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6   Synchrony as an adaptive mechanism for large-scale human social bonding

7   Jacques Launay[1,2], Bronwyn Tarr[1] & Robin I. M. Dunbar[1]

8   [1] Department of Experimental Psychology, University of Oxford, [2] Division of Psychology,

9   Brunel University London

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13   Corresponding Author: Jacques Launay

14   Division of Psychology,

15   Brunel University London

16   Kingston Lane

17   Uxbridge

18   UB8 3PH

19   Jacques.launay@brunel.ac.uk

20   Abstract

21   Humans have developed a number of specific mechanisms that allow us to maintain much

22   larger social networks than would be expected given our brain size. For our primate cousins,

23   social bonding is primarily supported using grooming, and the bonding effect this produces is

24   primarily mechanistically underpinned by the release of endorphins (although other

25   neurohormones are also likely to be involved). Given large group sizes and time budgeting

26   constraints, grooming is not viable as the primary social bonding mechanism in humans.

27   Instead, during our evolutionary history, we developed other behaviours that helped us to feel

28   connected to our social communities. Here we propose that synchrony might act as direct

29   means to encourage group cohesion by causing the release of neurohormones that influence

30   social bonding. By acting on ancient neurochemical bonding mechanisms, synchrony can act

31   as a primal and direct social bonding agent, and this might explain its recurrence throughout

32   diverse human cultures and contexts (e.g. dance, prayer, marching, music-making). Recent

33   evidence supports the theory that endorphins are released during synchronised human

34   activities, including sport, but particularly during musical interaction. Thus synchrony-based

35   activities are likely to have developed due to the fact that they allow the release of these

36   hormones in large-scale human communities, providing an alternative to social bonding

37   mechanisms such as grooming.

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39   Keywords: synchronisation; social bonding; humans; endorphins;

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42   Humans, like most anthropoid primates, live in bonded social groups (Dunbar & Shultz 2010)

43   which allow members to directly influence fitness by buffering individuals against the

44   stresses of social life (Wittig et al. 2008), enhancing infant survival (Flinn & England 1995;

45   Silk et al. 2003; Silk 2007; Oesch & Dunbar 2015) and mounting coordinated defence against

46   predators or raiders (Dunbar et al. 2014). During the process of human evolution, maintaining

47   relationships with members of our social networks has become increasingly important to our

48   health and wellbeing (Berkman 1984; Holt-Lunstad et al. 2010), so while our closest primate

49   relatives have social network sizes that are directly predicted by brain size (Dunbar 1992;

50   Kudo & Dunbar 2001), we have developed the ability to form larger networks than should be

51   cognitively feasible. The predicted upper limit to the number of possible human social

52   relationships (150; Dunbar 1992) is applicable to a wide variety of interpersonal situations,

53   including hunter-gatherer clans (Dunbar 1993), Christmas card networks (Hill & Dunbar

54   2003), and active Facebook relationships (Arnaboldi et al. 2013; Dunbar et al. 2015; Dunbar

55   2016), yet we can also experience a sense of connection with larger groups.

56   Primates bond their groups through social grooming, and the linear relationship

57   between group size and the time devoted to grooming across species (Dunbar 1991; Lehmann

58   et al. 2007; Dunbar & Lehmann 2013) appears to set an upper limit on the size of group that

59   can be so bonded at around 50 individuals. Time invested in a relationship is important in

60   order to gain benefits from social interaction, since relationship quality appears to reflect the

61   time invested in it (Sutcliffe et al. 2012). However, since the number of hours in a day is

62   limited (even if extended using fire: c.f. Dunbar 2014a), bonding larger groups than those

63   typical of non-human primates makes it necessary to develop behaviors that use time more

64   efficiently so as to allow bonding between multiple individuals simultaneously (Dunbar

65   2012). Humans might first have had to find solutions to these time constraints, then during

66   the development of increasingly large social networks repeatedly adopted new cognitive,

67   technological and sociological mechanisms to maintain cohesion. Here we argue that human

68   social behaviours that involve synchronised movements (e.g. sport, music, ritual) can be

69   understood as technologies developed to exploit existing neurobiological and psychological

70   mechanisms which are important in the maintenance of social bonds. Synchronisation might

71   initially have helped save time when socially bonding but recent evidence suggests, in the

72   case of singing, it can encourage social bonding in groups larger than 150 people (Weinstein

73   et al. 2015). Although unlikely to have increased cognitive constraints on the number of

74   genuine social ties that can exist this might demonstrate humans experiencing connection to a

75   larger social group to which others are associated, and thus a sense of shared communities

76   with those others. Music and dance are particularly well investigated examples of social

77   synchronisation, and here we focus on these examples, although further research into

78   activities such as sport and exercise is also warranted (c.f. Launay 2015a).

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80   **1. The neurobiology of social bonding**

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82   Over the past fifteen years, there has been a surge in interest in the neurobiological

83   underpinnings of social bonding, across mammal species including humans (Young & Wang

84   2004; Lim & Young 2006; e.g. Insel 2010). A large part of this interest originated from

85   research in species of monogamous and non-monogamous voles, which suggested that larger

86   numbers of receptors for the neuropeptide oxytocin are associated with monogamous

87   behaviour (Insel & Shapiro 1992), but that this monogamous behaviour can be blocked with a

88   selective oxytocin antagonist (Young et al. 2001). Administration of oxytocin has for a long

89   time been known to play a role in birth, lactation, and maternal behaviour (Pedersen &

90   Prange 1979), and given this relationship with monogamy oxytocin became a good candidate

91   as a 'social' neuropeptide. Early experimental studies in humans demonstrated, for example,

92   a relationship between oxytocin and increased trust (Kosfeld et al. 2005; Zak et al. 2005), eye

93   contact (Guastella et al. 2008), face memory (Savaskan et al. 2008), generosity (Zak et al.

94   2007), empathy and the ability to infer the mental state of others (Domes et al. 2007). More

95   recently, the administration of oxytocin in humans has been shown to have positive effects

96   towards both one's own in-group (e.g. De Dreu et al. 2011) and out-groups (Shamay-Tsoory

97   et al. 2013), with individual differences predicting some of this variability in behaviour (Ma

98   et al. 2015) This suggests that the effects of oxytocin generalise beyond dyadic bonding,

99   although more research is required to fully clarify these effects (Nave et al. 2015).

100   Although oxytocin plays a role in human social bonding, there is reason to doubt that

101   it is the only important social neurohormone in humans. Humans have a uniquely high

102   propensity to form social bonds with unrelated others (e.g. Dunbar & Shultz 2010), and it is

103   likely that this tendency is supported by an array of cognitive and neurobiological

104   mechanisms, almost certainly co-opted from neural systems that existed before we developed

105   such a large dependence on our social networks. Evidence indeed demonstrates that there are

106   multiple neurohormonal cascades involved in social bonding, which include not just oxytocin

107   and vasopressin (e.g. Carter 1998) but also neurotransmitters such as dopamine and serotonin

108   (e.g. Depue & Morrone-Strupinsky 2005), endocannabinoids (e.g. Trezza & Vanderschuren

109   2008) and the Endogeonous Opioid System (EOS; Curley & Keverne 2005; Dunbar 2010;

110   Machin & Dunbar 2011). While all of these pathways are likely to play some part in social

111   bonding that occurs between unrelated humans, here we concentrate on the role of endorphins

112   because there is a substantial body of evidence suggesting that these play an especially

113   important role in social bonding with unrelated conspecifics in non-human primates (e.g.

114   Meller et al. 1980), and that the system may be activated by physiological arousal (Howlett et

115   al. 1984; Harbach et al. 2000).

116   The EOS is central in opioid-mediated reward (Koob 1992; Olmstead & Franklin

117   1997; Comings et al. 1999), social motivation (Chelnokova et al. 2014), and pleasure and

118   pain perception (Janal et al. 1984; Leknes & Tracey 2008), and is associated with feelings of

119   euphoria (Boecker et al. 2008). The capacity for experiencing (positively reinforcing)

120   endorphin-related euphoria in a social setting is likely to encourage further interaction with

121   individuals who are present, making this neuropeptide a good candidate (from an

122   evolutionary perspective) for promoting social bonding. In addition, its opiate-like properties

123   of inducing relaxation and calmness may be instrumental in creating a sense of trust. In an

124   environment where the formation of closer social bonds is advantageous those behaviours

125   that encourage the release of endorphins in social situations are likely to be positively

126   selected for.

127   Evidence from non-human primates provides strong support that social bonding

128   activities are associated with activity of the EOS. An early finding demonstrated that male

129   talapoin monkeys administered with an endorphin receptor antagonist did not exhibit

130   increased sexual behaviour (as occurs in rats) but instead showed increased rates of dyadic

131   grooming (Meller et al. 1980). This result was replicated by Fabre-Nys (1982), and supported

132   in the same species through direct measurement of central nervous system levels of beta-

133   endorphins, which were found to be higher following grooming (Keverne et al. 1989; Martel

134   et al. 1995). Given that grooming is thought to be used by non-human primates to reinforce

135   social bonds and maintain peaceful relations and social cohesion, these results suggest that in

136   primate evolutionary history the opioid system was co-opted to mechanistically support our

137   need for enhanced social bonds (e.g. Curley & Keverne, 2005; Lehmann et al. 2007).

138   In humans, there is less direct evidence about the relationship between social

139   behaviour and the endogenous opioid system, but the Brain Opioid Theory of Social

140   Attachment (BOTSA) argues that there are notable similarities in the behaviour and emotions

141   of people addicted to exogenous opiates and people in intense relationships (Panksepp 1999;

142   Insel 2003). Early stages of opiate addiction and intense relationships both involve euphoria,

143   with feelings of pleasure and gratification leading to a desire to continuously seek out the

144   stimulus (Machin & Dunbar 2011; Eisenberger 2012). Furthermore there is some

145   experimental evidence to suggest that interfering with the activity of the EOS in humans can

146   affect the way that positive social stimuli are perceived (Chelnokova et al. 2014), and that

147   areas of the brain with high concentrations of opioid receptors are responsive to social

148   rejection and acceptance (Hsu et al. 2013; Eisenberger 2015). In summary, while evidence is

149   primarily correlational, BOTSA illustrates that for humans both social attachment and the

150   administration of exogenous opiates have similar neurophysiological effects (Nelson &

151   Panksepp 1998; Nummenmaa et al. 2016).

152   In addition to their potential role in social behaviour opioids are known to be released

153   in response to low levels of muscular and psychological stress (Howlett et al. 1984), for

154   example during exercise (Harbach et al. 2000), with evidence suggesting that the euphoric

155   state that follows exercise (termed 'runner's high') is due to endogenous opioids (Boecker et

156   al. 2008). Further to the effect on mood, opioids have a very strong analgesic effect (Van Ree

157   et al. 2000), being some 30 times more potent than morphine on a weight-for-weight basis

158   (Loh et al.1976), and much evidence suggests that endorphins are central in the pain

159   management system (Levine et al. 1979; Basbaum & Fields 1984; Janal et al. 1984; D'Amato

160   & Pavone 1993; Benedetti 1996; Zubieta et al. 2001; Fields 2007; Bodnar 2008; Dishman &

161   O'Connor 2009; Mueller et al. 2010). The release of endorphins during strenuous exercise

162   has both pain relieving and euphoric effects, increasing the positive reinforcement for an

163   individual.

164   Given that direct measures of endogenous opioids are costly and invasive in humans

165   (Dearman & Francis 1983), pain threshold is commonly used as a proxy measure of

166   endorphin release, and this has been operationalised using the length of time holding a hand

167   in ice water or a frozen vacuum sleeve on the arm (Depue & Morrone-Strupinsky 2005;

168   Dunbar et al. 2012a, b), a ski exercise (maintaining a squat position with legs at right angles:

169   Dunbar et al. 2012a), an electrocutaneous simulator (Jamner & Leigh 1999), pressure

170   produced using a blood pressure cuff (Cogan et al. 1987; Cohen & Ejsmond-Frey 2010;

171   Dunbar et al. 2012a, b), and the amount of pain medication requested by patients (Zillmann et

172   al. 1993). Given the evidence that endorphins act as analgesics, previous studies have used

173   changes in pain thresholds as an indicator of central endorphin release following a relevant

174   activity (e.g. engaging in sports).

175   According to the pain threshold assay, various exertive human social bonding

176   activities have an impact on endorphin release. A series of five experiments demonstrated

177   that pain thresholds are significantly increased as a consequence of laughter whilst watching

178   humorous videos (or live stand-up comedy) over non-humorous videos (or live drama), but

179   that a social context was required in order to evince this effect (Dunbar et al. 2012a). That it

180   is specifically endorphins that are involved in this has since been confirmed using positron

181   emission tomography (PET: Nummenmaa et al 2016). Studies in which people were asked to

182   exercise on rowing machines have demonstrated that exertive activity in the presence of other

183   people leads to a greater increase in pain thresholds than when alone, and that this can occur

184   in either the presence of known others, or with strangers (Cohen & Ejsmond-Frey 2010;

185   Sullivan & Rickers 2013).

186   This area of research has begun to demonstrate that synchronised exertive activities

187   can lead to a greater increase in pain thresholds than unsynchronised activities (Sullivan et al.

188   2014; Tarr et al. 2016). Importantly, the effects of synchronisation and exertion appear to be

189   additive, with each contributing towards an increase in pain thresholds independently (Tarr et

190   al. 2015), suggesting that activities which include both of synchrony and exertion might be

191   considered 'ideal' for the release of endorphins. In the following section we review this

192   evidence and will later return to our reasons to associate endorphin release and

193   synchronisation, using musical activities as an example of human activity that engages this

194   system.

195

196   **2. Synchronisation and social bonding**

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198   Synchronisation has, in the past few years, come under experimental investigation as a

199   potential means by which humans can become more socially bonded with one another (Hove

200   & Risen 2009; Wiltermuth & Heath 2009; Valdesolo & Desteno 2011; Launay et al. 2013). It

201   has long been argued that synchronisation and social bonding are related, based on, for

202   example, the known bonding effects of activities such as marching (McNeill 1995) and

203   evidence which demonstrates there is a reciprocal effect between mimicry and social bonding

204   (Chartrand et al. 2005). Given that synchronisation is essentially mimicry involving

205   temporally precise prediction of the movements of co-actors, it is likely to have similar, if not

206   more pronounced effects on bonding.

207   People have a tendency to spontaneously synchronise their movements with those of

208   other people, and this can happen unintentionally, and even when instructed not to do so

209   (Issartel et al. 2007; Oullier et al. 2008; van Ulzen et al. 2008). Prosocial people will

210   demonstrate more spontaneous synchronisation than people with pro-self tendencies

211   (Lumsden et al. 2012), and priming to believe that someone is more socially desirable can

212   encourage synchronisation between strangers (Miles et al. 2010, 2011), suggesting that

213   interpersonal synchronisation is a social and facilitative behaviour, rather than an automatic

214   motor process. People also report perceived synchrony to be an indicator of social closeness

215   between people for both basic sounds (Miles et al. 2009; Lakens & Stel 2011) and musical

216   stimuli (Hagen & Bryant 2003), suggesting that the tendency to associate synchronisation

217   with social behaviour is well engrained.

218   Importantly, there is recent evidence to show that that synchronisation between

219   strangers can have effects on subsequent measures of social bonding (Hove & Risen 2009;

220   Wiltermuth & Heath 2009; Valdesolo & Desteno 2011; Launay et al. 2013). This has been

221   demonstrated in a number of experimental studies in which participants tapping

222   synchronously with an experimenter (Hove & Risen 2009; Valdesolo & Desteno 2011), walk

223   in time with other people (Wiltermuth & Heath 2009; Wiltermuth 2012) or dance together

224   (Reddish et al. 2013), even when people have no visual access to one another but are

225   synchronising with the sounds of another person (Kokal et al. 2011; Launay et al. 2014).

226   These effects are also present throughout development (Kirschner & Tomasello 2010; Cirelli

227   et al. 2014a, b; Tunçgenç et al. 2015), suggesting that, if they are learned, this happens very

228   early in life.

229   In general, the social bonding effects of synchronisation have been attributed to self-

230   other blurring that might occur any time we match our movements exactly to the movements

231   of another person (e.g. Decety & Sommerville 2003). Perception of the movements of

232   another person is known to activate regions of the brain involved in making a similar

233   movement ourselves (e.g. Gallese et al. 1996; Rizzolatti & Craighero 2004), which means

234   that moving at the same time as another person leads to co-activation of similar neural

235   networks for perception and action. The Rubber Hand Illusion has demonstrated that it is

236   possible to perceive a sense of ownership over a rubber hand when feeling a stroking motion

237   synchronously with observing the hand being stroked (Botvinick & Cohen 1998), implying

238   that blurring of self and other is possible even in the case of cross-modal perceptual inputs.

239   However, this self-other matching process is likely to account for only some of the social

240   bonding effects of real synchronous human activities, such as dance, where there are likely to

241   be many people involved, movements that are not exactly matched between co-actors, and

242   associations with an external source, such as music.

243   From an evolutionary perspective an important potential reason for synchronised

244   activities to be socially bonding might be that they play a role in lekking (e.g. Ryder et al.

245   2011). When engaging in chorused activities, all-male bands of several species appear to be

246   able to attract females to their group due to the quality of the display (e.g. Merker 2000). It

247   would therefore seem logical that group members who are particularly capable or competent

248   should be sought out so as to enhance the quality of chorusing bouts. This might form part of

249   the origins of synchronised activities (Merker et al. 2009), but the lack of clear sexual

250   dimorphism in human abilities for synchronisation suggest that this is unlikely to be the only

251   purpose that these activities serve (Bowling et al. 2013). Synchronised activities could have

252   developed as a method for attracting mates, but then also served to aid evaluation of same-sex

253   companions, and a demonstration of a group's prowess or power. The knowledge gleaned of

254   same-sex companions could prove to be useful in determining group membership, making it

255   beneficial to co-opt these activities for social bonding purposes. Hitherto, it is only possible

256   to speculate on the extent to which this capacity has been consciously used to promote and

257   assess cohesion throughout history, but one recent study has shown that people moving in

258   synchrony are perceived as more formidable (e.g. Fessler & Holbrook 2016).

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260   **3. Music, social bonding and the Endogenous Opioid System**

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262   So far we have reviewed evidence which demonstrates that the endogenous opioid system is

263   involved in primate social bonding, and that the act of synchronising with other people can

264   lead to social bonding. Here we connect these two lines of research, and suggest that

265   synchronised musical activities are particularly conducive to the release of endorphins, by

266   virtue of encouraging exertive movement in the presence of other people, and as a

267   consequence of engaging regions of the brain involved in movement and social cognition.

268   Based on the recent evidence associating exertive activities and endorphin release

269   (e.g. Cohen & Ejsmond-Frey 2010; Sullivan & Rickers 2013; Tarr et al. 2015), a small

270   number of studies have started to investigate the effect of active engagement in musical

271   activities and the EOS. For example, sufficiently vigorous singing, dancing and drumming

272   trigger a significantly larger increase in both pain threshold and positive affect compared to

273   listening to music and engaging in low energy musical activities, suggesting that physical

274   activity is important in the relationship between music, endorphins and social bonding

275   (Dunbar et al. 2012b; Tarr et al. 2015). Another recent set of studies connected exercise

276   machines to musical output software so that individuals influenced a musical soundscape

277   though the exertive movements they made: when movement during group exercise resulted in

278   musical feedback, participants perceived their own exertion to be lower, reported enhanced

279   mood, and felt a greater desire to exert themselves further in comparison with when they

280   were exercising whilst listening (passively) to music that they had no control over (Fritz et al.

281   2013a, b). As such, musical agency (i.e. perception of a relationship between purposeful

282   movement and sounds that are being produced) is likely to be associated with greater

283   endorphin release, again suggesting that there is an important relationship between exertive

284   movements, music and the EOS.

285   However, the release of endorphins as a consequence of engaging with music is not

286   limited to situations involving exertion. There is a considerable amount of evidence to

287   suggest that listening to music can reduce perception of pain (Koch et al. 1998; Allen et al.

288   2001; Good et al. 2001; Lepage et al. 2001; Nilsson et al. 2001, 2003; Nilsson 2008) and

289   therefore diminish the need for opioid agonists following operative care (Cepeda & Carr

290   2006; Bernatzky et al. 2011). This effect is largely attributed to the activity of the EOS,

291   suggesting that listening to music alone can have similar effects on endorphins to those

292   experienced when actively engaging in musical activities.

293   More direct evidence using positron emission tomography has demonstrated that the

294   EOS is engaged during passive listening to music (Blood & Zatorre 2001; Stefano et al.

295   2004). Functional Magnetic Resonance Imaging has provided evidence that areas of the brain

296   with large numbers of opioid receptors that are involved in positive reinforcement (such as

297   the nucleus accumbens) are active during passive listening to music (Brown et al. 2004;

298   Menon & Levitin 2005; Koelsch 2014). The argument for a role of the EOS in musical

299   experiences is strengthened by evidence associating 'thrills' and a sense of elation

300   experienced whilst listening to music with endorphins (Goldstein 1980; Chiu & Kumar

301   2003). As well as calming music buffering stressful life events (see McKinney et al. 1997 for

302   a review), it has been argued that listening to techno music significantly changes emotional

303   states (and increases beta-endorphin levels) due to its strong rhythmic beat and engagement

304   of motor regions of the brain (Gerra et al. 1998).

305   This suggests that exertion is not necessarily required for music to engage the EOS,

306   and that the analgesic effects of listening to music are not simply attributable to its relaxing

307   properties. It is important to return to the ubiquitous human aptitude for entrainment to

308   rhythmic beats (Clayton et al. 2005; Brown & Jordania 2011), particularly those embedded in

309   music (e.g. Demos et al. 2012) and, in addition, the detection of human agency, which is

310   inextricably linked with the detection of rhythm and the desire to engage with that rhythm

311   (Launay 2015b). Being told that music is created by a person rather than a computer means

312   that listening to that music engages regions of the brain involved in social cognition, as well

313   as motor regions of the brain (Steinbeis & Koelsch 2009). People synchronise differently

314   when they believe they are interacting with a human compared with a computer (Konvalinka

315   et al. 2010), and children's drumming performance is improved when they believe they are

316 interacting with another person (Kirschner & Tomasello 2009). Importantly this might mean

317 that even in the absence of another person musical and rhythmic sounds are detected as

318 having some sense of agency, leading to some subjective social experience (Launay 2015b).

319 Given that synchronisation and social bonding are thought to be linked via self-other

320 coupling it is feasible that musical sounds, by virtue of the identification of agency, and

321 musical rhythm (Zatorre et al. 2007; which engages motor regions of the brain: Chen et al.

322 2008) leads to some imagined protosocial experience, and this has some influence on the

323 EOS. This is somewhat speculative and needs much further investigation, but does suggest an

324 evolutionary time course from making movements together to the pleasure and enjoyment we

325 currently derive from listening to music alone.

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327 **4. A proposed evolutionary time course from endorphins to music via synchronisation**

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329 At some point in primate history it became important to engage in social activities with non-

330 related conspecifics. Endorphins were co-opted from existing neural systems for pain

331 management, as it was relatively easy to encourage their release through mildly stimulating

332 interpersonal contact (Curley & Keverne 2005). However, as hominids started to rely on

333 increasingly large social groups there was a need to 'groom at a distance', requiring new

334 behaviours that allowed the release of endorphins without physical touch (Dunbar 2012).

335 Estimates of the time budgets for the main hominin taxa (based on calculations given

336 in Dunbar 2014b) suggest that without finding mechanisms for drastically reducing the costs

337 of social bonding as well as foraging, hominin time budgets would have been unsustainable

338 had they needed to live in larger groups than those characteristic of the most social monkeys

339 and apes. In the case of anatomically modern humans, the gross time budget would have

340 exceeded available active day time (defined by tropical daylight) by more than 50%. Social

341   grooming is extremely expensive time-wise (Dunbar 1991; Lehmann et al. 2007) because it is

342   a strictly one-on-one activity. Hence, one effective way of reducing the time costs of social

343   bonding is to increase the size of the 'grooming' group so that more individuals can be

344   'groomed' simultaneously.

345   Synchronisation and physical exertion in social settings allow both the co-ordination

346   of groups of people, and the release of endorphins though exertive motor activity, effectively

347   taking on the role previously filled by grooming. As well as solving problems of time

348   constraints these activities could make groups larger than 150 feel socially connected very

349   quickly (Pearce et al. 2015; Weinstein et al. 2015), although this connection is likely to be

350   felt towards the group as a whole rather than experienced as individual social relationships

351   (Pearce et al. in press). Forms of synchronised movement could have progressively evolved

352   and become positively reinforcing in their own right. When perceiving the music of the

353   people from our own social group, and correctly predicting the repetitive rhythms involved

354   we perform some mental synchronisation with those human driven sounds. While exertion is

355   no longer a necessity for experiencing a social high during musical activities, it inevitably

356   boosts the release of endorphins, meaning that active engagement in musical activities is

357   optimal for social bonding, although passive listening can be sufficient to lead to the release

358   of endorphins with some consequent analgesic effects. Importantly, as we noted above, both

359   synchronisation and exertive engagement have independent effects on activation of the EOS

360   and social closeness experienced by people engaging in musical activities together.

361   While this series of events cannot be verified, it should nonetheless be possible to

362   bring further evidence to bear on the question. More thorough testing of the relationship

363   between synchronisation, exertion, endorphins and social bonding might help to elucidate

364   potential causal pathways by which synchronous activities such as dance influence social

365   bonds more generally. In addition, our current understanding of the degree to which musical

366   sounds are perceived as agent driven and the underlying neural mechanisms that relate to

367   these differences in perception are relatively poor. By bringing these lines of evidence

368   together, it should be possible to determine the importance that synchronisation plays in our

369   social experience of musical activities, both passive and involving active performance.

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