix AA), before completing the PAR-Q (see Appendix P), a demographic questionnaire (see Appendix AB) and providing written informed consent (see Appendix Y). The researcher then measured the participant's height, weight, and resting HR. The psychological scales were then presented to the participant to enable familiarisation and reduce the likelihood of interpretation-related errors during the main-experimental phase. Thereafter, the participant was granted an opportunity to habituate her-/himself with the smartphone-powered VR HMD (Samsung S8; Samsung Gear VR; Suwon, the Republic of Korea Suwon). Once the participant was entirely comfortable in terms of wearing and adjusting the device, s/he was instructed to complete the experience *Introduction to Virtual Reality* (Oculus; California), which is designed to gradually acquaint users with the key concepts of VR. The participant was then introduced to the VR-enabled cycle ergometer and s/he was instructed to complete the *VirZOOM Arcade Demo* (VirZOOM; Cambridge, Massachusetts). This is designed to introduce a selection of games and the associated head movements that serve as in-game controls.

The participant was then required to remove the VR HMD in order to complete an incremental cycle ergometer test so that VT could be ascertained. This physiological index was used to determine the relative exercise intensity for each participant during the experimental trials. The participant entered a changing area to attach a HR monitor (Polar H7; Kempele, Finland), which facilitated recording of the cardiac stress induced by the increasing physiological load. The VR-enabled cycle ergometer enabled eight intensities ranging from 1 (*lightest*) to 8 (*heaviest*). Following a 2-min period of seated rest, the participant was required to pedal at 75 rpm at each intensity for 3 min, up to 75% of MHR (~145 bpm). MHR was calculated by use of an age-related equation (i.e., $208 - 0.7 \times \text{age}$; Tanaka, Monahan, & Seals, 2001). It was expected that VT would occur when the participant's HR reached ~135 bpm (Bigliassi et al., 2017). A cycling computer and cadence sensor (Garmin Edge 1000; Olathe, Kansas) were attached to the cycle ergometer to ensure that cadence remained at 75 ± 3 rpm throughout the test; this coincided with the cadence required in experimental trials.

Upon reaching 75% MHR, the participant completed a 5-min warm-down on the lightest intensity offered by the cycle ergometer. Thereafter, the R–R interval data were imported into Kubios HRV software. In accordance with the recommendations of Karapetian, Engels, and Gretebeck (2008), time-domain analyses (i.e., root mean square of successive RR interval differences [RMSSD], and standard deviation of normal-to-normal RR intervals [SDNN]) were graphically plotted for each stage of the incremental test. Subsequently, a visual inspection facilitated the detection of VT through use of HRV deflection points.

5.2.2.2 Main-experimental phase. A within-subjects design was adopted, and experimental testing took place at least 48 hr after the pre-experimental phase at the same time of day. Each participant was required to attach the aforementioned HR monitor in the designated changing area. Three experimental conditions (music, VR, and VR with music) and one control condition (no music and/or VR) were administered to identify the effects of audio-visual stimuli on affective, perceptual, enjoyment, and cardiac responses to cycle ergometry. In the music condition, participants were exposed to music while in a visually sterile environment. In the VR condition, participants were exposed to a VR experience by viewing it on a smartphone-powered VR HMD. The VR with music condition entailed participating in the VR experience while being exposed to music. In the control condition, the participant was not exposed to music or VR. Furthermore, the participant's eyes and ears were not occluded in order to maintain ecological validity (Jones et al., 2014).

Conditions were counterbalanced and randomised with each experimental trial lasting a total of 12 min (warm-up [3 min], exercise [6 min], and warm-down [3-min]). Experimental manipulations coincided with the 6-min exercise phase. Work intensity increased from the warm-up (0–3 min: 20% below VT), to the exercise bout (3–9 min: 10% below VT), and decreased during the warm-down period (9–12 min: 20 % below VT). Moreover, the participant was required to maintain a cadence of 75 ± 3 rpm throughout each stage of the experimental trial. It was expected that the exercise intensity would only induce mild fatigue-related symptoms (e.g., muscle acidosis, laboured breathing). Nonetheless, recovery periods that lasted 10 min were allocated in between conditions, so that the participant's HR could descend to within 10% of her/his resting value. Accordingly, participants only commenced the next experimental trial when they had fully recovered (see Figure 5.2). Word searches were administered during the 10-min recovery period as a means by which to negate any potential carryover effects of previous experimental conditions.

5.2.3 Music selection. The researcher selected *There's Nothing Holdin' Me Back* (122 bpm) by Shawn Mendes as a means of inducing positive affective responses, directing participants' attentional focus, and reducing the severity of fatigue-related symptoms. This piece of music was chosen due to its stimulative and uplifting qualities. The tempo lies within the range recommended for stationary cycling performed at low-to-moderate intensities (i.e., 115–134 bpm; Karageorghis, 2017). Moreover, the tempo of 122 bpm is not divisible by 75 rpm (i.e., the cadence that each participant was required to maintain during experimental trials), reducing the possibility of auditory-motor synchronisation. An extended version of this piece of music (i.e., 6 min) was used during the experimental trials, meaning that it could be played for the entire exercise phase of the experimental trial. Music was delivered via a laptop (Apple MacBook Pro; Apple Inc., California) placed directly next to the participant and sound intensity was standardised at ~70 dBA.

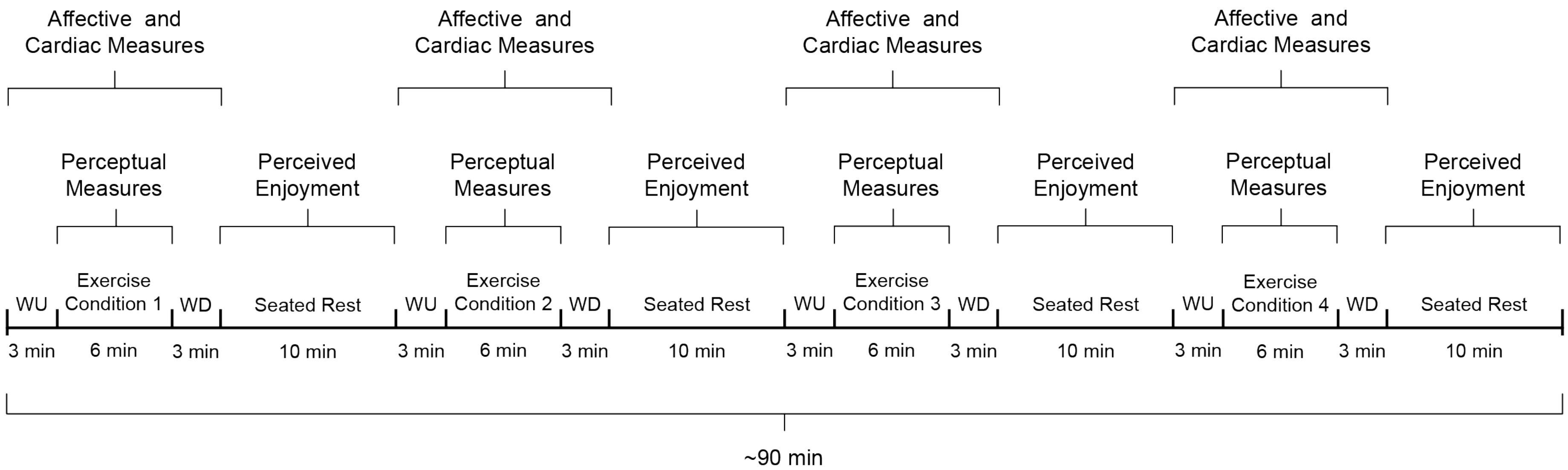

Figure 5.2. Diagrammatic representation of experimental procedures during Study 3. *Note.* WU = warm-up; WD = warm-down. Exercise was performed at 10% below ventilatory threshold and conditions were counterbalanced and randomised.

5.2.4 Virtual reality selection. The researcher selected the VR experience *Cycle: Le Tour* from the application *VirZOOM Arcade* (VirZOOM, Cambridge, Massachusetts) with a view to enhancing affective responses, directing the participant's attention externally, and minimising the severity of fatigue-related symptoms. This game leads participants to cycle through a virtual countryside scene and was selected for its appropriateness to the exercise modality under investigation. In order to steer the cycle ergometer in the virtual environment, the participant was required to move her/his head in pitch orientation (i.e., by moving the ears toward the shoulders). The VR experience was delivered via a smartphone-powered VR HMD. Appropriate hygiene levels were maintained by detaching the VR HMD foam after each experimental trial and replacing it with a clean one.

5.2.5 Psychological measures. Four psychological measures were taken at five time points (0.5, 2.5, 5.5., 8.5, and 11.5 min) throughout the experimental trials. Given that affect is conceptualised as a dimensional domain, affective valence was assessed using the FS (Hardy & Rejeski, 1989; see Appendix Q) and perceived activation using the FAS (Svebak & Murgatroyd, 1985; see Appendix R). The FS is a single-item, 11-point scale anchored by -5 ([*I feel*] *very bad*) and 5 (*very good*). The FAS is a single-item, 6-point scale anchored by 1 (*low arousal*) and 6 (*high arousal*). RPE was assessed using the Borg CR10 Scale (Borg, 1998; see Appendix S), which is anchored by 0 (*nothing at all*) and 10 (*extremely strong*). Attentional focus was measured using the AS (Tammen, 1996); see Appendix T), which is anchored by 0 (*Internal focus* [*bodily sensations, heart rate, breathing etc.*]) and 100 (*External focus* [*daydreaming, external environment, etc.*]). Participants were required to indicate their focus verbally during the exercise bout, with scores > 50 representing an external focus. The psychological measures were administered in the same order for each experimental trial (i.e., FS, FAS, RPE, AS).

After completing each experimental trial, the participant's perceived enjoyment was assessed using the PACES (Kendzierski & DeCarlo, 1991; see Appendix U). This scale includes 18 items attached to 7-point bipolar scales (e.g., 1 = *I enjoy it,* 7 = *I hate it* [item 1]). The participant was asked to rate how they felt about the activity they had just completed. In addition, her/his aesthetic appreciation of the music and/or VR experience was identified by use of a single-item liking scale ranging from 1 (*I do not like it at all*) to 10 (*I like it very much*), which was administered upon cessation of each experimental trial (see Appendix AC).

5.2.6 Heart rate variability. HRV data were recorded throughout each trial to elucidate the effects of music and VR on the autonomic balance during warm-up, exercise, and warm-down periods. Data were imported into Kubios HRV software and, in accord with the recommendations of Bigliassi et al. (2017), the signal was broken down into four samples each lasting 3 min. Two time-domain indices were extracted from the cardiac electrical signal. SDNN was used as an index of global activity of the sympathetic–parasympathetic system and RMSSD was used as an index of parasympathetic activity (Acharya et al., 2006).

5.2.7 Data analysis. Data were screened for univariate outliers using standardised *z*-scores (i.e., $z > \pm 3.29$; Tabachnick & Fidell, 2018) and multivariate outliers using the Mahalanobis distance test with $p < .001$. Data were examined for the parametric assumptions that underlie ANOVA and MANOVA. Affective variables (affective valence and perceived activation) were assessed using a 4 (Condition) × 5 (Time) MANOVA. Perceptual variables (RPE and attentional focus) were analysed using a 4 (Condition) × 2 (Time) MANOVA. Perceived enjoyment was assessed using a repeated-measures ANOVA. Cardiac variables (SDNN and RMSSD) were analysed using a 4 (Condition) × 4 (Time) MANOVA. Greenhouse-Geisser adjustments were made to *F* tests where the sphericity assumption was violated. Where the *F* ratio was significant, Bonferroni-adjusted pairwise comparisons or checks of *SE* were employed to determine where differences lay.

5.3 Results

Data screening revealed seven univariate outliers ($z > \pm 3.29$) pertaining to cardiac values (i.e., SDNN and RMSSD) and in all instances, the score was adjusted by assigning the outlying cases a raw score that was one unit larger (or smaller) than the next most extreme score in the distribution until $z < \pm 3.29$ (Tabachnick & Fidell, 2018). Tests of the distributional properties of the data in each cell of the analysis revealed violations of normality in 26 of the 92 cells (15 at $p < .05$, 5 at $p < .01$, and 6 at $p < .001$). Further testing revealed that 17 of the aforementioned violations of normality were associated with the cardiac variables, which displayed positive skewness coupled with leptokurtosis. Accordingly, square root transformations were applied to normalise these data. Follow-up tests revealed violations of normality in nine of the 92 cells (7 at $p < .05$ and 2 at $p < .001$) that were associated with the affective and perceptual variables. It was decided not to transform these data owing to psychometric concerns regarding the transformation of subjective data derived from Likert scales (Nevill & Lane, 2007). No multivariate outliers were identified.

5.3.1 Affective variables. The omnibus analysis revealed a significant Condition × Time interaction for affective valence ($p = .001$, $\eta_p^2 = .14$; see Table 5.1) that was associated with a moderate-to-large effect size. VR elicited significantly higher affective valence during the exercise bout (i.e., after 5.5 and 8.5 min) when compared to control and music conditions (see Figure 5.3a). Moreover, participants reported significantly higher affective valence scores in the VR with music condition during the exercise bout when compared to control. There was a significant Condition × Time interaction for perceived activation ($p < .001$, $\eta_p^2 = .24$; see Table 5.1) that was associated with a large effect size. VR and VR with music conditions elicited significantly higher perceived activation ratings during the exercise bout when compared to music and control conditions (see Figure 5.3b).

There was a main effect of condition for affective valence (*p* = .029, η_p^2 = .12) and perceived activation (*p* < .001, η_p^2 = .35), associated with a moderate-to-large and large effect sizes, respectively. Pairwise comparisons indicated that affective valence was significantly higher for VR when compared to the control condition (*p* = .017, 95% CI [0.06, 0.78]). Furthermore, the VR and VR with music conditions elicited significantly higher perceived activation when compared to the control (*p* = .002, 95% CI [0.16, 0.86] and *p* = .007, 95% CI [0.10, 0.82], respectively) and music conditions (*p* = .003, 95% CI [0.11, 0.61] and *p* = .016, 95% CI [0.04, 0.57], respectively).

There was a main effect of Time for affective valence (*p* = .027, η_p^2 = .14) and perceived activation (*p* < .001, η_p^2 = .58), both associated with a large effect size. Affective valence scores decreased incrementally throughout the exercise bout and subsequently increased during the warm-down phase. However, pairwise comparisons failed to identify any differences between time points (*p* > .05). Perceived activation scores increased incrementally throughout the exercise bout and subsequently decreased during the warm-down. Pairwise comparisons indicated that perceived activation was significantly higher at the end of the exercise bout (i.e., after 8.5 min) when compared to baseline and warm-up (*p* < .001, 95% CI [0.56, 1.36] and *p* < .001, 95% CI [0.37, 1.14], respectively). Moreover, perceived activation was significantly lower during the warm-down when compared to the end of the exercise bout (*p* < .001, 95% CI [-1.14, -0.39]).

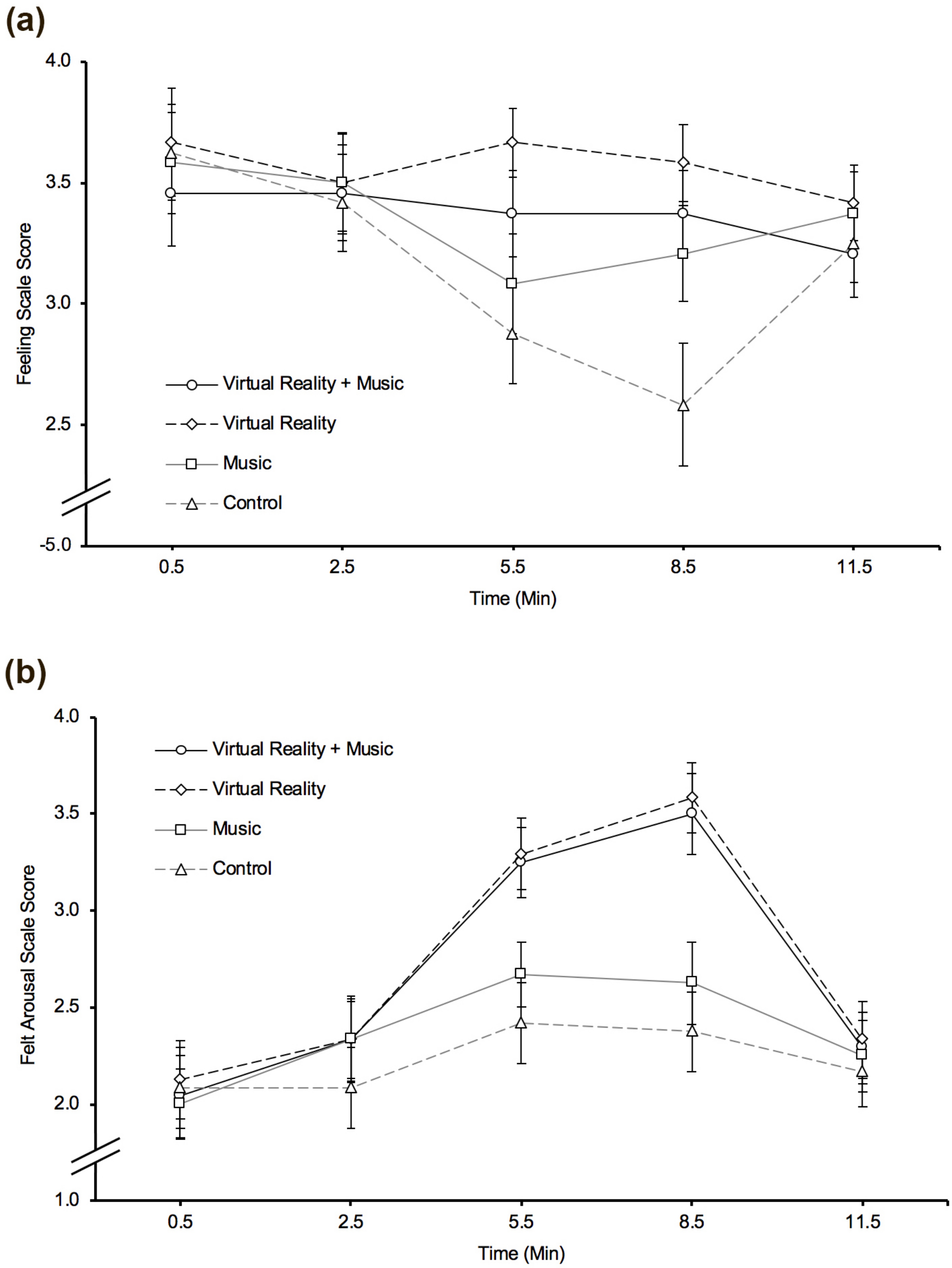

Figure 5.3. Feeling Scale (a) and Felt Arousal Scale (b) responses (*M* and *SE*) across conditions.

5.3.2 Perceptual variables. The omnibus analysis indicated that the Condition × Time interaction was nonsignificant (p = .636, η_p^2 = .03; see Table 5.1). There was, however, a main effect of Condition that applied only to state attention (p = .001, η_p^2 = .26) and was associated with a large effect size. Pairwise comparisons showed that the VR and VR with music conditions prompted a significantly greater external focus when compared to the control condition (p = .036, 95% CI [0.76, 31.32] and p = .004, 95% CI [4.69, 30.72], respectively; see Figure 5.4). There was a main effect of Time for perceived exertion only (p = .001, η_p^2 = .36). Pairwise comparisons revealed that participants reported significantly higher perceived exertion after 8.5 min when compared to 5.5 min (p = .001, 95% CI [0.11, 0.41]).

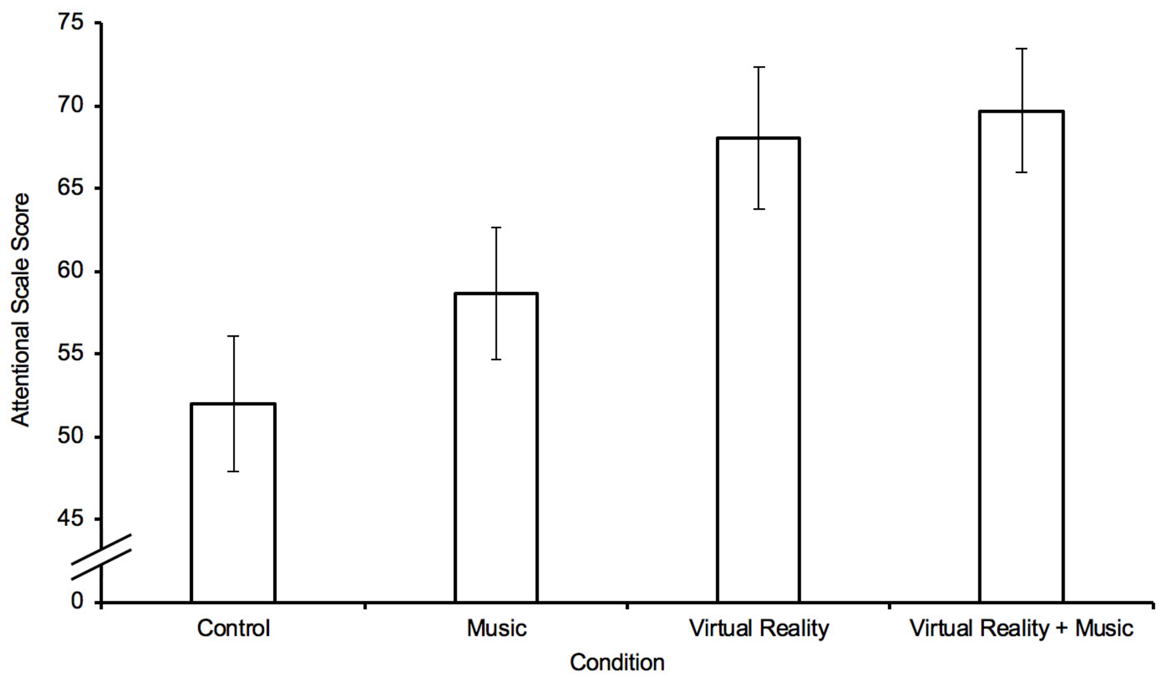

Figure 5.4. Attentional Scale responses (*M* and *SE*) across conditions.

5.3.3 Perceived enjoyment. RM ANOVA indicated a significant main effect of Condition ($p < .001$, $\eta_p^2 = .49$; see Table 5.1) that was associated with a large effect size. Pairwise comparisons indicated that the VR and VR with music conditions elicited significantly greater enjoyment when compared to control ($p < .001$, 95% CI [8.94, 32.81] and $p < .001$, 95% CI [9.81, 33.11], respectively) and music conditions ($p = .001$, 95% CI [4.93, 24.40] and $p < .001$, 95% CI [6.24, 24.26], respectively; see Figure 5.5).

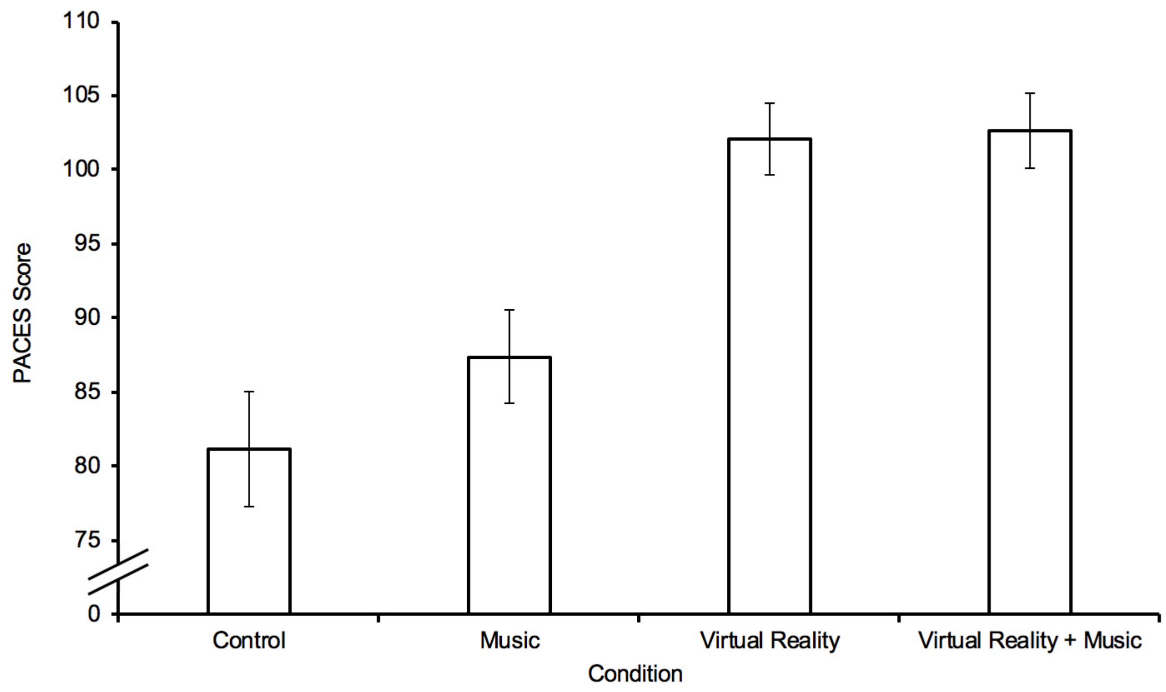

Figure 5.5. Physical Activity Enjoyment Scale responses (*M* and *SE*) across conditions.

5.3.4 Cardiac variables. The omnibus analysis revealed that the Condition × Time interaction was nonsignificant ($p = .163$, $\eta_p^2 = .06$; see Table 5.1). Nonetheless, there was a main effect of Time for SDNN ($p < .001$, $\eta_p^2 = .83$) and RMSSD ($p < .001$, $\eta_p^2 = .74$), both associated with a large effect size. SDNN and RMSSD values decreased incrementally throughout the exercise bout and subsequently increased during the warm-down. Pairwise comparisons indicated that SDNN was significantly lower at the end of the exercise bout (i.e., 6–9 min) when compared to warm-up and the start of the exercise bout ($p < .001$, 95% CI [-1.30, -0.83] and $p = .001$, 95% CI [-0.30, -0.07], respectively). Similarly, RMSSD was significantly lower at the end of the exercise bout when compared to warm-up ($p < .001$, 95% CI [-1.03, -0.55]).

Table 5.1

Inferential Statistics for all Dependent Variables

	Pillai's Trace	*F*	*df*	*p*	η_p^2
Affective Variables					
Condition x Time	.322	4.42	24, 552	.000	.16
Affective Valence	–	3.78	6, 146	.001	.14
Perceived Activation	–	7.27	6, 134	.000	.24
Condition	.382	5.44	6, 138	.000	.19
Affective Valence	–	3.19	3, 69	.029	.12
Perceived Activation	–	12.16	2, 49	.000	.35
Time	.618	10.29	8, 184	.000	.31
Affective Valence	–	3.72	2, 51	.027	.14
Perceived Activation	–	31.39	2, 50	.000	.58
Perceptual Variables					
Condition x Time	.061	.72	6, 138	.636	.03
Perceived Exertion	–	.70	3, 69	.553	.03
State Attention	–	.78	2, 53	.482	.03
Condition	.272	3.63	6, 138	.002	.14
Perceived Exertion	–	.02	3, 69	.997	.00
State Attention	–	7.90	2, 48	.001	.26
Time	.366	6.35	2, 22	.007	.37
Perceived Exertion	–	13.06	1, 23	.001	.36
State Attention	–	1.13	1, 23	.299	.05
Perceived Enjoyment					
Condition	–	22.09	2, 36	.000	.49
Cardiac Variables					
Condition x Time	.109	1.33	18, 414	.163	.06
SDNN	–	2.55	9, 207	.009	.10
RMSSD	–	1.45	4, 81	.231	.06
Condition	.050	.60	6, 138	.734	.03
SDNN	–	.69	3, 69	.564	.03
RMSSD	–	1.06	3, 69	.370	.04
Time	.870	17.71	6, 138	.000	.44
SDNN	–	109.48	2, 47	.000	.83
RMSSD	–	64.73	2, 40	.000	.74

5.4 Discussion

The present study builds upon Study 1 and Study 2 (see Chapters 3 and 4) and sought to explore the responses to a range of audio-visual stimuli during aerobic cycle ergometry. The auditory stimuli comprised motivational music and the visual stimuli comprised an interactive virtual environment delivered via a VR HMD. The dependent measures spanned core affect (affective valence and perceived activation), perceptual (state attention and RPE), enjoyment, and cardiac (HRV) variables.

5.4.1 Affective variables. It was hypothesised that VR and VR with music conditions would elicit the most positive affective valance and perceived activation. Moreover, it was expected that the music condition would prompt more positive affective valence and perceived activation when compared to control (H_1). The significant Condition × Time interaction effect for affective valence and perceived activation led to the acceptance of H_1. The finding that audio-visual stimuli can enhance affective valence during exercise when compared to control conditions is consistent with previous findings (Hutchinson et al., 2017; Jones et al., 2014). However, this is the first study to demonstrate that virtual stimuli delivered via a VR HMD can render the exercise environment more pleasurable when compared to music and control conditions.

The VR condition facilitated the most positive affective valence during the exercise bout (i.e., after 5.5 and 8.5 min) followed by the VR with music condition (see Figure 5.3a). Researchers have seldom employed a video-only condition when examining exercisers' affective responses to audio-visual stimuli. A notable exception concerns Jones et al. (2014), who reported significantly higher affective valence scores in a music and video condition when compared to video. It was, therefore, somewhat unexpected that the present participants reported greater pleasure when exercising with VR vs. VR with music (i.e., $M = 3.63$ vs. $M = 3.38$). The researcher made use of experimenter-selected rather than participant-selected music (cf. Hutchinson et al., 2018) and so it is possible that a lack of music familiarity bore influence on participants' affective valence scores during the exercise bout (Karageorghis, 2017).

The Condition × Time interaction effect for perceived activation showed that participants derived greater stimulation from all experimental conditions when compared to control (see Figure 5.3b). These findings add weight to the notion that music can elevate perceived activation during exercise (Hutchinson & Karageorghis, 2013). However, it is noteworthy that the VR and VR with music conditions elicited significantly greater perceived activation when compared to the music condition. This finding does not concur with the comparable finding of Jones et al. (2014), who reported that music elicited greater perceived activation than video during cycle ergometry. These authors suggested that their video content lacked stimulative qualities, although the visual stimuli used in Study 3 were of a similar nature (i.e., depicting a first-person perspective rural scene). Accordingly, the presence afforded by the VR HMD elevated participants' perceived activation during exercise (Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015). This is plausible given that no differences across conditions were found during the warm-down (after 11.5 min), before which participants were required to remove the VR HMD.

It was hypothesised that the control condition would be associated with the steepest affective rebound, owing to participants' more positive affective state during experimental conditions (H_2). The greatest difference in affective valence scores from the final in-task measurement (8.5 min) to the final measurement taken during the warm-down was observed in the control condition ($M_{\text{diff}} = 0.67$; see Figure 5.3a) and thus H_2 was accepted. This finding supports the notion that a rapid increase in pleasure is expected immediately following the cessation of exercise that is perceived as unpleasant (Ekkekakis et al., 2011).

5.4.2 Perceptual variables. It was hypothesised that the VR and VR with music conditions would facilitate the most dissociative thoughts and lowest RPE, followed by the music and control conditions (H_3). This outcome was observed only in state attention, thus providing partial support for H_3. The finding that audio-visual stimuli can promote attentional dissociation is consistent with previous research (Bigliassi, Greca, et al., 2019; Jones et al., 2014). It has been suggested that plural stimuli provide a more potent form of distraction during exercise when compared to a singular stimulus (e.g., music or video; Hutchinson et al., 2017). However, participants dissociated to a similar extent in the VR (M = 68.02) and the VR with music condition (M = 69.69). Accordingly, it is recommended that researchers consider not only the content of audio-visual stimuli, but also the means by which audio-visual stimuli are delivered in an exercise context. One of the key features of VR HMDs is the capacity to occlude the user from physical reality (Bailenson, 2018), making the experience more immersive than either video projection (Jones et al., 2014) or television screens (Barreto-Silva et al., 2018).

Despite capturing participants' attention, it appears that the experimental manipulation had no bearing on RPE. This was an unexpected finding that precluded full acceptance of H_3. Moreover, the finding is inconsistent with previous research that has found VR to be effective at reducing RPE scores during exercise when compared to non-VR control conditions (e.g., Zeng et al., 2017). Nonetheless, it is noteworthy that participants' RPE scores were relatively low across all conditions (M = 2.87, SD = 0.02). The present participants were healthy individuals who regularly engaged in exercise, which might account for this. They are likely to have developed a high tolerance for exercising at intensities proximal to the VT and this explanation is even more plausible when the RPE scores are considered in tandem with the elevated affective valence scores (see Figure 5.3a).

5.4.3 Perceived enjoyment. It was predicted that conditions involving VR would facilitate the greatest perceived enjoyment, followed by music and control (H_4). The main effect of Condition provided full support for H_4. Several researchers have demonstrated that music can engender greater exercise-related enjoyment (Jones et al., 2014; Stork et al., 2015). Moreover, the present findings add weight to the notion that exercise-related enjoyment can be bolstered by virtual environments (Zeng et al., 2017). These findings are encouraging when considering the chorus of eulogy for the role played by exercise-related enjoyment in exercise adherence (Ekkekakis, Zenko, et al., 2018; Stork et al., 2015).

5.4.4 Cardiac variables. It was hypothesised that conditions containing VR would elicit the least global activity of the ANS and the greatest parasympathetic activity, followed by the music, and control (H_5). The nonsignificant Condition × Time interaction for SDNN and RMSSD led to nonacceptance of H_5. Ostensibly, the selected exercise intensity (10% below VT) had a greater influence on cardiac stress than the audio-visual stimuli administered during experimental conditions, which is consistent with previous findings (e.g., Bigliassi et al., 2017). Close examination of the results provides support for an exercise intensity dose-response, wherein participants' SDNN and RMSSD values decreased throughout the exercise bout and rebounded during warm-down (Michael, Graham, & Davis, 2017).

5.4.5 Theoretical and practical implications. The present results are novel in demonstrating that VR technology can enhance affective states when people exercise at an intensity proximal to VT, which might hold value in the promotion of exercise adherence. From a mechanistic perspective, one of the salient mechanisms underlying the effects of audio-visual stimuli in the context of exercise concerns attentional processing (Hutchinson & Karageorghis, 2013). Researchers have theorised that perception has a limited capacity that proceeds automatically until such capacity is filled (Murphy et al., 2016). When an individual is engaged with a task that imposes high perceptual load, distractors cannot be processed. Alternatively, when an individual is engaged with a low perceptual load task, all available stimuli are processed.

It was hypothesised that VR HMDs induce a higher perceptual load when compared to music and control conditions, which prevent exercise-related interoceptive cues from entering focal awareness. It is plausible that such effects can be attributed to the high degree of presence afforded by modern VR HMDs (Slater & Sanchez-Vives, 2016). Indeed, the perceptual illusion of presence has been postulated to activate several areas of the brain, including the dorsal and ventral visual stream, the parietal cortex, the premotor cortex, mesial temporal area, the brainstem, and the thalamus (Jäncke, Cheetham, & Baumgartner, 2009).

In addition to the concept of presence, it was hypothesised that a VR HMD provides stimuli with which participants became unconsciously entwined. It has been postulated that mirror neurons in the premotor and parietal cortex discharge when an individual performs an action and when s/he observes another performing the same action (Kim, 2013). Moreover, there is evidence that the bodily states of observed others can stimulate similar bodily states in the self (cf., *bodily resonance*; Maister, Slater, Sanchez-Vives, & Tsakiris, 2015). Hence, it is possible that participants mirrored the behaviours and affective states of the characters depicted in the VR experience.

From a practical perspective, the present results provide evidence that VR HMDs are effective in rendering the exercise experience more pleasant. This is noteworthy given the burgeoning corpus of research that has emphasised a positive relationship between affective responses and adherence to exercise (Ekkekakis, Zenko, et al., 2018; Stork et al., 2015). Understanding how technology can be harnessed to promote physical activity has been highlighted as an important direction for future research (Lewis et al., 2017). Accordingly, the findings of Study 3 are timely and address the lack of practical information that pertains to enhancement of exercise-related affect (Zenko, Ekkekakis, & Ariely, 2016). Researchers and exercise professionals are encouraged to explore the potential benefits of employing VR HMDs within an exercise context as a means by which to reduce the disconcerting numbers in the developed world who refrain from engagement in regular physical activity (World Health Organization, 2018a). The ever-increasing rate at which VR is becoming accessible means that virtual experiences will be readily available to a large consumer base in the near future.

5.4.6 Strengths and limitations. Study 3 sought to provide an immersive experience by ensuring that the audio-visual stimuli were congruent with the exercise modality under investigation (i.e., cycle ergometry). Accordingly, the experimental manipulation detailed in the present study is the most sophisticated within the programme of research and represents one of the first attempts to examine commercially available audio-visual stimuli administered via a VR HMD during exercise. The decision to incorporate such technology was predicated on the findings of Study 2 (see Chapter 4) and add weight to a recent pilot study (Zeng et al., 2017), while addressing a number of methodological shortcomings evident in that study. Foremost among these were greater control over the audio-visual stimuli employed during each condition and the full counterbalancing of conditions to reduce the influence of order effects. In addition, the researcher assessed each participant's VT prior to conducting the experimental trials, which enabled him to standardise exercise intensity as well as reduce interindividual variability in metabolic state; a vital consideration when responding to affect-related measures (see Ekkekakis, 2003).

In terms of possible limitations, it is possible that the duration and repetitiveness associated with an extended piece of music was unfamiliar to participants. The music was selected for its motivational qualities and with a view to eliminating the possibility of auditory-motor synchronisation (Karageorghis, 2017). However, it is acknowledged that exercisers rarely listen to one piece of music for an entire exercise bout. An alternative approach would have entailed segueing multiple selections into a playlist (e.g., Jones et al., 2014), which would have enhanced the ecological validity of the experimental manipulation.

Another possible limitation pertains to responding to psychological scales while wearing a VR HMD. The author endeavoured to reduce the impact of this limitation by familiarising participants with the scales upon their entry to the laboratory. Moreover, the researcher administered the scales verbally in conditions that contained the use of the VR HMD. Finally, a sample that consisted largely of young, healthy individuals who regularly engage in exercise was employed in Study 3. Accordingly, the findings should not be generalised without replication using a sample that is more representative of the wider population.

5.4.7 Future directions. There are numerous lines of future research that emanate from Study 3. From a practical perspective, a useful extension would be to examine a range of audio-visual stimuli administered via a VR HMD in order to ascertain which has the greatest bearing on exercise-related affect. It is possible that subjecting exercisers to audio-visual stimuli that are unrelated to the exercise task might serve as a more potent form of distraction. Given that the *VirZOOM Arcade* application employed herein comprises a plethora of VR experiences, this represents a rather pragmatic extension. Allowing participants to choose from the full suite of VR experiences would potentially increase their autonomy, a building block of intrinsic motivation that is likely to enhance exercise-related affect (Hutchinson, Jones, et al., 2018).

From a methodological point of view, future work might entail longer exercise protocols than the one employed herein. Nonetheless, it is important to note that a possible side effect of using VR HMDs is simulation sickness (Slater & Sanchez-Vives, 2016). Researchers are therefore encouraged to employ VR-enabled exercise protocols that span relatively short durations (e.g., up to 20 min) and to schedule regular breaks in order to reduce the likelihood of sickness (Bailenson, 2018). Another avenue for future research entails the use of alternative exercise intensities, such as those predicated on self-paced exercise (Hutchinson, Jones, et al., 2018). In addition, future work should seek to further understanding of the psychophysiological mechanisms that underlie the effects of audio-visual stimuli in an exercise context. Such work might incorporate techniques such as EEG and/or functional near-infrared spectroscopy (see e.g., Bigliassi, Karageorghis, et al., 2018).

5.5 Conclusions

The current findings provide evidence that audio-visual stimuli administered via VR HMDs can assist in the promotion of a pleasurable exercise experience. This is predicated on the findings from several dependent variables given that the technology-mediated exercise was associated with more positive affective valence, greater perceived activation, more dissociative thoughts, and higher ratings of post-exercise enjoyment. It is noteworthy that the aforementioned effects were observed not only when compared to the control condition, but also when compared to the music condition. There is a corpus of evidence amassing that points to a link between exercise-related affect and adherence (Ekkekakis, Zenko, et al., 2018; Stork et al., 2015). In addition, researchers have been encouraged to consider how technology can provide the keystone for interventions that seek to promote regular engagement in physical activity (Lewis et al., 2017). Accordingly, VR technology should be considered by exercise scientists and health practitioners as a useful tool through which to facilitate a pleasurable exercise experience.

Chapter 6: General Discussion

The present programme of research stands on the shoulders of a vast knowledge base that has examined the scientific application of music in an exercise context. Importantly, the corpus of work contained herein makes an original contribution to the literature with the examination of immersive technology, such as VR, which are becoming increasingly popular within modern-day society (see Figure 1.1). The research programme is comprised of a substantial review of literature and three original studies. A range of settings was employed (i.e., real-world, laboratory), methodologies (i.e., qualitative and quantitative), exercise modalities (i.e., gym workouts, cycle ergometry) and consumer products (e.g., music-video channels, VR HMDs) in order to explore the main research question from varying perspectives. The results provide evidence that audio-visual stimuli can elicit a range of affective, cognitive, and behavioural effects during exercise. Moreover, it appears that the effects of such stimuli can be manipulated by presenting audio-visual stimuli through varying modes of immersive technology (e.g., video, VR HMDs). The following subsections provides the reader with the main findings that emanated from Chapters 3–5. Thereafter, similarities and differences are expounded, general limitations associated with the research programme are acknowledged, practical implications are discussed, and directions for future research are offered.

6.1 Overview of Main Findings

6.1.1 Study 1 (Chapter 3): A grounded theory of music-video use in an exercise facility. The first original study in the programme of research sought to investigate how the presence of a music-video channel influenced the social dynamics of exercising in a real-world context. It was acknowledged that the vast majority of research examining the effects of audio-visual stimuli in an exercise setting has taken place within controlled laboratory environments with samples of university students (e.g., Bigliassi et al., 2014; Bird et al., 2016; Jones et al., 2014). Accordingly, Study 1 addresses such limitations to more fully understand how music-videos affect individuals during exercise. It was recognised that individuals can draw upon conceptual frameworks (e.g., Clark, Baker, & Taylor, 2016b; Karageorghis, 2016) and rating inventories (e.g., Karageorghis, 2017) to facilitate the selection of music for exercise contexts, but a paucity of relevant theory inhibited individuals' audio-visual selections. Accordingly, a grounded theory methodology was employed in order to propose a substantive theory that explained and predicted the social process of exercising in the presence of a music-video channel (Corbin & Strauss, 2015).

During the iterative process of data collection and analysis (Corbin & Strauss, 2015), the perspectives of staff members were deemed important given that such individuals were actively involved in the exercise environment and responsible for the nature of the audio-visual stimuli. The research question changed to reflect this development (i.e., How does the presence of a music-video channel influence the social dynamics of running an exercise facility?) and members of staff were theoretically sampled accordingly (Corbin & Strauss, 2015; Weed, 2017). Although researchers have interviewed facility staff in previous music-related investigations (e.g., Priest & Karageorghis, 2008), the proposed substantive theory advances extant literature by presenting the dual perspective of individual exercisers and facility staff (cf. Clark, Baker, & Taylor, 2016b; Karageorghis, 2016).

The analysis provides support for a three-stage model that commences with the content of the music-video channel. A range of music properties (e.g., tempo, lyrics) are deemed salient and this is in alignment with previous research (Karageorghis, Bigliassi, Guérin, et al., 2018; Sanchez et al., 2014). However, an original contribution of Study 1 pertains to the identification of the video (e.g., characters, narrative) and music-video (e.g., congruence, variety) properties that warrant consideration when selecting audio-visual stimuli within an exercise context. The identification of the video and music-video properties are timely, given that music-videos have been frequently cited in studies that have examined the use of music as a sole stimulus (e.g., Bishop et al., 2007, p. 594; Karageorghis, Bigliassi, Tayara, et al., 2018, p. 117). Although music-videos represent the majority of the channel's content, additional material that can be considered extraneous (e.g., adverts, presenters) had the potential to prompt undesirable outcomes for exercisers.

The second stage of the substantive theory depicts a series of moderators. Specifically, exerciser (e.g., age, audio-visual preferences), exercise (e.g., modality, intensity), environmental (e.g., corporate image, audio-visual accessibility), and temporal factors (e.g., time of day, time of year) contribute towards the core category of the model; appraisal of appropriateness. It has been suggested that the core category of a substantive theory should capture in a few words the major theme or essence of a grounded theory study (Corbin & Strauss, 2015). Although appraisals of appropriateness are distinctly lacking from theoretical explanations of music use in the exercise context (e.g., Karageorghis, 2016), it is noteworthy that participants from previous qualitative investigations have hinted towards its relevance (e.g., "Some of the music that comes on is totally inappropriate for the gym" [Hallett & Lamont, 2015, p. 7]). In accordance with symbolic interactionism (Blumer, 1969; Corbin & Strauss, 2015), the moderators are organised in such a manner that they align with the relevant perspectives depicted by the model. Hence, exercise factors are the concern of individual exercisers and environmental factors are the concern of facility staff. Conversely, factors that influence both populations (i.e., exerciser factors, temporal factors, appraisals of appropriateness) are positioned centrally in the substantive theory.

Many of the proposed moderators provide support for findings that emerged in previous qualitative research. For example, Priest and Karageorghis (2008) reported that the "time of day" influenced exercisers' response to music. Specifically, the researchers cited that "a recreational exercise participant described her preference for gentle music early in the morning" (Priest & Karageorghis, 2008, p. 355). While the aforementioned material clearly alludes to the concept "time of day", the inductive content analysis employed by Priest and Karageorghis (2008) constrained the potential to identify the interaction among concepts (i.e., between “time of day” and “music preference”). On the other hand, the grounded theory approach employed in Study 1 afforded an exploration of the relationships among concepts (Corbin & Strauss, 2015). Hence, a range of bidirectional and unidirectional relationships were included to help facilitate understanding of how the associated moderators impacted one another (Corbin & Strauss, 2015; Holt, 2016; see Figure 3.2).

The final stage of the model presents a range of effects pertaining to individual exercisers and facility staff. The analysis revealed that exercising in the presence of a music-video channel could prompt a range of affective, cognitive, and behavioural outcomes which is consistent with previous research (Hutchinson et al., 2015; Lin & Lu, 2013). Nonetheless, the proposed model extends our understanding of audio-visual applications in an exercise context with the consideration that such outcomes can range from “desirable” to “undesirable” according to the degree to which individuals appraise content to be appropriate. Researchers have reported undesirable effects of music use in an exercise context at the individual level (e.g., reduced work output; Priest & Karageorghis, 2008). However, a novel finding from Study 1 pertains to the way in which exercise participants appraised the content of the music-video channel in relation to the collective preferences of other exercisers within the facility. Hence, the music-video channel had the capacity to engender negative affective responses when participants deemed the channel content inappropriate for themselves and others around them at any given point in time.

Participants indicated that music-videos were gender biased owing to the fact that females were frequently subjected to sexual objectification on-screen (Aubrey & Frisby, 2011; Rodgers & Hust, 2018). Moreover, music-videos typically featured thin females and muscular males (Bell et al., 2007; Mulgrew, Volcevski-Kostas, & Rendell, 2014). The promotion of such body types did not align with the inclusive corporate identity of the exercise facility, which sought to promote a healthy lifestyle for all shapes and sizes, irrespective of gender. Accordingly, it is possible that subjecting exercisers to music-videos might promote body dissatisfaction, where there is a discrepancy between actual body sizes and the perceived socio-cultural ideal (Campbell & Hausenblas, 2009). In line with SCT (Bandura, 1977, 1986, 1997, 2001), music-videos might be seen as a potent tool for reinforcing behavioural norms in a defined context and wider society (Cranwell, Britton, & Bains, 2017). This is perhaps the most compelling reason why the audio-visual selection process should not be taken lightly in a communal context, such as an exercise facility. Much like the way in which researchers are held accountable for their choice of measures (Ekkekakis, 2013b; Ekkekakis & Zenko, 2016b), facility staff should ensure that they are subjecting their members to appropriate audio-visual stimuli. A noteworthy limitation of the substantive theory presented in Chapter 3 (see Figure 3.2) is that it is specific to the group and place in which the data were collected (Corbin & Strauss, 2015; Holt, 2016). Hence, it is acknowledged that appropriate audio-visual selections are likely to differ across multiple exercise facilities.

6.1.2 Study 2 (Chapter 4): Effects of music, video, and 360-degree video on cycle ergometer exercise at the ventilatory threshold. The qualitative findings from Study 1 alluded to the suggestion that individuals preferred audio-visual stimuli that made them feel part of the action depicted by the visuals. Accordingly, the second original study in the present programme of research sought to examine the influence of a range of immersive audio-visual stimuli on affective and perceptual responses to exercise. In line with the DMT (Ekkekakis, 2003, 2005), the intensity of exercise is an important consideration when examining exercise-related affect. The VT represents a point of transition between aerobic–anaerobic metabolism during exercise and is associated with considerable interindividual variability in affect (Ekkekakis & Zenko, 2016a). While several teams of researchers have administered exercise proximal to VT when examining the effects of audio-visual stimuli (e.g., Hutchinson et al., 2015; Jones et al., 2014), an original contribution of Study 2 pertains to the use of 360-degree video administered via a VR HMD as a means of providing a more immersive exercise experience when compared to previous research (Barreto-Silva et al., 2018; Jones et al., 2014). VR HMDs represent a “new entry” in recent statistics concerning the household take-up of digital devices in the UK and therefore the examination of such technology appears timely (Ofcom, 2018; see Figure 1.1).

Participants were required to complete a 25-min protocol that consisted of 2-min seated rest, 5-min warm-up, 10-min exercise at VT, 5-min warm-down, and 3-min of seated rest. Furthermore, six conditions (i.e., music, video, music-video, 360-degree video, 360-degree video with music, control) were included so that comparisons could be drawn between the audio and visual stimuli used singularly and in combination. The dependent variables spanned affective (affective valence and perceived activation), perceptual (state attention and RPE) and enjoyment variables.

The results indicated a Condition × Time interaction for perceived activation. The 360-degree video ($M = 3.20$) and 360-degree video with music ($M = 3.37$) conditions engendered significantly higher perceived activation during the exercise bout when compared to the control condition ($M = 2.59$). This finding aligns with previous research that has employed traditional displays (e.g., television screens, video projection) to administer audio-visual stimuli during exercise (Bigliassi, Karageorghis, et al., 2019; Jones et al., 2014). Although the Condition × Time interaction for affective valence was nonsignificant, a main effect of condition for perceived enjoyment emerged. The results indicated that participants derived the most enjoyment in the 360-degree video with music condition ($M = 97.89$) and the least in the control condition ($M = 84.67$), providing evidence that audio-visual stimuli can be used to good effect when promoting an enjoyable exercise experience (Hutchinson et al., 2017).

The results of Study 2 also indicated a main effect of condition for state attention. Specifically, the 360-degree video ($M = 59.07$) and 360-degree video with music ($M = 64.30$) conditions yielded a significantly greater external focus when compared to the control condition (*M* = 42.96). It has been suggested that audio-visual stimuli experienced in tandem are likely to elicit greater attentional dissociation when compared to music or video experienced singularly (Hutchinson et al., 2015). While there is some evidence emerging to support this notion (e.g., Chow & Etnier, 2017) it is noteworthy that such studies typically involve just one means of delivering the visual stimuli (i.e., television screens). Study 2 provides an original contribution to the extant literature with the inclusion of multiple modes of delivery (e.g., laptop, VR HMD). The findings indicate that the aforementioned suggestion of Hutchinson et al. (2015) might be too simplistic, as the 360-degree video condition (i.e., a sole stimulus; *M* = 59.07) engendered greater attentional dissociation when compared to the music-video condition (i.e., audio-visual stimuli; *M* = 55.41). It is entirely plausible that immersive VR technology might induce a higher perceptual load on exercisers when compared to more traditional means of audio-visual display (e.g., video projection), leaving comparatively less attentional processing for the physiological sensations associated with fatigue (Rejeski, 1985; Tenenbaum, 2001). Accordingly, researchers are urged to considered not only the content of audio-visual stimuli, but the means in which such stimuli is delivered too.

6.1.3 Study 3 (Chapter 5): Effects of music and virtual reality on cycle ergometer exercise. The findings of Study 2 indicated that exercising in the presence of 360-degree video prompted several affective, perceptual, and enjoyment benefits. However, a limitation was that the visual stimuli and the movements associated with the exercise modality (i.e., cycle ergometry) were incongruent. Hence, if a participant were to alter their cycling cadence, the accompanying video would remain unaffected. This limitation is evident in many related studies in the realm of exercise sciences (e.g., Barreto-Silva et al., 2018; Jones et al., 2014). As a means of extending previous work, the purpose of the third original study was to investigate the effects of music, VR, and VR with music on cycle ergometer exercise.

An effort was made to enhance ecological validity through inclusion of a commercially available VR-enabled cycle ergometer.

Participants were required to complete a 12-min protocol that consisted of 3-min warm-up, 6-min exercise at 10% below VT, and 3-min warm-down. The four conditions (i.e., music, VR, VR with music, control) were counterbalanced and randomised. Moreover, HRV data were recorded throughout each trial as a means by which to elucidate the physiological mechanisms that underlie the effects of audio-visual stimuli during aerobic exercise (Bigliassi, Greca, et al., 2019).

The main findings indicated a Condition × Time interaction for both affective valence and perceived activation. Affective valence was more positive during the exercise in the VR condition ($M = 3.63$) when compared to the control ($M = 2.73$) and music ($M = 3.15$) conditions. Researchers have theorised that the decisions to repeat behaviours are influenced by an evaluation of the peak-and-end affect experienced during an encounter (Fredrickson, 2000; Williams, Dunsiger, et al., 2008). The peak affect concerns the most pleasant or unpleasant point during an encounter whereas the end affect signifies that the experience is completed, and the meaning of the situation can be evaluated with certainty (Hargreaves & Stych, 2013). A close examination of the results of Study 3 across conditions reveals that the most pleasurable peak affect was experienced during the VR condition (i.e., at 5.5 min; $M = 3.67$), whereas the most unpleasant peak affect was experienced during the control condition (i.e., at 8.5 min; $M = 2.58$). Accordingly, this finding supports the notion that immersive VR technology can facilitate peak pleasure during exercise, which might lead to greater exercise adherence. Despite large differences in peak affect, it is noteworthy that the affective valence scores observed across conditions were in close proximity during the final point of measurement (i.e., at 11.5; $M_{\text{diff}} = 0.21$). This provides support for the measurement of affective responses across the entire exercise bout (i.e., pre-, during-, and post-exercise), as opposed to simply measuring affective responses pre-to-post exercise, which would have misrepresented the true shape of the affective trajectory as it unfolds over time (Ekkekakis, 2013a).

A similar pattern of results emerged for perceived activation, wherein the VR (M = 3.44) and VR with music (M = 3.38) condition elicited greater perceived activation when compared to the music (M = 2.65) and control conditions (M = 2.40). It was somewhat unexpected that the VR condition prompted more positive affective valence and greater perceived activation when compared to the VR with music condition. This finding stands contrary to the suggestion that audio-visual stimuli are more effective than either music or video used singularly (Bird et al., 2016; Hutchinson et al., 2017; Jones et al., 2014). It is plausible that participants did not find the piece of music sufficiently motivating, given that it was not self-selected (cf. Hutchinson et al., 2018). In line with SDT, the use of experimenter-selected music might have undermined participants' sense of autonomy (Ryan & Deci, 2017). Furthermore, an extended version of one piece of music was used throughout the 6-min exercise bout and so the musical accompaniment could have been perceived as monotonous. Conversely, researchers typically draw upon a short playlist of 3–4 selections when examining the effects of music in exercise settings (e.g., Bird et al., 2016; Jones et al., 2014).

A main effect of condition for state attention indicated that participants were more likely to focus their attention externally during the VR (M = 68.02) and VR with music (M = 69.69) conditions compared to control (M = 51.98). The results also indicated a main effect of condition for perceived enjoyment, wherein participants reported significantly greater enjoyment in the VR (M = 102.04) and VR with music (M = 102.63) conditions when compared to music (M = 87.38) and control (M = 81.17). The finding that the VR and VR with music conditions elicited very similar scores for enjoyment suggests that the music used in Study 3 might not have been sufficiently motivational for the sample employed; franked by the fact that the music condition received the lowest liking score across conditions. Nonetheless, the perceived enjoyment scores support the notion that immersive technology can be used as a means by which to render the exercise experience more enjoyable. This finding bolsters those of Zeng et al. (2017), who also reported that participants derived greater enjoyment when exercising in VR when compared to traditional exercise.

6.2 Similarities and Differences Across the Programme of Research

The previous subsection provided an overview of the main findings on a study-by-study basis. Taken holistically, several points of convergence and divergence can be observed across the breadth of the programme of research, which will be expounded here.

6.2.1 Affective responses. It has been suggested that the affect heuristic might play an important role in the promotion of future physical activity behaviour (Smith et al., 2015; Tempest & Parfitt, 2013; Williams et al., 2012). Therefore, a central theme running throughout each of the original studies pertains to the affective responses of individuals exercising in the presence of audio-visual stimuli. A potential barrier to the study of affective phenomena within the realm of exercise is the lack of consensus regarding the conceptualisation of affect (Williams, Rhodes, & Conner, 2018). To this end, the distinction between key affective terms (i.e., affect, emotion, and mood) were made from the outset of the present programme of research.

In Study 2 and Study 3, the FS (Hardy & Rejeski, 1989) and FAS (Svebak & Murgatroyd, 1985) were employed to measure affective valence and perceived activation, respectively. The FS and FAS are frequently administered in tandem as a means of measuring affective responses to exercise (e.g., Lind, Ekkekakis, & Vazou, 2008; Rose & Parfitt, 2012; Welch, Hulley, Ferguson, & Beauchamp, 2007). However, this is merely an observation in the extant literature; the popularity of measures does not constitute a compelling rationale for their selection (Ekkekakis, 2013b). The decision to employ the FS and FAS was the result of a three-tiered decision-making process advocated by Ekkekakis and Zenko (2016b) as a means of selecting appropriate measures of affect.

Results from Study 2 and Study 3 provided evidence that audio-visual stimuli can elicit more positive affective valence when compared to control conditions and this is a finding that aligns with previous research (Hutchinson et al., 2015; Jones et al., 2014). Nonetheless, an original contribution of the present programme of research concerned the delivery of such stimuli using consumer ready VR HMDs. Findings from Study 2 and Study 3 indicate that this technology is particularly potent, to the point that individuals reported more positive affective valence in conditions that embraced VR technology compared to those that used music as a sole stimulus. A typical affective response to strenuous exercise entails a decline in pleasure during exercise, followed by a post-exercise rebound (Ekkekakis, 2013a). This common response was observed in 80% (i.e., 8 out of 10) of the trials conducted during Study 2 and Study 3. The exceptions arose during trials that embraced the VR HMD and VR-enabled cycle ergometer in combination. Indeed, participants reported a reduction in affective valence during the warm-down, when they were required to remove the VR HMD, despite a reduction in exercise intensity.

A similar pattern of results was observed for perceived activation during Study 2 and Study 3. The addition of audio-visual stimuli was found to prompt higher FAS scores when compared to control conditions, which is consistent with previous work (Hutchinson & Karageorghis, 2013). A notable contribution of the present research programme is the finding that VR technology consistently facilitated greater perceived activation when compared to all other conditions (i.e., experimental and control). Given that VR technology has only recently become available to consumers (Bird, 2019), it is possible that many of the participants recruited for Study 2 and Study 3 lacked previous experience of using VR HMDs. Hence, the novelty of using this technology for the first time might have contributed towards the heightened perceived activation scores observed during the present programme of research.

Self-report measures of affect, such as those employed in Study 2 and Study 3, might be considered the “gold standard” method of affect assessment (Williams et al., 2018).

However, qualitative approaches, such as grounded theory, represent a useful means by which to explore phenomena in their natural settings (Corbin & Strauss, 2015; Smith & Sparkes, 2016b). Accordingly, Study 1 provided the first qualitative exploration into the effects of audio-visual stimuli in an exercise context, allowing participants the opportunity to talk at length about the impact of this ubiquitous stimuli (Corbin & Strauss, 2015). The findings indicated that exercisers could "borrow" (Participant 4; interview) the affective states that were projected by performers on-screen. This is referred to as "emotional contagion" in the extant literature (Hatfield et al., 1994), wherein individuals "catch" the affective states of others unconsciously and unintentionally. Indeed, participants revealed that they "caught" a range of affective states that were considered to range from desirable (e.g., happy) to undesirable (e.g., sleepy) in an exercise context.

In accordance with the ART of exercise and physical activity (Brand & Ekkekakis, 2018), it is possible that exercising in the presence of appropriate audio-visual stimuli might facilitate exercise adherence via Type 1 and Type 2 processes. Regarding Type 1 processes, deriving more positive affective valence during an exercise bout is likely to result in a more positive automatic affective valuation when an individual is faced with an exercise-related stimulus, promoting the impulse to approach exercise (Ekkekakis & Brand, 2019). Moreover, it has been postulated that Type 2 processes have the potential to override automatic affective valuations when self-control resources are high. Type 2 processing might entail higher-level cognitive operations (Brand & Ekkekakis, 2018), such as weighing the pros and cons of behaviour change as expounded in SCT (Bandura, 1977, 1986, 1997, 2001). Hence, it is plausible that the addition of audio-visual stimuli might represent an additional advantage to engage in exercise. This is perhaps best illustrated by a participant of Study 1:

> If I was sitting here and somebody said "well, you know, we have our own music-video channel that has been specifically researched and it has particular music for particular times of the day, so if you're here at 9.00 am it's feel-good music but if

> you're here at 5.00 pm it's de-wind after your stressful day at work music", I mean that actually sounds quite cool. (Participant 3; interview)

The results obtained from the PACES (Kendzierski & DeCarlo, 1991) during Study 2 and Study 3 provide additional evidence that individuals derive enjoyment when exercise is accompanied by audio-visual stimuli. The finding that music can enhance exercise-related enjoyment has been identified in previous work (Jones et al., 2014; Stork et al., 2015). However, the studies contained in the present research programme represent preliminary attempts to gauge exercise-related enjoyment when using immersive VR technology. It is noteworthy that the top 3 PACES scores recorded across Study 2 and Study 3 all involved the use of immersive VR technology. These findings are particularly encouraging given the emerging link between exercise-related enjoyment and exercise adherence (Stork et al., 2015).

6.2.2 Attentional processing. One of the key mechanisms underlying the effects of audio-visual stimuli in an exercise context pertains to attentional processing (Karageorghis, Bigliassi, Guérin, et al., 2018). Drawing upon the work of Rejeski (1985) and Tenenbaum (2001), it has been suggested that audio-visual stimuli have the potential to occupy the limited capacity for attentional processing, thereby reducing the severity of unpleasant somatic sensations associated with fatigue (Hutchinson & Karageorghis, 2013; Hutchinson & Tenenbaum, 2007). It is important to note that the intensity of exercise plays a pivotal role in attentional processing. Indeed, it is progressively more difficult to hold a dissociative attentional focus as the intensity of exercise increases beyond fixed metabolic markers such as the VT and RCP (Ekkekakis, 2003; Tenenbaum, 2001). Nonetheless, dissociation is frequently included in conceptual frameworks that seek to expound the benefits of music in exercise and sport settings (e.g., Karageorghis, 2016; Terry & Karageorghis, 2006).

The qualitative findings from Study 1 indicate that audio-visual stimuli might prompt a dissociative attentional focus and this aligns with previous music-related qualitative research (Bishop et al., 2007; Hallett & Lamont, 2015). Moreover, congruent audio-visual stimuli (e.g., music-videos) appeared to influence attentional processing to a greater extent than other forms of audio-visual stimuli in which the audio and visual content were incongruent (e.g., sporting footage with music). This finding provides qualitative support for previous studies conducted within a laboratory, wherein music-videos prompted greater dissociation than rural parkland-based video footage with music accompaniment (Hutchinson et al., 2015; Jones et al., 2014). Importantly, both the Hutchinson et al. (2015) and Jones et al. (2014) studies involved exercising at 10% below VT, allowing for valid comparisons to be drawn between findings.

There was evidence to suggest that attentional dissociation was deemed desirable (e.g., "a positive distraction to what I'm doing" [Participant 2; interview]) and undesirable (e.g., "a distraction rather than a help" [Participant 4; interview]). The findings from Study 1 indicated that when attentional dissociation was deemed undesirable, it would very often result in reduced work output, which echoes previous research (e.g., "If you're watching the telly then you might not be going as fast you, trying to watch your pace and stuff so no, I don't watch the telly" [Hallett & Lamont, 2015, p. 9]. It is plausible that the extent to which an individual deems attentional dissociation to be desirable/undesirable is influenced, to a degree, by their dominant attentional style (i.e., associators, dissociators, attentional switchers; Hutchinson & Karageorghis, 2013).

Study 2 and Study 3 included the direct measurement of attentional focus using the AS (Tammen, 1996). The findings of Study 2 support a growing corpus of research indicating that audio-visual stimuli can facilitate more dissociative thoughts when compared to a sole stimulus (Chow & Etnier, 2017; Hutchinson et al., 2017). Participants reported slightly higher AS scores when they exercised with audio-visual stimuli delivered via a laptop ($M = 55.41$) when compared to music ($M = 52.04$) or video ($M = 47.87$). However, the same audio-visual footage administered via a VR HMD elicited significantly higher AS scores throughout the exercise bout (*M* = 64.30). This finding is noteworthy given that Study 2's protocol entailed exercising at VT, the point at which internal sensations begin to enter focal awareness (Ekkekakis, 2003; Tenenbaum, 2001). A likely explanation for the findings of Study 2 pertains to the degree of immersion afforded by VR HMDs. One of the fundamental features of immersion concerns the way in which VR technology occludes the participant from physical reality (Bailenson, 2018; Slater, 2018). Accordingly, it would have been extremely difficult for participants to avoid focusing their attention on the audio-visual stimuli while wearing the immersive VR HMD compared to viewing the stimuli on a laptop. The AS scores observed during Study 3 corroborated those of Study 2. Greater AS scores were observed during the VR (*M* = 68.02) and VR with music (*M* = 69.69) conditions when compared to music (*M* = 58.65) and control (*M* = 51.98). It is noteworthy that the AS scores observed in Study 3 were higher than those observed in the previous original study. Given that attentional processing narrows as a function of exercise intensity (Tenenbaum, 2001), it is plausible that the observed differences can be attributed to the slightly lower exercise intensity that participants were required to maintain in Study 3 (i.e., 10% below VT).

6.2.3 Research setting. While the measurement of affective responses and attentional processing represents two strong points of convergence within the present research programme, the research setting represents a notable point of divergence looking across the three studies. The author conducted Study 2 and Study 3 in a laboratory setting, which aligns with the vast majority of research that has sought to examine the effects of audio-visual stimuli in an exercise context (Barreto-Silva et al., 2018; Chow & Etnier, 2017; Hutchinson et al., 2015; Jones et al., 2014). However, this approach can be problematic when investigating the effects of technology within an exercise context, because such experiments rarely afford the research participant to engage with technology in a manner that is representative of real-world settings. To illustrate, during Study 2 and Study 3 the researcher remained on hand to pass the VR HMD to each research participant at precisely the point at which they were required to engage in exercise. The researcher had previously readied the 360-degree video (i.e., during Study 2) and the VR experience (i.e., during Study 3) to ensure that the audio-visual stimuli would coincide with the start of the exercise bout. While this approach was useful to establish causality in a highly controlled laboratory setting, it is unlikely that exercisers would have such assistance when engaging with VR technology in a real-world setting (i.e., they would need to handle/prepare the equipment themselves). Accordingly, this approach can be likened to a racehorse wearing blinkers; chaos may be ensuing in the race, but the horse's focus remains firmly fixated on the track ahead.

Study 1 was conducted in an exercise facility and made use of a music-video channel that is widely available via Freeview. Accordingly, a strength of Study 1 is its high-degree of external validity. Importantly, the analysis of Study 1 revealed that audio-visual stimuli had the potential to elicit several outcomes that can be considered to range from "desirable" to "undesirable" according to the degree in which participants appraised the content to be appropriate. It has been suggested that there is an abundance of research oriented towards the "enabling" qualities of audio-visual stimuli and that greater care should be taken to consider the degree to which audio-visual stimuli can have a deleterious effect (Dibben, 2017). To this end, it might be argued that Study 1 provides the most balanced account of how audio-visual stimuli influences the exercise experience. Although the research setting represents a point of divergence between Study 1 and Studies 2 and 3, displaying diversity in research methods is considered a significant strength of the present programme of research.

6.2.4 Towards a new theoretical model. Bearing the aforementioned similarities and differences into consideration, the researcher presents a theory herein that integrates the findings from each of the original studies that constitute the present programme of research (see Figure 6.1).

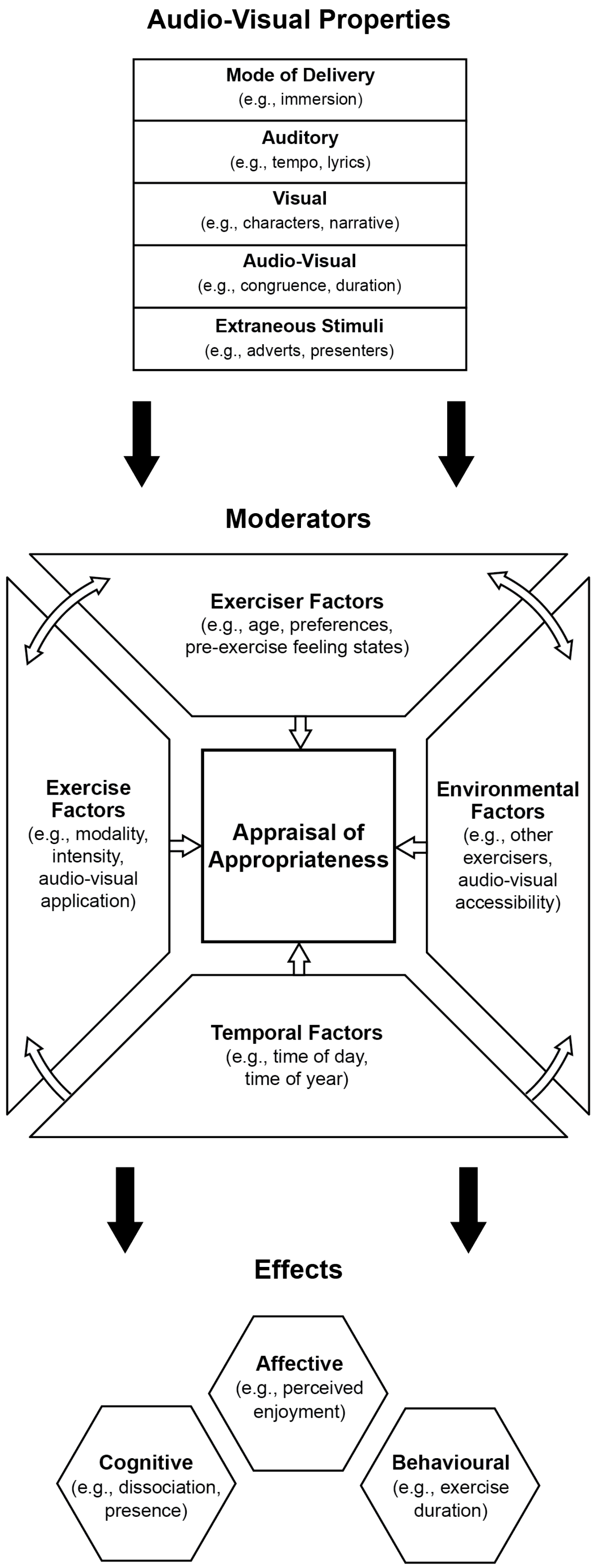

Figure 6.1. The use of audio-visual stimuli in the exercise domain: A theoretical model.

The theory is oriented towards the perspective of exercisers, given that exercise samples were integral to each study. The structure of the model largely follows that of the substantive theory proposed in Study 1 (see Figure 3.2). Specifically, the researcher theorises a three-stage process commencing with the audio-visual stimuli, passing through a series of moderators, and ending with a range of effects on individual exercisers. Nonetheless, the theory has evolved to accommodate the findings of Study 2 and Study 3.

To illustrate, the mode of delivery is now placed within the first stage of the model. The inclusion of this concept represents a notable departure from existing music-related conceptual frameworks (e.g., Clark, Baker, & Taylor, 2016b; Karageorghis, 2016), as greater emphasis is now placed on *how* to deliver audio-visual stimuli, in contrast to focusing solely on *what* to present individuals in an exercise context. It is paramount that researchers strive to examine the effects of audio-visual stimuli using a range of delivery modes given that the number of digital devices available to modern consumers continues to rise (see Figure 1.1).

Study 2 and Study 3 made use of a VR HMD, which is considered a more immersive form of technology in comparison to the traditional television screens used in Study 1, owing to the capacity of VR technology to allow perception through natural sensorimotor contingencies (Slater & Sanchez-Vives, 2016). Researchers have suggested that the higher the degree of immersion, the more likely an individual is to experience presence, which refers to the perceptual illusion of being inside a virtual environment (Slater, 2018). Accordingly, presence is included in the proposed theory as a cognitive effect of exercising with audio-visual accompaniment (see Figure 6.1).

Perhaps the most novel contribution of the proposed theory is that it originates from a programme of research that has incorporated mixed methods. Such an approach has emerged as a response to the "unproductive debates" concerning the advantages and disadvantages of quantitative vs. qualitative approaches to research (Feilzer, 2010, p. 6). Mixed methods are considered a powerful paradigm choice that often provides the most informative, complete, balanced, and useful research results (Johnson & Onwuegbuzie, 2004). Hence, an advantage of the proposed theory is that it provides a holistic account of the effects and contingencies of the use of audio-visual stimuli within an exercise context (Anguera, Camerino, & Castañer, 2012). The qualitative approach employed in Study 1 facilitated the acquisition of rich and thick data (Sparkes & Smith, 2014). An in-depth exploration of audio-visual stimuli from participants' perspectives was vital when identifying the factors that comprise an appraisal of appropriateness. Conversely, the quantitative approach adopted in Study 2 and Study 3 allowed for control of relevant factors in demonstrating the effects of several forms of immersive technology (e.g., television screens, VR HMDs) during exercise (Creswell, 2015). In accord with a pragmatist research philosophy (Morgan, 2014), the proposed theory can be used as a practical framework to facilitate the selection of audio-visual stimuli within an exercise context and to aid future research.

6.3 Limitations

It might be argued that asking a sample of exercisers to simultaneously complete diary sheets over a 4-week period does not strictly adhere to the iterative process of grounded theory that underpinned Study 1. However, the reader is urged to consider that it is possible to theoretically sample from existing data (Corbin & Strauss, 2015). Indeed, it is a common misconception that theoretical sampling equates to simply recruiting new participants at each stage of the analysis. Doing so would have required an additional 13 months to complete the study, which was not feasible. Rather, the 91 pages of diary entries were regarded as valuable sources of data and were used to facilitate information recalled during the semi-structured interviews. The music-video channel used in Study 1 was not curated for an exercise context. However, the researcher was constrained to the few channels that the exercise facility had access to.

Regarding Study 2 and Study 3, it might have been difficult to respond to the psychological scales (i.e., FS, FAS, AS, Borg CR10) while wearing a VR HMD. The researcher attempted to reduce the impact of this potential limitation by refamiliarising participants with the scales each time that they visited the laboratory. Moreover, the researcher administered the scales verbally for conditions that required the use of the VR HMD. This was done in the same order and using the same terminology to ensure full standardisation of the study protocol. Nonetheless, it is acknowledged that the behaviour of the researcher is a factor that might have influenced participants' responses to the self-report measures used during the present research programme (i.e., expectancy bias; Williams, 2008).

The sample employed in Study 2 and Study 3 consisted of young white females and males who had spent their formative years in the UK. Accordingly, the results of these studies should not be generalised without replication studies using a sample that is more fully representative of the general population. That said, the decision to employ a narrow sample for Study 2 and Study 3 was taken on the basis that the effects of auditory stimuli are highly influenced by personal factors, such as age and ethnicity (Clark, Baker, & Taylor, 2016b; Karageorghis, 2017). Another personal factor that has been proposed to influence the impact of music on the exercise experience is music preference (Hutchinson, Jones, et al., 2018). Participants in Study 2 and Study 3 were not afforded the opportunity to self-select the music used in experimental trials, which might be considered a limitation. However, a non-standardised approach to the selection of music for exercise has been suggested to pose a threat to internal validity (Jones et al., 2017). Hence, the researcher employed a panel to rate the motivational qualities of the music during Study 2 and adhered to the recommendations of Karageorghis (2017) to help select an appropriate piece of music for Study 3.

6.4 Practical Implications

Although there are several texts dedicated to the scientific application of music in exercise settings (Karageorghis, 2017; Karageorghis & Terry, 2011), guidelines for best practices concerning audio-visual stimuli are comparatively lacking. To this end, the substantive theory proposed in Study 1 can be used as a practical tool to help inform the selection of music-videos. It is recommended that music-videos channels should only be presented if they are deemed *appropriate* with respect to exerciser, exercise, environmental, and temporal factors. When selections are considered appropriate, the theory predicts that desirable effects will follow (e.g., positive affective states). Conversely, inappropriate selections are predicted to elicit undesirable effects (e.g., reduced exercise duration) that are likely to cause conflict between exercisers and members of staff.

In line with symbolic interactionism (Blumer, 1969), the substantive theory incorporates a dual perspective from individual exercisers and facility staff, which serves to enhance the practical utility of the model (see Figure 3.2). Accordingly, exercisers can use the concepts situated on the left-hand side of the model to consider the moderators (e.g., exercise factors) and the effects (i.e., affective, cognitive, behavioural) of music-video consumption. Conversely, facility staff can use the concepts on situated on the right-hand side of the model to appreciate the moderators (e.g., environmental factors) and implications (i.e., logistical, staff training, member related) of displaying a music-video channel in their facility.

Another practical implication to emerge from Study 1 concerns the identification of the music, video, and music-video components that are deemed salient within exercise settings. Researchers can draw upon such components when choosing music-videos for scientific investigations in order to fully justify their selections, as opposed to focussing solely on the motivational qualities of the music (e.g., Lin & Lu, 2013). Importantly, exercisers and facility staff are encouraged to recognise that music-video channels often contain additional audio-visual stimuli (e.g., celebrity news) that can be considered extraneous within an exercise context. Not only does this form of audio-visual stimuli have the potential to prompt undesirable outcomes, extraneous stimuli also appear to disrupt the audio and visual stimulation provided by music-videos.

Study 2 and Study 3 presents exercise professionals with evidenced-based options for rendering the exercise experience more pleasant at intensities at and proximal to VT. This intensity of exercise is likely to be experienced by countless individuals, including those from “at-risk” populations such as the obese or people with type 2 diabetes. Researchers have suggested that there is a lack of information pertaining to how exercise professionals can enhance affective responses to exercise and that the use of technology represents an important direction for future intervention research (Lewis et al., 2017; Zenko, Ekkekakis, & Ariely, 2016). Therefore, the results of the present programme of research appear timely. The importance of enhancing affective responses during exercise should not be underestimated, given the corpus of research linking affective responses to exercise adherence (Ekkekakis, Zenko, et al., 2018). An advantage of inserting audio-visual stimuli into the exercise environment pertains to its relative ease of implementation. Perhaps more importantly, this intervention has the added benefit that it is predicated on a behaviour that is firmly embedded within individuals’ daily functioning (i.e., engaging with technology).

From a practical perspective, it is important to highlight that not all exercise modalities are conducive to the consumption of audio-visual stimuli. Cycle ergometry was employed in Study 2 and Study 3 because it ensured that participants remained in a seated position and entailed relatively few degrees of freedom in terms of kinematics, thereby ensuring participants’ safety. This point is of paramount importance when audio-visual stimuli is delivered via VR HMDs, owing to the technologies capacity to occlude the user from their physical reality (Slater & Sanchez-Vives, 2016). Accordingly, it is recommended that individuals should be monitored when engaging with VR HMDs to reduce the likelihood of the occurrence of accidents. A reported side-effect of using VR HMDs is simulation sickness (Bailenson, 2018). Hence, it is advised that exercisers should engage with VR content for a predetermined time and schedule regular breaks to reduce the possibility of simulation sickness from occurring.

6.5 Future Directions

The present programme of research sought to further understanding of the effects of audio-visual stimuli within an exercise context. The findings of the research programme elucidate how audio-visual stimuli has the capacity to engender a range of affective, cognitive, and behavioural responses during exercise. Moreover, the findings serve as a catalyst for a variety of future research directions that are expounded herein.

6.5.1 Immersive technology. During Study 2 and Study 3, the researcher employed the use of immersive VR technology in order to encourage the psychological perception of presence (Slater, 2018), wherein individuals experience the virtual environment as their primary reality (Bailenson, 2018). It is possible that Study 3 facilitated greater perceptions of presence when compared to Study 2, owing to the fact that participants' leg movements (i.e., cycle ergometry cadence) directly influenced the visual stimuli delivered via the VR HMD. Nonetheless, future research might assess participants' perceptions of presence during VR scenarios as a means of furthering our understanding of this underlying mechanism (Witmer & Singer, 1998).

Researchers are encouraged to employ the latest commercially available technology in future work, in order to provide a contemporary account of the technology that individuals are engaging with in real-world settings. This is particularly important given the time associated with the peer review process that is required for the publication of research articles (Clark, Singleton-Jackson, & Newsom, 2000). For example, a study that was recently published in the *Journal of Behavioral Medicine* sought to examine the effects of a cycle ergometry exergame (Rhodes, Blanchard, et al., 2017). In an experimental condition, the researchers employed an exergame that used the Sony PlayStation 3, which launched in 2006 and was discontinued in 2016, rendering the findings obsolete prior to publication. Concerning the use of VR technology, researchers have suggested that "the most psychologically powerful medium in history is getting an alpha test on-the-fly, not in an academic lab but in living rooms across the globe" (Bailenson, 2018, p. 12), which emphasises the importance of research that uses cutting edge consumer technology. To this end, the researcher employed a contemporary VR-enabled cycle ergometer that was released 18 months prior to the start of Study 3 data collection.

Looking forward, researchers might strive to examine the potential of additional technologies to enhance the exercise experience, such as augmented reality and mixed reality. Such technologies do not fully occlude the user's physical reality and might be more suitable in an exercise context, where safety is an active concern. Perhaps the most salient example of an AR application that prompts physical activity is *Pokémon Go*, which has reportedly been played by tens of millions of users worldwide (Althoff, White, & Horvitz, 2016). This is a smartphone application that encourages users to walk around their environments, viewing the world through their cellular device, and using the smartphone to "catch" a variety of characters (LeBlanc & Chaput, 2017).

6.5.2 Affect-regulated exercise intensity. A key theme throughout the present programme of research is that the number of individuals engaging in regular physical activity remains low and that exercise-related affect has importance implications for future exercise behaviours (Ekkekakis, Zenko, et al., 2018; Williams, 2018; Williams et al., 2016). The DMT (Ekkekakis, 2003) was used to help select an appropriate exercise intensity for Study 2 (i.e., VT) and Study 3 (10% below VT). Alternatively, researchers have begun to examine the impact of regulating exercise intensity according to affective responses (Ekkekakis & Brand, 2019; Zenko, O'Brien, Berman, & Ariely, 2017).

Baldwin et al. (2016) conducted a randomised controlled trial in order to compare the efficacy of affect- and HR-regulated exercise prescriptions. Participants in the affect-regulated intensity group were told to exercise at an intensity that felt pleasant (i.e., at or above "0" on the FS [Hardy & Rejeski, 1989]). The findings indicated that the efficacy of the affect-regulated exercise prescription was moderated by cardiorespiratory fitness. After 1 week, participants with low estimated cardiorespiratory fitness displayed significantly greater levels of physical activity than those in the HR-regulated condition. After one month, the same pattern of results emerged albeit that the differences were nonsignificant. Accordingly, the findings indicate that affect-regulated exercise prescriptions might be particularly useful for adults with the least cardiorespiratory fitness (Zenko et al., 2017).

Researchers are beginning to employ affect-regulated exercise intensities in studies that seek to explore the influence of music. For example, Hutchinson et al. (2018) found that listening to music can prompt individuals to exercise with more intensity when compared to a no-music control, despite the instruction to maintain a “good” feeling throughout the exercise bout (i.e., maintaining a score of “3” on the FS [Hardy & Rejeski, 1989]). It is plausible that self-regulating exercise intensity might yield stronger perceptions of autonomy (Vazou-Ekkekakis & Ekkekakis, 2009; Williams, 2008), which is theorised to promote intrinsic motivation (Ryan & Deci, 2017). Accordingly, a fruitful direction for future research could entail an exploration into the effects of auditory, visual, and audio-visual stimuli on affect-regulated exercise.

6.5.3 Longitudinal effects of audio-visual stimuli. Empirical investigations concerning the long term-effects of audio-visual stimuli on exercise adherence are distinctly sparse (Karageorghis & Priest, 2012a, 2012b). Study 3 employed a VR-enabled cycle ergometer that comes with a range of games for users to enjoy. Hence, such technology can be labelled under the rubric “exergame”. While there is evidence to suggest that exergames can promote energy expenditure that is similar to moderate-intensity physical activity (Barnett, Cerin, & Baranowski, 2011), it has been suggested that the use of exergames declines over time, as users become familiar with the game design (Rhodes, Blanchard, et al., 2017). As VR HMDs become more widely accessible to the general population, it is plausible that the novelty of such devices might begin to wear off. Nonetheless, individuals are likely to continue using VR HMDs within an exercise context if the content compels them to do so.

It is well documented that individuals can become desensitised to motivational music if they are exposed to the same selections for a prolonged time period (Karageorghis & Priest, 2012a, 2012b). Accordingly, best practices advocate that individuals regularly update their selections in order to reduce the likelihood of desensitisation (Karageorghis, 2017). With respect to VR exergames, the challenge is for game developers to frequently release additional content as a means of sustaining high levels of engagement over time. Practically, this might entail the completion of weekly challenges to unlock cosmetic items (e.g., skins for avatars). Given that the VR-enabled cycle ergometer employed in Study 3 comes with a range of VR experiences, testing the effects of these over a prolonged time period represents a pragmatic extension to this line of scientific research. Future work might employ the use of the 7-Day PAR (Blair et al., 1985; Sallis et al., 1985), which has been shown to be reliable and valid when implemented with adults (Pereira et al., 1997).

6.5.4 Qualitative research. To the best of the researcher's knowledge, Study 1 in the present programme of research represents the first qualitative attempt to understand how audio-visual stimuli is implemented in an exercise context. Therefore, the knowledge base remains significantly dominated by research that is predicated upon quantitative methodologies. A qualitative approach allows for the exploration of behaviours, perspectives, and experiences of people in their daily lives (Sparkes & Smith, 2014). Given the ubiquity of audio-visual consumption within modern-day society (LeBlanc & Chaput, 2017), there is considerable scope for researchers to investigate the experiences of exercisers using qualitative research methodologies.

The author examined the influence of a music-video channel in Study 1. Hence, a logical extension to this study would be to explore the impact of other channels (e.g., news channels, sports channels) as a means of determining which is the most appropriate within an exercise context. A further layer of complexity might be achieved with the selection of a research site that has access to VR-enabled exercise equipment (e.g., *VirZOOM;*

NordicTrack) in addition to television screens as employed in Study 1. This would allow for a fulsome exploration into the possible role of immersion on the experience of exercise. Such work might entail a grounded theory approach (e.g., Corbin & Strauss, 2015), as this could facilitate the linking of substantial theories into a more formal grounded theory model (Corbin & Strauss, 2015; Weed, 2017). Alternatively, researchers might wish to conduct thematic analysis (e.g., Hallett & Lamont, 2015) or employ the use of open-ended questionnaires (e.g., Hallett & Lamont, 2017).

6.5.5 Generalisability. Additional research is required to examine the effects of VR HMDs using a range of exercise modalities (i.e., to go beyond easy-to-control cycle ergometry). As more companies develop innovative products and services that are predicated on VR, this will become a more viable line of scientific inquiry in the near future. For example, omnidirectional treadmills allow individuals to safely navigate virtual environments while using a VR HMD (Frissen, Campos, Sreenivasa, & Ernst, 2013). In addition to employing products that are commercially available, exercise psychologists might collaborate with relevant university departments, such as computer sciences, in order to develop customised content (Bird, 2019). However, it is noteworthy that this approach lacks ecological validity when compared to interventions that are commercially accessible to the general population.

The mainstay of research that has investigated the effects of audio-visual stimuli in exercise contexts has employed a young, healthy sample of individuals who often originate from a sport and exercise science background (e.g., Bird et al., 2016). A notable exception concerns a study by Hutchinson et al. (2017), who found that music and music-videos could engender more positive affective valance for elderly exercisers (M_{age} = 66.0 years) in a clinical exercise setting. Employing participants at the opposite end of the lifespan, Vazou, Mischo, Ladwig, Ekkekakis, and Welk (2019) reported that children (M_{age} = 10.39) derived higher levels of enjoyment during a novel exercise lesson, which included the use of audio-visual stimuli, when compared to a traditional lesson. Accordingly, it appears that audio-visual stimuli might be used to good effect to reverse the "cultural message that exercise is not fun and something that she [children] 'has' to do in physical education" (Vealey, 2006, p. 149). Nonetheless, there remains ample opportunity to test the efficacy of audio-visual stimuli with other populations than those contained herein. This is important because a range of personal factors (e.g., age, training status) are proposed to influence the effects of such stimuli within an exercise context (Karageorghis, 2017).

6.6 Conclusions

From the outset of the present programme of research, it was acknowledged that physical inactivity represents the greatest public health problem of our generation (Blair, 2009; Sallis, 2009; Trost et al., 2014). There are comparatively fewer opportunities to engage in physical activity when compared to our predecessors and individuals currently partake in a range of sedentary behaviours, many of which entail the use of screen-based technology (Castro et al., 2018; Päivärinne et al., 2018). It has been suggested that researchers should embrace the use of technology in order to devise innovative solutions that seek to promote physical activity (Gier et al., 2018; Lewis et al., 2017; Straker et al., 2018). To that end, the present programme of research sought to examine the effects of audio-visual stimuli during exercise, using immersive, commercially available technology. The findings detailed herein stand on the shoulders of an expansive corpus of literature that has examined the scientific application of music in an exercise context. Moreover, the outcomes are perhaps more relevant to today's exercisers, given that audio-visual stimuli are ubiquitous within the exercise domain (Karageorghis & Priest, 2012a, 2012b).

A substantive theory was proposed in Study 1 that sought to explain and predict the social process of exercising in the presence of a music-video channel. The theory can be used as a practical tool by exercisers and exercise facility staff alike as a means of enhancing the audio-visual selection process. With respect to individual exercisers, it appears that music-video channels can elicit a range of affective (e.g., positive affective valence), behavioural (e.g., enhanced work output), and cognitive (e.g., attentional dissociation) effects that are considered to range from desirable to undesirable, according to the extent in which the individual deems the content to be appropriate. Study 1 represented the first qualitative study to examine audio-visual stimuli within an exercise context and it appears that implementing such stimuli entails a more complex process than previously thought.

Study 2 embraced the use of 360-degree video footage administered via immersive VR technology and entailed exercising in a range of conditions to elucidate the effects of auditory and visual stimuli in tandem and singularly. The findings indicated the 360-degree video with music condition was associated with the most positive affective valence, highest perceived activation, largest number of dissociative thoughts, and greatest perceived enjoyment. These findings are of particular importance from a theoretical and applied perspective, given that participants exercised at VT, an intensity associated with considerable interindividual variability in affect (Ekkekakis, 2013a).

Although Study 2 employed 360-degree video, the focus of Study 3 was to provide a more immersive exercise experience with the inclusion of a VR-enabled cycle ergometer. The findings clearly demonstrated the efficacy of such technology, as conditions that entailed VR elicited the most positive affective valence, highest perceived activation, largest number of dissociative thoughts, and greatest perceived enjoyment. Using the work of Rejeski (1985) and Tenenbaum (2001) as a lodestar, it was theorised that VR HMDs induce a higher perceptual load when compared to more traditional forms of audio-visual stimuli delivery (e.g., video projection), thereby preventing exercise-related interoceptive cues from entering focal awareness. As a similarity to Study 2, the findings of Study 3 have positive implications for applied practitioners, given that the VR-enabled cycle ergometer employed in the study is readily available for consumers to purchase.

Taken holistically, the present body of work demonstrates that audio-visual stimuli can serve as a catalyst for several affective, cognitive, and behavioural effects during various exercise modes and intensities. Perhaps the most encouraging finding of the present programme of research concerns the capacity of audio-visual stimuli to enhance positive affective responses to exercise. These findings are timely given that researchers are beginning to recognise the importance of affective responses in shaping future exercise behaviour (Brand & Ekkekakis, 2018; Ekkekakis, Zenko, et al., 2018; Williams et al., 2018). It has been suggested that there is a need for interventions targeted at enhancing affective responses to exercise (Zenko, Ekkekakis, & Ariely, 2016). The addition of audio-visual stimuli within the exercise environment represents a cost-effective and easily implementable intervention. Moreover, individuals are extremely adept at consuming audio-visual stimuli, meaning that such interventions require little in the way of training.

Several lines of scientific inquiry have emerged from the present programme of research. Scholars are encouraged to examine the effects of immersive technologies (e.g., VR, augmented reality, mixed reality) within an exercise context. Investigators might employ longitudinal research designs to determine whether the effects detailed herein can translate to greater exercise adherence. Moreover, researchers might use qualitative methodologies such as grounded theory (Corbin & Strauss, 2015), as a means of facilitating a rich understanding of how immersive technology shapes the exercise experience. Lastly, future research might examine the effects of such technology with other populations, including the obese and people with type 2 diabetes.

It is particularly notable that in UK households, the most popular digital device are televisions (i.e., 95% ownership), while VR HMDs are situated at the opposite end of the spectrum, representing a new entry for 2018 (i.e., 5% ownership; Ofcom, 2018; see Figure 1.1). Given that the VR market is projected to expand at a considerable rate over the next 3 years (MarketWatch, 2018), it is likely that numerous products offering an immersive exercise experience will become available to consumers in the near future. Although more research is required to demonstrate the efficacy of such technology, the prospect of immersing individuals into virtual scenarios is exciting. After all, the applications are only as limited as one’s imagination.

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Bird, J. M., & Karageorghis, C. I. (2016, November). *The application of music-video in exercise: A grounded theory approach.* Paper presented at the British Association of Sport and Exercise Sciences (BASES) Conference, Nottingham, UK.

Bird, J. M., Karageorghis, C. I., Baker, S. J., & Brookes, D. A. (2018, November). *Effects of music, video, and 360-degree video on cycle ergometer exercise at the ventilatory threshold.* Poster presented at the College of Health and Life Sciences (CHLS) Conference, London, UK.

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Appendices

Appendix A: Approval Letter from Institutional Ethics Committee (Study 1)

Head of School of Sport & Education
Professor Ian Rivers

Brunel
UNIVERSITY
LONDON

Heinz Wolff Building,
Brunel University, Uxbridge,
Middlesex, UB8 3PH, UK
Tel +44 (0)1895 266494
Fax +44 (0)1895 269769
www.brunel.ac.uk

Jonathan Bird

16th June 2014

Dear Jonathan

RE58-13 A grounded theory of music and video accompanying exercise within exercise facilities

I am writing to confirm the Research Ethics Committee of the School of Sport and Education received your application connected to the above mentioned research study. Your application has been independently reviewed to ensure it complies with the University/School Research Ethics requirements and guidelines.

The Chair, acting under delegated authority, is satisfied with the decision reached by the independent reviewers and is pleased to confirm there is no objection on ethical grounds to grant ethics approval to the proposed study.

Any changes to the protocol contained within your application and any unforeseen ethical issues which arise during the conduct of your study must be notified to the Research Ethics Committee for review.

On behalf of the Research Ethics Committee for the School of Sport and Education, I wish you every success with your study.

Yours sincerely

pp Dr Richard J Godfrey
Chair of Research Ethics Committee
School Of Sport and Education

THE QUEEN'S ANNIVERSARY PRIZES
2011

Appendix B: Informed Consent (Study 1)

Brunel University London

Informed Consent
A Grounded Theory of Music-Video Accompanying Exercise Within Exercise Facilities

Please complete the whole of this sheet:

	Please tick the appropriate box YES	NO
Have you read the Research Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to? ______________________		
Do you understand that you will not be referred to by name in any report concerning the study?	☐	☐
Do you understand that you are free to withdraw from the study:		
- at any time?	☐	☐
- without having to give a reason for withdrawing?	☐	☐
- without affecting your future treatment?	☐	☐
I agree to my interview being recorded.	☐	☐
I agree to the use of non-attributable direct quotes when the study is written up or published.	☐	☐
Do you agree to take part in this study?	☐	☐

Signature of Research Participant:	**Date:**
Name in capitals:	
Study ID No:	

<u>Witness statement</u>
I am satisfied that the above-named has given informed consent.

Witnessed by:	**Date:**
Name in capitals:	

Researcher name:	**Signature:**

Appendix C: Written Consent to Access Research Site (Study 1)

CLC
SPORTS
CENTRE

CLC Sports Centre
Malvern Road
Cheltenham
GL50 2NX
Telephone (01242)
261346

I hereby provide written consent for Jonathan Bird to collect data at the CLC Sports Centre for his research entitled "A grounded theory of music-and-video accompanying exercise within exercise facilities", as supervised by Dr. Costas Karageorghis at Brunel University.

Jonathan has explained his proposed research and the measures that he wishes to use throughout his study and will provide me with a copy of ethical approval as and when it is granted.

Name in capitals: KIRK MAHON

Signed: K. Mahon

Position: OPERATIONS MANAGER

Date: 14/05/14

Appendix D: Participant Recruitment Poster (Study 1)

Appendix E: Participant Information Sheet (Study 1; Exercisers)

Brunel University London

Participant Information Sheet

Study title: A Grounded Theory of Music-Video Accompanying Exercise Within Exercise Facilities

Purpose of the study
To investigate the mental and physical effects of using music-videos to accompany exercise and the mechanisms that influence these effects.

Criteria for volunteering for the study
You can volunteer to participate in this study if you are aged 20–50 years. You should have experience in regularly exercising within the exercise facility at least twice a week and hold an active interest in music listening.

Description of procedures
After an initial meeting, you will complete a daily diary recording which music-videos you use to accompany exercise during a period of four weeks. The specifics will be explained further during the meeting. The contents of the diary will be discussed during a subsequent interview. For the interview, you will be required to identify two particularly memorable music-videos used when exercising, and you will complete a brief questionnaire about these videos and how they make you feel. The interview will last approximately 45 minutes and will be carried out by one interviewer. It will include questions relating to the qualities of the music-videos, the selections that you favour, and your perception of the influence of music-videos on your mental and physical state during exercise.

Potential risks of taking part
There are no known risks associated with this study.

Benefits to volunteers
The main benefits associated with taking part in the study are that it may further your knowledge of the impact that music-videos can have on exercise. The researcher will be pleased to provide you with articles on the subject matter once data collection has been completed.

Will my participation in this study be kept confidential?
Your identity will be coded and will not be revealed to anyone outside of the research team. You will be given a participant identification number.

What happens if I change my mind about participating?
You are free to withdraw from the study at any time, without giving a reason. You will not be penalized for not completing the study.

Who is organising the research?
The research is organised by researchers in the Department of Life Sciences at Brunel University London. If you have any questions about the project, please contact the lead researcher Jonathan Bird via email at jonathan.bird@brunel.ac.uk or his mobile phone on 07890-418 976.

When will the study begin?
The study will begin in January 2015 and conclude in August 2015. Your participation will span just four weeks.

This study has been reviewed and approved by the College Research Ethics Committee. *Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research.*

Appendix F: Demographic Questionnaire (Study 1)

Brunel University London

Demographic Questionnaire

Details About You

Surname: ______________________________ First name: ______________________________________

Age: ___________ years Sex: Male Female (please circle)

Means of contact if you would like a report on the findings: _____________________________________

____

Contact telephone number: ____

Nationality (e.g. British, French, Indian, Nigerian): ____

First language (e.g. English, French, Urdu, Mandarin): ____

Ethnic Background: (Please tick one of the following options)

White	Mixed	Asian or Asian British	Black or Black British	Chinese or Other Ethnic Group
British ☐	White and Black Caribbean ☐	Indian ☐	Caribbean ☐	Chinese ☐
Irish ☐	White and Black African ☐	Pakistani ☐	African ☐	
	White and Asian ☐	Bangladeshi ☐		
Any other White background (Please state)	Any other Mixed background (Please state)	Any other Asian background (Please state)	Any other Black background (Please state)	Any other ethnic group (Please state)

How would you describe your sexual orientation: ____
(e.g. Gay, Lesbian, Bisexual, Heterosexual etc.)

In which country did you attend secondary school? ____

Do you have a hearing or sight deficiency of any sort: Yes No (please circle)

Appendix G: Attentional Focus Questionnaire

Attentional Focus Questionnaire

Please place an "X" in the space that indicates how much you would engage in each of the following activities during exercise:

		would not do at all (1)						would do a lot (7)
1	Letting your mind wander (daydreaming)							
2	Monitoring specific body sensations (e.g., leg tension, breathing rate)							
3	Trying to solve problems in your life							
4	Paying attention to your general level of fatigue							
5	Focusing on how much you are suffering							
6	Singing a song in your head							
7	Focusing on staying loose and relaxed							
8	Wishing the exercise session would end							
9	Thinking about school, work, social relationships etc.							
10	Focusing on your performance goal							
11	Wondering why you are even exercising in the first place							
12	Making plans for the future (e.g., a shopping list)							
13	Getting frustrated at yourself over your performance							
14	Writing a letter or a paper in your head							
15	Paying attention to your form or technique							
16	Reflecting on past experiences							
17	Paying attention to your exercise rhythm							
18	Thinking about how much you want to quit							
19	Focusing on the surrounding environment							
20	Thinking about strategy or tactics							

21	Counting (e.g., objects in the environment)							
22	Monitoring how hard you are working							
23	Thinking about how much the rest of the exercise session will hurt							
24	Meditating (focusing on a mantra)							
25	Encouraging yourself to exercise							
26	Trying to ignore all physical sensations							
27	Concentrating on the exercise session							
28	Wondering whether you will be able to finish the exercise session							
29	Thinking about pleasant images							
30	Monitoring the time of the exercise session							

Brewer, B. W., Van Raalte, J. L., & Linder, D. E. (1996). Attentional focus and endurance performance. *Applied Research in Coaching and Athletics Annual, 11,* 1–14.

Appendix H: Participant Diary Sheet (Study 1)

Brunel University London

About your day: __/ __/ 2015

1. Which exercise were you performing when you listened/viewed music-videos?		**Try to think of the most memorable music-videos that you encountered within the exercise facility today:**
2. How did you feel BEFORE listening/viewing the music-videos?	1.	Track title Artist
3. What effect did the music-videos have on your feelings, if any?	2.	Track title Artist
4. What effect did the music-videos have on your behaviour, if any?	3.	Track title Artist
5. What effect did the music-videos have on your thoughts, if any?		**Additional comments**
6. What did you associate with these music-videos?		

Appendix I: Brunel Music-Video Rating Inventory

Brunel University London

Brunel Music-Video
Rating Inventory

The purpose of this questionnaire is to assess the extent to which the music-video you are about to watch and hear would facilitate your exercise experience. For our purposes, the term 'facilitate' means that you would enjoy the exercise session more, want to engage in it with greater intensity or keep at it for longer. After approx. 2 mins of watching and hearing the music-video, indicate the extent of your agreement with the statements listed below by circling one of the numbers to the right of each statement. We would like you to provide an honest response to each statement and the music-video will continue to run as you complete the inventory. Give the response that best represents your opinion and avoid dwelling for too long on any single statement.

	Music Aspect	**Strongly disagree**			**In-between**			**Strongly agree**
1	The rhythm of this music would facilitate my exercise session	1	2	3	4	5	6	7
2	The style of this music (i.e. rock, dance, jazz, hip-hop, etc.) would facilitate my exercise session	1	2	3	4	5	6	7
3	The melody (tune) of this music would facilitate my exercise session	1	2	3	4	5	6	7
4	The tempo (speed) of this music would facilitate my exercise session	1	2	3	4	5	6	7
5	The sound of the instruments used (i.e. guitar, synthesizer, saxophone, etc.) would facilitate my exercise session	1	2	3	4	5	6	7
6	The beat of this music would facilitate my exercise session	1	2	3	4	5	6	7

Please turn over ⇨

	Video Aspect	Strongly disagree		In-between			Strongly agree	
7	The setting/scene in this video would facilitate my exercise session	1	2	3	4	5	6	7
8	The central characters depicted in this video would facilitate my exercise session	1	2	3	4	5	6	7
9	The activities depicted in this video would facilitate my exercise session	1	2	3	4	5	6	7
10	The storyline depicted in this video would facilitate my exercise session	1	2	3	4	5	6	7
11	The colours used in this video would facilitate my exercise session	1	2	3	4	5	6	7
12	The lighting in this video would facilitate my exercise session	1	2	3	4	5	6	7
	Music-Video Aspects	**Strongly disagree**		**In-between**			**Strongly agree**	
13	The associations evoked by this music-video would facilitate my exercise session	1	2	3	4	5	6	7
14	The relationship between the music and the visual images would facilitate my exercise session	1	2	3	4	5	6	7
15	The distractive nature of the music-video would facilitate my exercise session	1	2	3	4	5	6	7
16	The stimulating nature of the music-video would facilitate my exercise session	1	2	3	4	5	6	7
17	The motivating nature of the music-video would facilitate my exercise session	1	2	3	4	5	6	7
18	The entertaining nature of the music-video would facilitate my exercise session	1	2	3	4	5	6	7

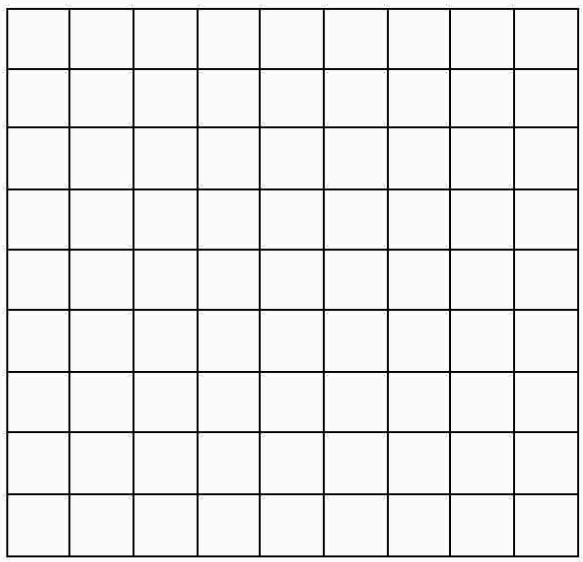
Appendix J: Affect Grid

Affect Grid

The purpose of the Affect Grid is to describe feelings. It is in the form of a square, a kind of map for feelings. The centre of the square represents a neutral, average, everyday feeling. It is neither positive nor negative. The vertical dimension represents the degree of arousal, which has to do with how wide awake or alert a person feels independent of whether the feeling is positive or negative. The bottom represents sleep, and the higher you go, the more awake a person feels. The right half of the grid represents pleasant feelings, the further to the right, the more pleasant. The left half represents unpleasant feelings, the further to the left, the more unpleasant. Please indicate on the grid how your chosen music-video makes you feel by placing an "X" in a corresponding square.

Stress **High Arousal** Excitement

Unpleasant Feelings



Pleasant Feelings

Depression **Sleepiness** Relaxation

Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect Grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*(3), 493–502. doi:10.1037/0022-3514.57.3.493

Appendix K: Participant Information Sheet (Study 1; Staff Members)

Brunel University London

Participant Information Sheet

Study Title: A Grounded Theory of Music-Video Accompanying Exercise Within Exercise Facilities

Purpose of the study
To examine how music-video channels influences the social dynamics of running an exercise facility.

Criteria for volunteering for the study
You can volunteer to participate in this study if you are a member of staff at the facility.

Description of procedures
You will be required to attend a one-off interview that will last approximately 45 minutes and will be carried out by one interviewer. It will include questions relating to music-videos, the selections that are favoured, and your perception of the influence of music-videos on members' mental and physical state during exercise.

Potential risks of taking part
There are no known risks associated with this study.

Benefits to volunteers
The main benefits associated with taking part in the study are that it may further your knowledge of the impact that music-videos can have on exercise. The researcher will be pleased to provide you with articles on the subject matter once data collection has been completed.

Will my participation in this study be kept confidential?
Your identity will be coded and will not be revealed to anyone outside of the research team. You will be given a participant identification number.

What happens if I change my mind about participating?
You are free to withdraw from the study at any time, without giving a reason. You will not be penalized for not completing the study.

Who is organising the research?
The research is organised by researchers in the Department of Life Sciences at Brunel University London. If you have any questions about the project, please contact the lead researcher Jonathan Bird via email at jonathan.bird@brunel.ac.uk or his mobile phone on 07890-418 976.

When will the study begin?
The study will begin in January 2015.

This study has been reviewed and approved by the College Research Ethics Committee. *Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research.*

Appendix L: Approval Letter from Institutional Ethics Committee (Study 2)

Brunel University London

College of Health and Life Sciences Research Ethics Committee (DLS)
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

3 March 2017

LETTER OF APPROVAL

Applicant: Mr Jonathan Bird

Project Title: Effects of music, video, and virtual reality on exercise

Reference: 4773-LR-Mar/2017- 6526-1

Dear Mr Jonathan Bird

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Christina Victor

Chair

College of Health and Life Sciences Research Ethics Committee (DLS)
Brunel University London

Page 1 of 1

Appendix M: Informed Consent (Study 2)

Brunel University London

Informed Consent

Environmental Influences on Exercise at the Ventilatory Threshold

Please complete the whole of this sheet:	***Please tick the appropriate box*** YES	NO
Have you read the Research Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to? ______________________________		
Do you understand that you will not be referred to by name in any report concerning the study?	☐	☐
Do you understand that you are free to withdraw from the study:		
- at any time?	☐	☐
- without having to give a reason for withdrawing?	☐	☐
- without affecting your future treatment?	☐	☐
Do you agree to take part in this study?	☐	☐
Signature of Research Participant:	**Date:**	
Name in capitals:		

Study ID No:	
Researcher name:	**Signature:**

Appendix N: Brunel Music Rating Inventory-3

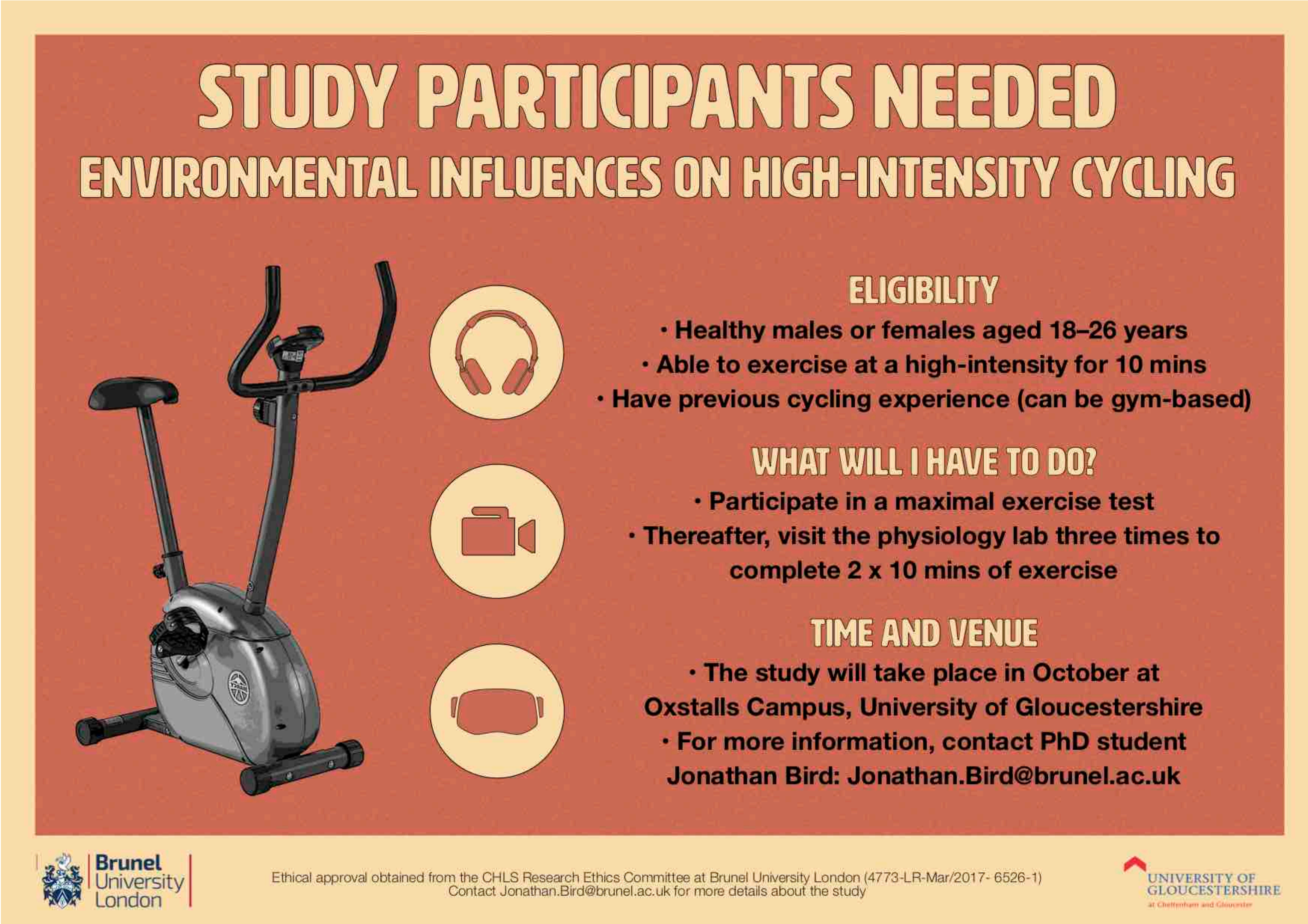
Brunel University London

Research into Preferred Music for Stationary Cycle Exercise- Brunel Music Rating Inventory (BMRI-3)

The purpose of the Brunel Music Rating Inventory is to assess the extent to which the piece of music you are about to hear would motivate you during moderate-to-high-intensity stationary cycle exercise. For our purposes, the word *motivate* means that you would want to engage in the stationary cycle exercise with greater intensity, stick at it for longer, or both. As you listen to the piece of music, indicate the extent of your agreement with the six statements by circling *one* of the numbers to the right of each statement. We would like you to provide an honest response to each statement. Give the response that best represents your opinion and avoid dwelling for too long on any single statement.

	Track 1	**Strongly disagree**			**In-between**			**Strongly agree**
1	The rhythm of this music would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7
2	The style of this music (i.e., rock, dance, jazz, hip-hop, etc.) would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7
3	The melody (tune) of this music would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7
4	The tempo (speed) of this music would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7
5	The sound of the instruments used (i.e., guitar, synthesizer, saxophone, etc.) would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7
6	The beat of this music would motivate me during stationary cycle exercise.	1	2	3	4	5	6	7

Appendix O: Participant Recruitment Poster (Study 2)



Appendix P: Physical Activity Readiness Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ______________________________ DATE ______________________

SIGNATURE OF PARENT ______________________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

Appendix Q: Feeling Scale

Feeling Scale

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Scientists have developed this scale to measure such responses.

+5 Very good

+4

+3 Good

+2

+1 Fairly good

0 Neutral

-1 Fairly bad

-2

-3 Bad

-4

-5 Very bad

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport & Exercise Psychology, 11(3),* 304–317. doi:10.1123/jsep.11.3.304

Appendix R: Felt Arousal Scale

Felt Arousal Scale

Estimate here how aroused you actually feel. Do this by pointing to the appropriate number. By "arousal" we meant how "worked-up" you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness.

1 LOW AROUSAL

2

3

4

5

6 HIGH AROUSAL

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality and Social Psychology, 48*(1), 107–116. doi:10.1037/0022-3514.48.1.107

Appendix S: Borg CR10 Scale

Borg CR10 Scale

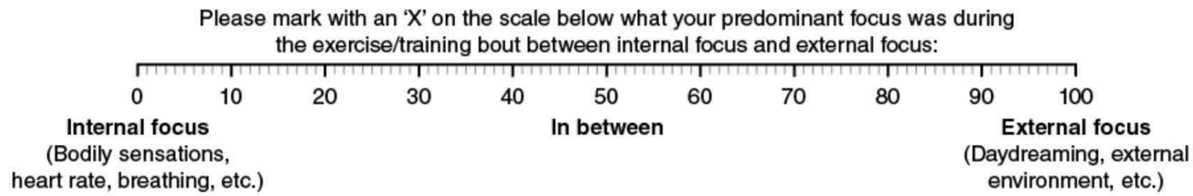
The RPE scale is used to measure the intensity of your exercise. The RPE scale runs from 0-11. The numbers below relate to phrases used to rate how easy or difficult you find an activity. For example, 0 (nothing at all) would be how you feel when sitting in a chair; 10 (extremely strong) is how you feel at the end of an exercise stress test or after a very difficult activity.

0	**Nothing at all**	
0. 3		
0.5	**Extremely weak**	**Just noticeable**
0.7		
1	**Very weak**	
1.5		
2	**Weak**	**Light**
2.5		
3	**Moderate**	
4		
5	**Strong**	**Heavy**
6		
7	**Very strong**	
8		
9		
10	**Extremely strong**	**"Maximal"**
11		
⇣		
●	**Absolute maximum**	**Highest possible**

Borg, G. (1998). *Borg's perceived exertion and pain scales.* Champaign, IL: Human Kinetics.

Appendix T: Attention Scale

Attention Scale



Tammen, V. V. (1996). Elite middle and long distance runners associative/dissociative coping. *Journal of Applied Sport Psychology, 8*(1), 1–8. doi:10.1080/10413209608406304

Appendix U: Physical Activity Enjoyment Scale

Physical Activity Enjoyment Scale
(PACES)

PACES

INSTRUCTIONS: Please rate how you feel at the moment about the physical activity you have been doing.

1.	I enjoy it	① ② ③ ④ ⑤ ⑥ ⑦	I hate it
2.	I feel bored	① ② ③ ④ ⑤ ⑥ ⑦	I feel interested
3.	I dislike it	① ② ③ ④ ⑤ ⑥ ⑦	I like it
4.	I find it pleasurable	① ② ③ ④ ⑤ ⑥ ⑦	I find it unpleasurable
5.	I am very absorbed in this activity	① ② ③ ④ ⑤ ⑥ ⑦	I am not at all absorbed in this activity
6.	It's no fun at all	① ② ③ ④ ⑤ ⑥ ⑦	It's a lot of fun
7.	I find it energizing	① ② ③ ④ ⑤ ⑥ ⑦	I find it tiring
8.	It makes me depressed	① ② ③ ④ ⑤ ⑥ ⑦	It makes me happy
9.	It's very pleasant	① ② ③ ④ ⑤ ⑥ ⑦	It's very unpleasant
10.	I feel good physically while doing it	① ② ③ ④ ⑤ ⑥ ⑦	I feel bad physically while doing it
11.	It's very invigorating	① ② ③ ④ ⑤ ⑥ ⑦	It's not at all invigorating
12.	I am very frustrated by it	① ② ③ ④ ⑤ ⑥ ⑦	I am not at all frustrated by it
13.	It's very gratifying	① ② ③ ④ ⑤ ⑥ ⑦	It's not at all gratifying
14.	It's very exhilarating	① ② ③ ④ ⑤ ⑥ ⑦	It's not at all exhilarating
15.	It's not at all stimulating	① ② ③ ④ ⑤ ⑥ ⑦	It's very stimulating
16.	It gives me a strong sense of accomplishment	① ② ③ ④ ⑤ ⑥ ⑦	It does not give me any sense of accomplishment
17.	It's very refreshing	① ② ③ ④ ⑤ ⑥ ⑦	It's not at all refreshing
18.	I felt as though I would rather be doing something else	① ② ③ ④ ⑤ ⑥ ⑦	I felt as though there was nothing else I would rather be doing

Kendzierski, D. & DeCarlo, K. J. (1991). Physical Activity Enjoyment Scale: Two validation studies. *Journal of Sport & Exercise Psychology, 13*(1), 50–64. Doi: 10.1123/jsep.13.1.50

Appendix V: Participant Information Sheet (Study 2)

Participant Information Sheet

Brunel University London

Study Title: Environmental Influences on Exercise at the Ventilatory Threshold

Researcher's name: Jonathan Bird (PhD student) **Email:** jonathan.bird@brunel.ac.uk

Telephone number: 07890-418 976

Purpose of the study
This study will aim to explore the effects of a range of audio-visual stimuli during exercise and immediately after exercise.

Criteria for volunteering for the Study
To volunteer for this study, you **must** fit all of the following criteria:

- Be 18-31 years of age.
- Be fit and healthy based on successful completion the Physical Activity Readiness Questionnaire (PAR-Q), engaged in some form of physical activity each week and confident that you would be able to exercise continuously at a relatively high-intensity for 10 mins. Possible reasons for not being able to do this are injuries, illness and lack of fitness. Please speak to the lead researcher in case that you require any clarification.
- Have previous cycling experience (can be stationary cycling in a gym).
- Have no visual or auditory impairment that is not corrected for (e.g., with contact lenses).

N.B. You are free to not respond to any questions regarding eligibility or any of the questions on the PAR-Q; however, if you fail to prove your eligibility for the study, you will not be able to volunteer.

Description of Procedures
You will be required to meet with the researcher in a University of Gloucestershire laboratory on **four** separate occasions. The dates and times will be arranged in such a way that they fit comfortably into your schedule. Kindly note that the 2nd, 3rd and 4th visits to the laboratory are required to be at the same time of day. During the first laboratory visit you will be familiarised with the experimental procedures and be administered a preliminary exercise test. Results of the test will inform the experimental procedure, which will take place over the subsequent three visits.

In preparation, you must ensure that you follow the instructions below on all four occasions:

- **Refrain from high-intensity training for 24 hours prior to testing**
- **Get adequate sleep the night before each visit to the laboratory**
- **Do not ingest caffeine (e.g., cups of coffee) on the day of the visit (i.e., prior to the visit)**
- **Maintain proper hydration on the day of the meeting (i.e., immediately prior to the visit)**
- **Do not consume alcohol on the day before the visit and immediately prior to the visit**
- **Do not consume food for at least 3 hours before testing**

If you do not feel that you can follow these four instructions, then do not volunteer for the study.

Preliminary Testing
The lead researcher will measure your height and weight and then introduce you to a range of scales and questionnaires that will be used during the experimental trials. You will be instructed to exercise briefly on a cycle ergometer while the researcher administers the scales that will be used during the experimental phase of the study. This is for familiarisation purposes only and your responses will not be used in the study analyses.

Thereafter, you will perform a maximal exercise test on the stationary cycle. This will involve you cycling at a set cadence, with the workload increasing in a progressive manner. Oxygen uptake and carbon dioxide production will be measured by use of a metabolic cart. Kindly note that you will be required to wear a headpiece that holds a breathing tube in place during the test. The exercise will continue until you reach volitional exhaustion (i.e., when you feel you can not continue cycling). Therefore, please be informed that you will be exercising at a very high intensity towards the end of this maximal test. Your *ventilatory threshold* (the point at which breathing becomes laboured) will later be determined by the lead researcher using computer software.

Intervention Testing
The 2nd, 3rd and 4th visits to the lab will require you to follow the same exercise protocol that is described herein. On arrival, you will be required to strap a heart rate monitor around your chest. Following a 2-min rest period, heart rate will be recorded and used as a resting value. Thereafter, you will warm-up on a stationary cycle by pedalling at a constant speed (65 rpm). You will then cycle continuously for 10 mins at *ventilatory threshold* (the point at which breathing becomes laboured) at a constant speed (75 rpm). The precise workload will have been calculated from the exercise test that you completed during your first visit to the lab. You will then perform a 5-min cool-down at 65 rpm. The workload for the warm-up and cool-down will be half of the weight used during the 10 min ventilatory threshold exercise. A brief series of scales and questionnaires will be administered throughout each experimental trial. There are six experimental conditions that will be presented to you: two on each of your three subsequent visits to the lab. All of the experimental methods are safe and non-invasive in nature.

Potential risks of taking part
When performing high-intensity exercise, there is an increased risk of having a cardiac episode (such as a heart attack) when compared to resting. However, the risk of a cardiac episode during exercise for young, fit and healthy volunteers is extremely low. If you think that you heart is unlikely to cope with the physical stress associated with high-intensity exercise, then you should certainly not volunteer for this study.

High-intensity exercise can be perceived as uncomfortable. However, as you are required to be fit and healthy to volunteer for the study, you will most likely have some experience of exercising at a high-intensity and know how this feels. If at any point during the experimental procedures you experience any of the following symptoms: loss of awareness, eye strain; eye or muscle twitching; involuntary movements; altered, blurred, or double vision or other visual abnormalities; dizziness; disorientation; impaired balance; impaired hand-eye coordination; increased salivation; nausea; light headedness; discomfort or pain in the head or eyes; drowsiness; fatigue; or any symptoms similar to motion sickness, you can ask the researcher to halt the procedures. There is absolutely no penalty associated with stopping or withdrawing from the experiment.

Benefits to volunteers
Volunteers can receive their maximal exercise test results (which are a strong indicator of cardiovascular fitness). If you would like to receive these results, please let the lead researcher know.

Will my participation in this study be kept confidential?
None of the information we collect will identify people by name. No names will be provided in any research reports or presentations that emanate from the study. In accordance with American Psychological Association guidelines, the information/data gathered from the research will be stored at Brunel University London for a period of 5 years and destroyed thereafter (i.e., shredded).

What happens if I change my mind about participating?
You are free to withdraw from the study at any time, without giving a reason. You will not be penalised for not completing the study. There is no course credit associated with your participation in this study.

Who is organising the research?
The research is organised by researchers in the Department of Life Sciences at Brunel University London. If you have any questions about the project, please contact the lead researcher Jonathan Bird via email at jonathan.bird@brunel.ac.uk or his mobile phone on 07890-418 976.

This study has been reviewed and approved by the College Research Ethics Committee.

Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research.

For complaints and questions about the conduct of the research contact:
Professor Christina Victor, Chair College of Health and Life Sciences Research Ethics Committee, E-mail: christina.victor@brunel.ac.uk

Appendix W: Demographic Questionnaire (Study 2)

Brunel University London

Demographic Questionnaire

Details About You

Surname: ______________________________ **First name:** ____________________________________

Age: __________________ years

Gender (please circle): Female Male

Contact Telephone Number: ____

Email Address: ____

Course of Study: ____

Level of Study (please circle): Undergraduate Postgraduate

Ethnic Group or Background (please specify): ____

[e.g., White, Mixed/Multiple ethnic groups, Asian, Black etc.]

Nationality (e.g. British, French, Indian, Nigerian): ____

First language (e.g. English, French, Urdu, Mandarin): ______________________________________

In which country did you attend secondary school? ____

Do you have a hearing or sight deficiency of any sort (please circle): Yes No

Height: ____

Weight: ____

Resting Heart Rate: _______________________________

Appendix X: Approval Letter from Institutional Ethics Committee (Study 3)

Brunel University London

College of Health and Life Sciences Research Ethics Committee (DLS)
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

23 May 2018

LETTER OF APPROVAL

Applicant: Mr Jonathan Bird

Project Title: Brain mechanisms that underlie the effects of motivational audiovisual stimuli during exercise

Reference: 10786-A-May/2018- 12761-1

Dear Mr Jonathan Bird

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Christina Victor

Chair

College of Health and Life Sciences Research Ethics Committee (DLS)
Brunel University London

Page 1 of 1

Appendix Y: Informed Consent (Study 3)

Brunel University London

College of Health and Life Sciences

Department of Life Sciences

Informed Consent

Environmental Influences on Exercise at Low-to-Moderate Intensity

Please complete the whole of this sheet:

	Please tick the appropriate box YES	NO
Have you read the Research Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Who have you spoken to? ______________________		
Do you understand that you will not be referred to by name in any report concerning the study?	☐	☐
Do you understand that you are free to withdraw from the study:		
- at any time?	☐	☐
- without having to give a reason for withdrawing?	☐	☐
Do you agree to take part in this study?	☐	☐

Signature of Research Participant:	**Date:**
Name in capitals:	

Study ID No:	
Researcher name:	**Signature:**

Appendix Z: Participant Recruitment Poster (Study 3)

Appendix AA: Participant Information Sheet (Study 3)

Brunel University London

College of Health and Life Sciences

Department of Life Sciences

Participant Information Sheet

Study title: Environmental Influences on Exercise at a Low-to-Moderate Intensity

Researcher's name: Jonathan Bird (PhD student) **Email:** jonathan.bird@brunel.ac.uk

Telephone number: 07890-418 976

Invitation paragraph
You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?
This study will aim to explore the effects of a range of audio-visual stimuli during exercise and immediately after exercise.

Why I have been invited to participate?
You have been invited to participate because you meet the following criteria:

- Be 18-35 years of age.
- Be fit and healthy based on successful completion the Physical Activity Readiness Questionnaire (PAR-Q), engaged in some form of physical activity each week and confident that you would be able to exercise continuously at a low-to-moderate intensity for 6 mins. Possible reasons for not being able to do this are injuries, illness and lack of fitness. Please speak to the lead researcher in case that you require any clarification.
- Have previous cycling experience (can be stationary cycling in a gym or at home).
- Have no visual or auditory impairment that is not corrected for (e.g., with contact lenses).

N.B. You are free to not respond to any questions regarding eligibility or any of the questions on the PAR-Q; however, if you fail to prove your eligibility for the study, you will not be able to volunteer. Approximately 25 volunteers will be involved in the present study. The number of participants has been derived by the research team as part of a statistical power analysis.

Do I have to take part?
As participation is entirely voluntary, it is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason. You will not be penalised for not completing the study. There is no course credit associated with your participation in this study.

What will happen to me if I take part?
You will be required to meet with the researcher in a University of Gloucestershire laboratory on **two** separate occasions. The dates and times will be arranged in such a way that they fit comfortably into your schedule. Kindly note that the second visit to the laboratory is required to be at the same time of day and 2–7 days after your first visit. During the first laboratory visit you will be familiarised with the experimental procedures and administered a preliminary exercise test. Results of the test will inform the experimental procedure, which will take place during the second visit.

Preliminary testing
On arrival, you will be required to strap a heart rate monitor around your chest. Resting heart rate will be recorded following a 3-min period of seated rest. The lead researcher will measure your height and weight and then introduce you to a range of scales and questionnaires that will be used during the experimental trials. You will be instructed to exercise briefly on a cycle ergometer while the researcher administers the scales that will be used during the experimental phase of the study (i.e., during your second visit). This is for familiarisation purposes only and your responses will not be used in the study analyses.

Thereafter, you will perform a graded exercise test on the stationary cycle. This will involve you cycling at a set cadence (speed), with the workload increasing in a progressive manner. The exercise will continue until your heart rate reaches ~145 bpm. Therefore, please be informed that you will be exercising at a moderate intensity towards the end of this graded test. Your *ventilatory threshold* (the point at which breathing becomes laboured) will later be determined by the lead researcher using computer software.

Experimental testing
On arrival for your second visit, you will be required to strap a heart rate monitor around your chest. Once resting heart rate has been assessed, you will warm-up on a stationary cycle for 3-min by pedalling at a constant speed (75 rpm). You will then cycle continuously for 6 min at ~10% below *ventilatory threshold* (the point at which breathing becomes laboured) at a constant speed (75 rpm). The precise workload will have been calculated from the exercise test that you completed during your first visit to the lab. You will then perform a 3-min warm-down at 75 rpm. The workload for the warm-up and warm-down will be 25% below ventilatory threshold. A brief series of scales and questionnaires will be administered throughout each experimental trial. There are four experimental conditions that will be presented to you, each separated by a 10-minute rest period. All of the experimental methods are safe for healthy young adults and non-invasive in nature.

What do I have to do?
In preparation, you must ensure that you follow the instructions below on both occasions:

- **Get adequate sleep the night before each visit to the laboratory**
- **Do not ingest caffeine (e.g., cups of coffee) on the day of the visit (i.e., prior to your visit)**
- **Maintain proper hydration on the day of the visit (i.e., immediately prior to the visit)**
- **Do not consume alcohol on the day before the visit and immediately prior to the visit**

If you do not feel that you can follow these four instructions, then you are kindly requested not to volunteer for the study.

What are the possible disadvantages and risks of taking part?
When performing exercise, there is an increased risk of having a cardiac episode (such as a heart attack) when compared to resting. However, the risk of a cardiac episode during exercise for young, fit and healthy volunteers is extremely low. If you think that your heart is unlikely to cope with the physical stress associated with moderate-intensity exercise, then you should certainly not volunteer for this study.

Moderate-intensity exercise *can* be perceived as uncomfortable. However, as you are required to be fit and healthy to volunteer for the study, you will most likely have some experience of exercising at a moderate intensity and know how this feels. If at any point during the experimental procedures you experience any of the following symptoms: loss of awareness, eye strain; eye or muscle twitching; involuntary movements; altered, blurred, or double vision or other visual abnormalities; dizziness; disorientation; impaired balance; impaired hand-eye coordination; increased salivation; nausea; light headedness; discomfort or pain in the head or eyes; drowsiness; fatigue; or any symptoms similar to motion sickness, you can ask the researcher to halt the procedures. There is absolutely no penalty associated with stopping or withdrawing from the experiment.

What are the possible benefits of taking part?
Volunteers can receive their graded exercise test results. Should you wish to receive these results, please let the lead researcher know.

What if something goes wrong?
If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action, but you may have to pay for it.

For complaints and questions about the conduct of the research contact:
Professor Christina Victor, Chair College of Health and Life Sciences Research Ethics Committee, E-mail: christina.victor@brunel.ac.uk

Will my participation in this study be kept confidential?
None of the information we collect will identify people by name. No names will be provided in any research reports or presentations that emanate from the study. In accordance with American Psychological Association guidelines, the information/data gathered from the research will be stored at Brunel University London for a period of 5 years and destroyed thereafter (i.e., shredded).

What will happen to the results of the research study?
The research data will be coded (for anonymity) and analysed by the researcher(s) before being reported. The results will be used primarily in a PhD thesis and may be later reported at a conference or in a scientific journal. The anonymised research data may also be shared with other researchers for further analysis, but at no point will any uniquely identifiable data be shared. If you take part in this research, you can obtain a copy of the publication by contacting the researcher.

Who is organising and funding the research?
The research is organised by researchers from the Department of Life Sciences at Brunel University London. If you have any questions about the project, please contact the lead researcher Jonathan Bird via email at jonathan.bird@brunel.ac.uk or his mobile phone on 07890-418 976. The research is not receiving any external funding.

What are the indemnity arrangements?
Brunel University London holds insurance policies which apply to this study. If you can demonstrate that you experienced harm as a result of your participation in this study, you may be able to claim compensation. Please contact Prof Peter Hobson, the Chair of the University Research Ethics committee (Peter.hobson@brunel.ac.uk) if you would like further information about the insurance arrangements which apply to this study.

Who has reviewed this study?
This study has been reviewed and approved by the College Research Ethics Committee.

Research integrity
Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from our researchers during the course of their research.

Contact for further information and complaints
If you have any questions about the project, please contact the lead researcher Jonathan Bird via email at jonathan.bird@brunel.ac.uk or his mobile phone on 07890-418 976. Dr Costas Karageorghis is supervising this piece of research (costas.karageorghis@brunel.ac.uk). For complaints and questions about the conduct of the research contact: Professor Christina Victor, Chair College of Health and Life Sciences Research Ethics Committee, E-mail: christina.victor@brunel.ac.uk

Appendix AB: Demographic Questionnaire (Study 3)

Brunel University London

Demographic Questionnaire

Details About You

Surname: ______________________________**First name:** ____________________________________

Age: __________________years

Gender (please circle): Female Male

Contact Telephone Number: ____

Email Address: ____

Course of Study: ____

Level of Study (please circle): Undergraduate Postgraduate

Ethnic Group or Background (please specify): ____

[e.g., White, Mixed/Multiple ethnic groups, Asian, Black etc.]

Nationality (e.g. British, French, Indian, Nigerian): ____

First language (e.g. English, French, Urdu, Mandarin): ______________________________________

In which country did you attend secondary school? ____

Do you have a hearing or sight deficiency of any sort (please circle): Yes No

Height: ____

Weight: ____

Resting Heart Rate: _______________________________

Appendix AC: Liking Scale

Brunel University London

College of Health and Life Sciences
Department of Life Sciences

Liking Scale

Rate how much you like this audio/visual/audio-stimuli in the context of low-to-moderate intensity stationary cycling.

1 I do not like it at all

2

3

4

5

6

7

8

9

10 I like it very much