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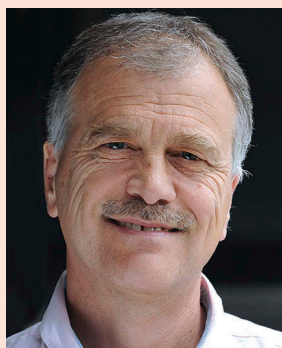
SPORT | RESEARCH ARTICLE

Wearable technology-stimulated social interaction for promoting physical activity: A systematic review

Vassil Girginov^{1*}, Philip Moore², Nils Olsen³, Tarryn Godfrey⁴ and Frances Cooke³

Abstract: Wearable technology has become increasingly popular and available since the mid-2000s, raising hopes for new and innovative ways to address long-standing issues of physical inactivity that have plagued modern societies. Despite growing interest in the field and a voluminous body of literature, analyses of wearable technology-induced social interactions and their effect on people's physical activity are virtually non-existent. This systematic review addressed the question "Does wearable technology enhance social interactions and subsequent physical activity?" The review covered studies published between 2007 and December 2018 and was conducted in accordance with PRISMA guidelines. Searches were performed within 12 databases, and a total of 3,426 sensitivity publications were identified, but only 136 (4%) met the specificity criterion, and 20 publications were included in the review. The results revealed that: (i) wearable technology has the potential to both motivate and demotivate individuals to

ABOUT THE AUTHOR



Vassil Girginov

The present study is part of a larger project investigating the role of wearable technology for promoting physical activity conducted by the members of the research team based at Brunel University London and George Washington University. The first stage of the project included a series of three research seminars held in 2018–2019 in the UK; the second stage reports the results of a systematic review of literature on the subject (i.e., present study), and the third stage of the project involves submitting a grant application which, if successful, will allow for empirically establishing the effects of wearable technology on social interactions and ultimately people's behaviour. The project carries important theoretical and practical implications for researchers and health and physical activity professionals.

PUBLIC INTEREST STATEMENT

Wearable technology has become increasingly popular raising hopes for innovative ways to address long-standing issues of physical inactivity that have plagued modern societies. Despite years of research, analyses of wearable technology-induced social interactions and their effect on people's physical activity are virtually non-existent. This study addressed the question "Does wearable technology enhance social interactions and subsequent physical activity?" The results revealed that: (i) wearable technology has the potential to both motivate and demotivate individuals to engage in physical activity; (ii) interactions stimulated by wearable technology included mainly cooperation, competition and social recommendations; and (iii) those interactions are temporary, physically organised, and can be repeated in different contexts. Wearable technology also tend to be responsible for two important tacit transformations including being used for personal/group self-actualisation to a competitive environment encouraging real-time physical and virtual contests, and for framing physical activity as a mainly personal problem by shifting the responsibility for healthy and active living from professional agencies to the individual.

engage in PA; (ii) interactions are made up of at least three main activities, including cooperation, competition and social recommendations, which is a rather limited spectrum of activity; and (iii) those interactions are temporary, physically organised, and can be repeated in different contexts. Wearable technology also tend to be responsible for two important tacit transformations including being used for personal/group self-actualisation to a competitive environment encouraging real-time physical and virtual contests, and for framing physical activity as a mainly personal problem by shifting the responsibility for healthy and active living from professional agencies to the individual. The social and economic implications of such a shift would be profound.

Subjects: Sport and Exercise Science; Sports Development; Sport and Leisure Management

Keywords: physical activity and sport; real-time and virtual contests; social interactions; tacit transformations; wearable technology

1. Introduction

Wearable technology (WT) has become increasingly popular and available since the mid-2000s, raising hopes for new and innovative ways to address long-standing issues of physical inactivity that have plagued modern societies (Friedrich, 2017). Wearable technology (i.e., technology worn on the body) such as smartphones, smartwatches, wristbands and smart textiles are self-tracking tools capable of monitoring vital signs, weight, fitness, sleep, diet, emotions and even social interactions. Recent estimates suggest that there are over 500 such self-tracking tools and approximately 325,000 mHealth (mobile health, or the use of mobile devices to collect information and educate consumers about preventive healthcare services) applications, 44,384 of which are available in the Apple App store alone, and a global market worth 37 USDb in 2019 (Aitken & Gauntlett, 2013; Milculic, 2019). Björnsjö et al.'s (2014) global survey including the USA, UK, Germany, India, China and Japan found that 8% of individuals aged 11 to 55 owned a wearable fitness monitor and 6% owned a wearable health device.

Wearable technology has also become increasingly important to health researchers, providers and policy makers. Given its ability to continuously monitor biological, behavioural, and environmental outcomes, wearable technology provides an ideal platform for delivering and assessing health-related interventions, including those focused on physical activity. For example, it can be used to measure heart rate, galvanic skin response, and allow documenting activities on cameras, as well as geo-sensors (GPS) for tracking exact geographic movements of participants. Such technologies allow performance monitoring of aspects related to health and physical activity with high precision and sampling frequency and over longer time periods than more traditional methods. Wearable technologies are also well suited not only for self-assessment aspects of behaviour but also for delivering digitised interventions.

Lomborg and Frandsen (2016) noted that the application of self-tracking has been studied in the context of health care, interaction design and systems development research, and its implications have been discussed under a critical-sociological lens in terms of surveillance, labour and loss of privacy. There have been several systematic reviews around the topic of wearable technology and health/physical activity/sport (Adesida et al., 2019; Chambers et al., 2015; Edwards et al., 2016; Lynch et al., 2019; Müller et al., 2016), including one registered on the Prospero systematic reviews data base (Stephenson et al., 2017). While these reviews offer valuable insights about the current state of research in the field, none of them addresses the relationship between wearables, PA and social interactions. Moreover, analyses of wearable technology-induced social interactions and their effect on people's physical activity are virtually non-existent. This is an important aspect of technology, for information from customers' use of wearables could be combined with healthcare

and physical-activity delivery systems to provide information about the meaning people attach to wearables, and to better tailor these and other interventions. As Petticrew and Roberts (Petticrew & Roberts, 2008, p. 198) conclude, “The systematic review is a method of critically appraising, summarizing, and attempting to reconcile the evidence on a particular problem” and one of its main benefits is that it provides a synthesis of studies in a particular field which sport policy makers and practitioners cannot realistically follow and evaluate themselves.

2. Unpacking the key concepts

This study explores the relationship between three key concepts including wearable technology, social interactions, and physical activity and thus it is important to define them before the analysis proceeds further. Global comparative use of the search terms “wearable technology”, physical activity’ and “social interactions” on Google search engine suggests that global interest in these three terms varied over the five-year period (May 2014– May 2019) but follows similar patterns with PA being a far more searched term at the time that these data were collected. When examining the interest for the same three concepts but as topics (as opposed to terms), it transpires that both WT and PA have been searched-for far more regularly than social interactions.

2.1. Wearable technology

The conceptual meaning of WT goes well beyond that of a self-tracking tool. Lupton (2016) defines self-tracking as “practices in which people knowingly and purposefully collect information about themselves, which they then review and consider applying to the conduct of their lives” (p. 2). Personal informatics, or more broadly data collection, therefore, represents the essence of the self-tracking movement which has been captured by the term “quantified self”. In the words of Wolff and Kelly (2014), who coined the term, the aim of the “quantified self” movement “is to help people get meaning out of their personal data”. More specifically, the “quantified self” movement seeks to replace intuition and emotions with quantified data and emphasizes the power of numbers. Proponents of the movement claim that numbering things allows for the development of tests, comparisons and experiments (Lupton, 2016).

In combination—tests, comparisons and experiments—constitute the essence of the process of knowledge creation. According to Nonaka and Takeuchi (1995), the knowledge creation process includes four interrelated stages known as the SECI model. It starts with *socialisation* (S) where people share tacit knowledge through observation, imitation, practice and participation in formal and informal communities. Socialisation in the context of the present study usually takes place in a physical or virtual space, where sports clubs, centres and gyms represent the typical locations for such interactions. Online forums offered by wearable industry leaders such as Fitbit, Apple, Jawbone and others are examples of virtual spaces for interactions. The second stage is *externalisation* (E) where tacit knowledge is articulated into explicit knowledge. The key aspect of this process is the dialogue where individuals commit to the group, and thus help transfer individual knowledge into group knowledge. The third stage is that of *combination* (C), in which organisations—including sports authorities and wearable technology producers—develop and incorporate the knowledge of their members. Finally, *internalisation* (I) is the process of converting organisational knowledge (i.e., owned by sports authorities and technology providers) into individual knowledge. A key feature of the SECI model relevant to this study is the central place afforded to interactions as the main mechanism for knowledge creation. Interactions are critical for conducting tests, comparisons and experiments, the main outcome of which is the creation of new knowledge. Self-tracking also has significant social implications, and as Lupton (2013a) observes “In a social context in which self-management for optimising one’s life is idealised and rewarded, those who fail to do so are disadvantaged both in terms of financial costs and in attracting moral judgements from others” (p. 18).

2.2. Social interactions

While wearables are essentially personal devices designed to provide cognitive feedback on one’s physical activity and on a range of bodily functions, they also offer several opportunities for social

interaction. Social bonds are necessary for people's optimal psychological functioning, and the need for these connections provides the stimulus for social interactions (Ryan et al., 1995). The need to belong urges individuals to seek out interpersonal contacts and cultivate relationships with other people.

Social interactions are central for engagement with any physical activity, and they largely determine what people do in this domain, and how they do it. Turner (1998, p. 13–14) defines social interactions as “the process whereby the overt movements, covert deliberations, and basic physiology of one individual influence those of another and vice versa” (p. 14). Therefore, social interactions present a unique situation where the behaviours of one actor are consciously recognised by another actor who then interprets them and reacts either overtly or covertly.

There is an extensive body of literature on how people interact and develop relationships across contexts in everyday life, both on and off digital media (e.g., Boyd, 2008; Ellison et al., 2007; Lomborg, 2014; Wellman & Haythornthwaite, 2002). Lomborg and Frandsen (2016) approached self-tracking from a communication perspective and suggested that “communication is predominantly a means of achieving a common practice and shared understanding of the situation at hand, of maintaining social order and thus finding meaning and pleasure in a sense of belonging” (p. 18). This statement illustrates a central aspect of PA concerned with establishing one's sense of belonging and social recognition. In the context of the present study, wearable technology offers enhanced affordances for social interactions. As Lomborg and Frandsen (2016) explicated “the practice of communicating with others implies an ongoing negotiation of what is appropriate, relevant and expected to be communicated in a given context and with a given set of people” (p. 18).

Social interactions also have important economic implications. Downward and Riordan (2007) highlighted the central role of social interaction in shaping people's involvement with sport, and contended that social interactions—reflected in the development of lifestyles—are essential to the popular demand for sports, and that these processes can be understood as the accumulation of personal and social capital, respectively. Social interactions help further develop social networks where members of the network affect the relationship quality by offering opportunities, information, and support (Sprecher et al., 2002). These networks can be real (where members engage in physical interactions by attending the same group or event), or virtual (including social network sites (SNS) such as Facebook, Twitter or wearable device firms' own websites). Boyd and Ellison (2007) define SNS as “web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system”.

Social interactions have three interrelated properties including motivational, interactional, and structuring (Turner, 1988). The *motivational* aspect refers to how it affects the process of interaction. The *interactional* processes concern what people actually do when they influence each other. The *structuring* processes “denote the fact that social interactions are often repeated across time as well as organised in physical space” (p. 16).

2.3. Physical activity

Physical activity (PA) is a socially constructed umbrella term which refers to certain values, beliefs, practices and behaviours, and can be defined as “any bodily movement produced by skeletal muscles that requires energy expenditure” (World Health Organisation [WHO], 2015). Physical activity covers a wide range of bodily movements, including informal activities such as walking, running, dancing, exercising, and playing, as well as formal activities of physical training, practicing and competing experienced within the framework of set rules, fixed environments, norms and competition structures. Both formal and informal forms of PA provide participants with a site to develop mutual close social relationships, and to validate their sense of self by gaining social

status and recognition. Personal identities, social status and recognition are central determinants of people's involvement with PA and sport. This study concerns all forms of PA, regardless of the purpose of the activity, the level of participation, and the age, gender or abilities of participants.

Evidence for the impact of wearables on physical activity is mixed, with some studies findings positive associations (Butte et al., 2012; Helbostad et al., 2016; Muntaner-Mas et al., 2016), while other results were less positive (Baker et al., 2017; Jakicic et al., 2016; Kerner & Goodyear, 2017). Piwek et al. (2016) noted that a key weakness of existing studies is their reliance on the subjective experiences of small participant samples. Piwek et al. also cited the often-temporary nature of WT use, noting that 32% of users reported stopping their use of WT devices after six months, and 50% after one year.

3. Method

The overall aim of this systematic review was to understand the meaning people attach to their social interactions that have been stimulated by their use of wearable technology. More specifically, the study addressed the following main research question "Does wearable technology enhance social interactions that in turn affect people's physical activity?" The study, therefore, does not aim to establish the effectiveness of WT on people's level of physical activity, nor on their level of satisfaction with these devices. These questions had been addressed by others.

This review was conducted and reported in accordance with PRISMA guidelines (Moher et al., 2009), and the protocol is presented below. This review also followed Petticrew and Roberts (2006) detailed practical guide for conducting systematic reviews, and comprised four interrelated stages including studies identification, screening, eligibility and inclusion (see Table 1). The review protocol was independently peer-reviewed by a scholar with extensive experience in the field, two heads of research for the leading sport organisation in England, and a global market research company. Review feedback was used to refine the study protocol.

3.1. Search eligibility criteria

This review employed six eligibility criteria for inclusion. Studies were included if they (i) followed qualitative, survey, case study, and control trials design, as well as similar systematic reviews; (ii) included population of any age, gender, ethnicity and background; (iii) examined any level and form of physical activity; (iv) were using wearables such as smart watches, wristbands, phones and textiles (smart clothing); (v) analysed on-line and off-line interactions including participation in chat forums, campaigns, activity groups, gyms, leisure/sport clubs and centres, events, and studies; and (vi) were published in English.

The *primary outcome* of this review was objectively or subjectively documented cognitive/social interactions (stimulated by possessing a wearable) that resulted in: (i) changing PA behaviour and/or in engaging with other people; (ii) impacting on one's interpretations of their PA and health; and

Table 1. Flowchart for the selection of studies on wearable technology-stimulated social interactions promoting physical activity

Identification	Records identified through database searching (n = 3,422)	Additional records identified through other sources (n = 4)
	Records after duplicates removed (n = 3,211)	
Screening	Records screened by title and abstract (n = 3,211)	Records excluded (n = 3,075)
Eligibility	Full-text articles assessed for eligibility (n = 69)	Full-text articles excluded with reasons (n = 67)
Included	Studies included in the review (n = 20)	

(iii) repeated and organised actions with others across time and space. The *secondary outcome* included the (i) number of wearable users and (ii) depth and forms of social interactions.

3.2. Search strategy

Two teams of two researchers undertook a systematic search in which the results from the initial search were reviewed independently by each researcher, and then compared before a selection was made. Searches were performed within the following databases: Scopus, Medline, Psychinfo, PubMed, Sports Discuss and Web of Science. The grey literature databases included: COPAC, Dissertation abstracts; Index to Social Sciences and Humanities Proceedings and Mintel. In addition, the PROSPERO (University of York <https://www.crd.york.ac.uk/prospero/>) database was consulted for relevant studies. The search covered studies published between 2007—when Nike+iPod launched the first fitness tracking application—and December 2018.

For each database, search terms were combined with the appropriate Boolean Operators: wearable technology AND physical activity; AND sport; AND social interactions; AND exercise; AND social influence. Those words were used also in combination including WT, PA, sport and exercise and social interaction/influences. Studies concerning the accuracy and reliability of wearable technology as well as their use for enhancing athletes' performance, the effectiveness on people's level of physical activity and their level of satisfaction with the device were excluded from the selection. There were disagreements between authors over the inclusion of three studies. These were resolved by re-reading the papers by four members of the research team and ensuring that all inclusion criteria were met. As a result, a consensus was reached and the three studies in question were excluded from the final list.

3.3. Quality appraisal

The review followed the principles of critical interpretive synthesis to inform the data synthesis, as proposed and evidenced by Dixon-Woods et al. (2007). The authors examined the application of three structural approaches for appraising qualitative research and concluded that structured approaches did not appear to yield higher agreement than that by unprompted judgement. Critical interpretive synthesis (CIS) is not a formal method for critically appraising the quality and methodological rigour of included studies. Rather, it recognises that the critical evaluation and integration of disparate forms of evidence is essentially a product of the authorial voice. As Dixon-Woods et al. (2006, p. 10) elaborated "CIS does not aim to offer a series of pre-specified procedures for the conduct of review. It explicitly acknowledges the 'authorial voice'; that some aspects of its production of the account of the evidence will not be visible or auditable; and that its account may not be strictly reproducible. Its aim is to offer a theoretically sound and useful account that is demonstrably grounded in the evidence".

Systematic reviews that include predominantly qualitative studies such as the present one, cannot unproblematically use the hierarchy of evidence approach to evaluate study designs. This is not to suggest that there is no method to be followed in the CIS. Therefore, three of the authors made judgements about the relevance and underlying assumptions of articles, which were then incorporated into the data analysis. We employed the "line of argument strategy" for evaluating the studies. Dixon-Woods et al. (2006) suggested that the output of an line of argument synthesis is a synthesising argument, which integrates evidence from across the studies. Its main function is to "to provide more insightful, formalised, and generalisable ways of understanding a phenomenon" (p. 5). Since the focus of the systematic review was on social interactions stimulated by WT, the evaluation concentrated on identifying the key constructs that make up social interactions. The analysis that follows in the results and discussion section reviews the evidence and develops a synthesising argument. Three synthesising arguments were developed concerning the motivational, interactional and structural properties of social interaction. The CIS has been successfully applied in systematic reviews in the past (i.e, Perski et al., 2017).

3.4. Data extraction

Following procedures outlined in Petticrew and Roberts (2006), a data extraction form including 13 items was developed. This form was then piloted on two studies by all four researchers to ensure consistency of analyses, and to make refinements based on co-authors feedback. The same steps as in initial searches were then followed, where researchers in each team would review each other's data forms to assess accuracy and completeness. Where necessary, discussions were held to clarify appropriateness of studies for inclusion.

4. Results and discussion

The aim of the literature search was not to retrieve all publications that contain the search terms in the title or abstract, but rather only those studies relevant to the aims of the review. According to Petticrew and Roberts (Petticrew & Roberts, 2006, p. 83), there are two terms that ensure the achievement of this aim: sensitivity and specificity. *Sensitivity* refers to the "proportion of all studies that were retrieved by the search" and *specificity* concerns the "proportion of studies that were retrieved, that were relevant". As Table 1 shows, searches returned 3,426 sensitivity publications including journal articles, conference proceedings, three dissertations and two reports published between 2007 and 2018. A total of 136 (4%) publications met the specificity criterion.

Studies were published in various outlets pertinent mainly to health and computer sciences, with notable examples being *Journal of Health Communication* and *Lecture Notes in Computer Science*. Interestingly, we found no studies in sport or physical activity-related journals. The full text of 69 publications (41 journal articles, 3 book chapters, and 25 conference proceedings) was analysed and a final list of 20 studies was established. There were also 3 PhD dissertations, (Johnson-Siegel, 2017; Kinney, 2017; Ramirez, 2016), which were included in the analysis.

Overall, most studies were poorly theorised, and only 7 studies (35%) mentioned explicitly the theoretical framework underpinning the research. No study employed the social interaction theory. There were three predominant research designs, including qualitative ($n = 8$), experimental ($n = 7$) and mixed method ($n = 5$). The focus of most studies was on evaluating the effectiveness of PA monitors and their impact on people's intention to exercise. Studies were conducted in three types of settings including outdoor ($n = 9$), indoor ($n = 1$), online ($n = 7$) and three studies did not specify where they took place. Populations subject to investigation included university students, company workers, runners and gym goers with sample sizes varying between 20 and 1,149. Two systematic reviews we also included in the review because they provided useful overview of the role of WT in changing people's physical activity behaviours including strategies involving social interactions.

The main type of WT used in these studies was smartphones ($n = 10$) followed by wristbands (e.g., Fitbit = 8), sociometric badges (1), and smart clothing (1). Study duration also varied significantly from a single session to 12 months, however 60% of the studies did not provide this information. There were three main forms of social interactions stimulated by wearables. The dominant interaction took place in social media (e.g., Facebook), but other interactions (e.g., collaboration, competition and social recommendations) also featured prominently. No interactions were reported on wearable producers' online platforms (i.e., Fitbit, Apple, Jawbone), with the exception of Jawbone, who provided opportunities for virtual engagement. All wearable producers' online platforms allow for setting up online groups, and in this way, they tend to stimulate more cooperation rather than competition between participants. It should also be noted that WT themselves are typically not enough to encourage interaction, but rather need a mediating device in the form of a mobile application, as in the case of 'Aaron2' and "Race by hearths". This conclusion is also supported by Kinney's (2017), Johnson-Siegel's (Johnson-Siegel, 2017) and Ramirez (2016) comprehensive studies. Table 2 synthesizes the studies included in this review.

Table 2. A summary of the studies included in the review

Study	Design and Country	Research Question/Objectives	Participants and WT used	Theoretical framework	Method	Key Findings
Baker et al. (2017)	Collaborative self-study, USA	Examines the influence of wearable fitness technology on physical activity	7, Apple watch	None specified	Autoethnography and self-ethnography	Encourage sport management researchers to consider self-study as an appropriate and useful research method
Boratto et al. (2017)	Experimental Italy	Examines the role of eCoaching ecosystem on trainers' engagement	103, Android, Virtual (on-line e-coaching platform)	None specified	Survey, online analysis	The support of a human trainer is clearly more motivating and engaging with respect to the virtual trainer that reveals itself alone insufficient to fulfil athletes needs
Chang et al. (2016)	Qualitative study, Taiwan	Explores how Internet and mobile technologies, could work together to foster sustainable PA behavior changes and habits among middle-aged adults (40–60 years old)	15, Smart watches, Garmin	None specified	Interviews and focus groups	Social support (SS), delivered/obtained via Social Network Services, increased users' adherence and engagement with WTs, which in turn reinforced SS in shaping PA behaviours and habits
Chen et al. (2016)	2*2 experiment design, China	Explores the effects of online social network and wearable devices on the enhancement of Chinese females' subjective well-being	28, Various wearable devices	None specified	Sentiment analysis	Wearable devices showed no influence on positive affect and were significantly related to anxiety.
Dharia et al. (2016),	Experimental evaluation, USA	Develops a framework for incorporating physical activity and fitness partner/interactions	24, PRO-Fit app on smart phones	None specified	Experiment/User survey	Socially enhanced fitness activity recommendations outperform the non-socially enhanced ones
Goodyear et al., 2019	Qualitative case study, UK	Examines young people's uses of a wearable health device	100 school students, Fitbit	Foucault surveillance (1977)	Focus groups interview	The Fitbit device encouraged the young people to do more physical activity because of the self-surveillance practices promoted by the Fitbit through; (i) the monitoring and recording of steps and calories burned, and (ii) peer comparison (or monitoring); negative feelings were also promoted though
Gui et al. (2017)	Qualitative, China	Investigates how integrating fitness features into complex pre-existing social network affects users' fitness tracking practices and social interactions	32 (14 F; 18 M) We-Run users; We-Run app, smartphone	None specified	Semi-structured interviews	Findings indicate that sharing fitness data with pre-existing social networks motivates users to continue self-tracking and enhances their existing social relationships.

(Continued)

Table 2. (Continued)

Study	Design and Country	Research Question/Objectives	Participants and WT used	Theoretical framework	Method	Key Findings
Kerner and Goodyear (2017)	Mixed method sequential intervention design, UK	How does the Fitbit and app support or hinder relatedness?	84, 13–14 years old, Fitbit	Self-determination theory	Questionnaire and focus groups interview	Competition with peers emerged as a key component function of the app that promoted social relationships. Pupils reported that they set up competitions in their peer groups and that these competitions encouraged them to engage in more physical activity; for some competition resulted in negative feelings of self though
Lynch et al. (2019)	Systematic review, Global	Examines whether a fitness tracker (FT) intervention changes physical activity (PA) behavior	21 relevant articles evaluated	N/A	PRISMA protocol	Trackers may enhance PA interventions, as a general positive effect is found in step count. However, there is no evidence of a positive effect when interventions are compared to an alternative intervention
Mauriello et al. (2014)	Qualitative and quantitative; USA	Presents and pilots a set of wearable e-textile displays for running groups called Social Fabric Fitness (SFF). SFF provides a glanceable, shared screen on the back of the wearer's shirt to increase awareness and motivation of group fitness performance.	52 (35 F; 17 M) wearable e-textile displays	None specified	Questionnaires and interviews	A majority of participants agreed that SFF motivated them to run at or faster than the target group pace. A majority of participants felt that the display motivated the group to stay together. Participants reported feeling more aware of both their individual performance as well as the group's performance.
Nishiyama et al. (2016)	Qualitative and quantitative; Japan	Evaluates six different types of lifelong sharing models among team members for their exercise promotion, leveraging the concepts of "competition" and "collaboration."	64 (32 baseball, 32 general research students), smartphone app	None specified	Logged data and interviews (mixed methods)	Of the six kinds of proposed models, the external competition concept model was the most effective for teams in competitive situations, such as sport teams.

(Continued)

Table 2. (Continued)

Study	Design and Country	Research Question/Objectives	Participants and WT used	Theoretical framework	Method	Key Findings
Ridgers et al. (2017)	Cluster randomised controlled trial design, Australia	Examines the short- and longer-term impact of a wearable activity monitor combined with digital behaviour change resources on adolescents' daily physical activity levels	300, Fitbit	Social Cognitive Theory and Behavioural Choice Theory	Survey, data logs, participatory	Social support and personal/virtual engagement with other participants is important for enhancing physical activity
Ridgers et al. (2018)	Qualitative, Australia	Examines the usability and acceptability of a wearable activity tracker among adolescents.	60, Fitbit	None specified	Focus groups	Adolescents cited their enjoyment of engaging with their peers through the app, including the option to undertake challenges with their friends. There were mixed opinions as to the motivational impact of the achievement badges (rewards) awarded via the Fitbit app
Rosales et al. (2017)	Qualitative, Spain and Italy	What are the participants' initial patterns of usage and negotiation of the smartwatch in terms of practices, sense giving processes, learning strategies, and identity performances?	11, Moto G 360 smartwatch	Domestication approach	Semi-structured interviews, training sessions, and complementary support	The smartwatch provided a boost in social status (associated with attributes such as cool, snobbish, young) but limited interactions
Schaefer et al. (2016)	Qualitative and quantitative, USA	Examines the effectiveness and feasibility of Fitbit tracking devices on youth (11–12) engagement	24, Fitbit	None specified	Fitbit data logs, focus groups	When youth wore their devices, they noticed and engaged with their real-time device data in reflective ways and with other people and compared their PA levels.
Sonne and Jensen (2014)	Empirical study, Denmark	Investigates the effects of introducing technology that facilitates a social interaction through real-time sharing of biometric data in an indoor gym context, thereby enabling competition in an otherwise non-competitive sport setting	20, Smart phone app—Race by Hearts	None specified	Interviews	Sharing biometric data in real-time strengthens social relations between participants, increases their motivation, and improves the enjoyment of the fitness activity. But introducing competition based on real time sharing of biometric data can cause exasperation and discouragement

(Continued)

Table 2. (Continued)

Study	Design and Country	Research Question/Objectives	Participants and WT used	Theoretical framework	Method	Key Findings
Stragier et al. (2015)	Structural equation model, Belgium	Explores the determinants and motivations of recreational athletes to share physical activity status updates on the social networking sites Facebook and Twitter.	400, Smart phone, Strava	Self-determination theory	Survey	Intrinsic motivations (altruism, information-sharing and self-monitoring) have a significant impact on sharing physical activities on Twitter and/or Facebook; social support not a key factor
Sullivan and Lachman (2017)	Review of literature	Examines both the promotion and measurement of physical activity using behavior change strategies and fitness technology	Fitness trackers, smart phones	Coventry, Aberdeen, and London-Refined (CALO-RE) taxonomy of behavior change techniques	Review of evidence	Fitness technology needs to include theoretically derived behaviour change techniques that are useful for their intended population. Strategies such as goal setting, self-monitoring, feedback, rewards, social support, and coaching seem to be especially helpful in increasing activity and healthy behaviours.
Yingling et al. (2017)	Participatory-observations, USA	Evaluates the use of electronic wrist-worn PA monitors, for objectively measuring PA in a predominantly African-American church population.	99 church goers; wrist-worn PA monitors Dynamo Activity Tracker	None specified	Mixed method	Individuals who have already-established healthy behaviours may already have the motivation for healthy behaviours and desire a trigger or a means of receiving positive reinforcement to maintain or improve upon already-established healthy behaviours; social support plays a role in an individual's engagement with the device.
Zhu et al. (2017)	Qualitative, USA	Explores the effects of two communicative features of wearable fitness devices—social sharing and social competing—on individuals' intention to exercise.	238 workers and university students, Fitbit	Theory of Planned Behaviour	Survey	The ways in which exercise data are shared significantly influence the exercise intentions, and these intentions are mediated by individuals' evaluation of exercise, belief about important others' approval of exercise, and perceived control upon exercise.

4.1. Motivational properties of social interactions

As discussed earlier, social interactions have at least three interrelated properties, including motivational, interactional, and structuring (Turner, 1988). We found no study explicitly examining the relationship between WT, PA and social interactions, as interpreted in this review. The work of Kerner and Goodyear (2017) could be considered as an exception as the authors have tried to answer the question “how does the Fitbit and app support or hinder relatedness?” amongst three other research questions. Regarding motivational and interactive aspects, the results of this review are overwhelmingly supportive of technology. Almost without exception, studies highlighted the positive motivational effect of using a wearable, although this motivation was not necessarily related to enhanced social interactions. The effects of WT on participants’ motivation and interactions were not unidirectional though as negative effects were also reported by researchers (Goodyear et al., 2019; Kerner & Goodyear, 2017). However, evidence for the role of intrinsic and extrinsic motivation was mixed. In contrast to other studies, Stragier et al. (2015) found that intrinsic motivations such as altruism, information-sharing and self-monitoring (rather than extrinsic motivations such as goal commitment, social support and connecting to others) have a significant impact on sharing physical activity data within the Twitter and/or Facebook platforms. For example, Kinney (2017) documented the effects of WT on college students and noted their positive influence of students’ confidence and motivation for participation in PA.

Interestingly, social interactions did not feature amongst the motivation of college students to use WT. Rather, all reasons mentioned were intrinsic, or for personal gains such losing weight, improve workout or monitor sleep. Ramirez (2016) extensive review of 17 behaviour change techniques (BCT) related to WT identified only two—social support (i.e., practical and emotional) and social comparison—as being affected. The review found instances in support of extrinsic motivation as well: Johnson-Siegel (2017) reported a significant increase in women’s PA when supported by their partner. Critical for any social interaction is the establishment first of individual or group identities. Dunne et al. (2014) discussed the importance of visual expression particularly in the case of smart clothing.

4.2. Interactive properties of social interactions

The interactive properties of social interactions draw attention to the processes of what people actually do when they influence each other. Three primary activities emerged from the studies in this review, including *cooperation* (information sharing), *competition* (with oneself or with others) and *recommendation* (endorsement). Information sharing includes either real-time biometric data collection and posting/sharing or posting information to be viewed/used later by other people. Findings indicate that sharing fitness data with pre-existing social networks motivates users to continue self-tracking and enhances their existing social relationships. For example, Curmi et al. (2013) found that sharing real-time biometric data on Facebook strengthened the social tie between an athlete and her Facebook friends. Several studies reported that information sharing has been widely used to promote competition (Chen et al., 2016). While competing with oneself or with others can and has indeed stimulated higher levels of physical activity, it has also been responsible for some negative effects. Sonne and Jensen (2017) documented how introducing real-time biometric data sharing technology facilitated a social interaction in an indoor-gym context by transforming a non-competitive activity into a competitive one. With that said, this transformation was not unidirectional, and it had demotivating effects for many participants, suggesting that competition was not the main motivation for their participation in PA and sport, which is consistent with previous research (Kerr & Mackenzie, 2012). The most elaborate study in this category was by Ramirez (2017) who identified 40 unique BCTs that were used by participants. The most common techniques were goal setting (behaviour), feedback on behaviour, and self-monitoring of behaviour. Other highly used BCTs include social comparison, review behavioural goal(s), and action planning. The most infrequently reported BCTs were behavioural experiments, future punishment, identification of self as role model, and valued self-identity (p. 78). Interestingly, Ramirez (2016) noted that social comparison, defined as drawing

attention to others to allow comparison with the person's own performance, was the only technique within the comparison of behaviour domain.

Wearable devices also stimulate another significant tacit transformation in the field of PA and sport noted by Lupton (2013b) in a different context. By giving feedback to users on their performance in real-time and over time, self-tracking not only promotes self-care, but it also shifts the responsibility for good health and fitness from the professional system (i.e., healthcare & sport establishments) to the individual.

4.3. Structuring properties of social interactions

Social interactions' structuring processes concern the repetition and organisation of interactions across time and physical space. Several studies included in this review provided insights into this property of social interactions. For example, Nishiyama et al. (2016) studied the effects of an online-based exercise app (Aaron2) on a sport and a non-sport team's behaviour in Japan. The findings suggest that lifelong data closely related to the performance indicator of the team and can effectively enhance team behavioural change. The authors tested six behaviour-change models, and they concluded that the *external competition concept model* was the most effective for teams in competitive situations. This model encourages competition among team members, as well as competition among multiple teams, with collaboration between team members occurring simultaneously. This model also allows team members to access comprehensive information on their own activity, the activity of other team members, the total amount of activity achieved by the team they belong to, and the total amount of activity achieved by competing teams. Thus, the online application has enabled the organisation of interactions over time and space.

Some WT providers such as Fitbit offer two features that directly incorporate social comparison and allow it to be repeated across physical and virtual domains. This is achieved through the main interactive screen in the Fitbit mobile application called "Friends" leader board. It allows users to connect with each other and share activity data. If individuals are connected, they will show up in the leader board under the Friends tab. The leader board contains all connected friends and ranks them (and the user) according to their running 7-day total. Fitbit also provide another feature, called Challenges, that involves a comparison of performance between users.

5. Conclusions

The main research question addressed by this study was "Does wearable technology enhance social interactions that affect people's physical activity?" We found a very limited number of studies that addressed the relationship between the concepts of wearables, PA and social interaction. This indicates that, conceptually and practically, there is still a great deal of work to be done to better understand the role of technology in mitigating problems of physical activity through social interaction. The systematic review defined social interactions in terms of three key aspects, including motivational, interactional and structural properties. The results revealed that the evidence in all three properties was mixed, suggesting that: (i) wearable technology has the potential to both motivate and demotivate individuals to engage in PA; (ii) interactions are made up of at least three main activities, including cooperation, competition and social recommendations, which is a rather limited spectrum of activity. There was no evidence that using technology promoted physical interactions, either by individuals or PA organisations; and (iii) those interactions are temporary, physically organised, and can be repeated in different contexts, but there was no evidence for their institutionalisation. In the context of the present study, the initialisation of social interactions refers to the creation by groups or organisations of real or virtual spaces, supported by relevant technologies, which allow people to meet, share information and experiences, build identities and enhance their wellbeing. The only exception was wearable producers own online platforms, but the research team could not secure access to the functioning of these platforms. In spite of that, we do know that wearables tend to be responsible for at least two important, tacit transformations. The first involves the transformation of time and space from being used for personal/group self-actualisation to a competitive environment encouraging real-

time physical and virtual contests. The second transformation involves the changing role of professional agencies (e.g., sport and health organisations), who can use wearables to frame physical activity as a mainly personal problem and shift the responsibility for healthy and active living to the individual. The social and economic implications of such a shift would be profound.

As with any systematic review, the current study also has some limitations. These include examining publications in English language only as opposed to considering other languages since the problem of WT and PA has global relevance. A further limitation concerns analysing only certain types of studies such as qualitative, survey, case study and control trials designs, but participatory research could also have been included. Not providing specific recommendations for policy makers and practitioners might also be considered by some as a limitation of the study as one of the main functions of systematic reviews is to inform evidence-based policy making. However, the authors believe that despite those limitation the study provides some original insights into this little explored topic.

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