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Signals through music and dance: Perceived social bonds and formidability on collective movement

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ABSTRACT

Previous studies have suggested that the prosocial effects which arise following synchrony during music and dance may serve as a mechanism for people to bond socially. However, other research has proposed that synchrony could be a mechanism for signalling coalition to demonstrate fitness, which is expressed by a group's ability to effectively cooperate. In the present studies, we compared these theories by showing participants realistic virtual avatars engaged in different forms of group dance and then examining their perceived social closeness and formidability of the dance groups. We conducted two studies to assess the perceptual influence of movement type (unison vs. coordinated) and movement quality (temporally aligned vs. temporally misaligned). We predicted that the difference in the ratings of closeness and formidability would only emerge when the groups align movements, and this was supported. We also hypothesised that unison movement would better signal formidability while coordinated movement would better signal a group's social closeness. However, unison movement yielded higher ratings than coordinated movement for both formidability and social closeness, suggesting that a group should move in complete synchrony to maximally indicate their fitness and social bonds.

1. Introduction

Like most primates, humans form large social networks and live in close social groups (Launay, Tarr, & Dunbar, 2016). Although all animals are social in a broad sense, anthropoid primates construct a more complex form of *bonded sociality*, facilitated by one-to-one interactions (Dunbar, 2016). Living in groups provides advantages, such as protecting individuals from predators and maintaining a large territory (Shultz & Finlayson, 2010); however, such benefits also come with a cost. When a social group expands, more time must be invested to ensure strong relationships are maintained; otherwise, the overall group is likely to split due to internal conflicts (McNeill, 1995; Sutcliffe, Dunbar, Binder, & Arrow, 2012). Therefore, to successfully maintain a large community without schism, it is beneficial to adopt a mechanism to promote cohesion that will lead to effective cooperation (Shultz & Dunbar, 2010).

Arguably, large scale cooperation is an important factor that enabled humans to dominate the entire globe, even though our physical strength is significantly inferior to that of the deadliest mammals (Boyd & Richerson, 2009; Tomasello, Melis, Tennie, Wyman, & Herrmann, 2012). To promote group cooperation, the primate species most similar to our own groom each other to bond socially, which is suggested to promote the release of oxytocin and beta-endorphins to provide feelings of warmth and togetherness (Dunbar, 2010). Nevertheless, this physical grooming method sets a upper limit on troop size (50 on average) because the act of grooming demands a considerable amount of time (Lehmann, Korstjens, & Dunbar, 2007). Yet most humans form larger and more complex social networks than other primates do. It is therefore plausible that humans developed a more effective technology for social bonding through evolutionary history that allows for individuals to bond simultaneously at a large scale (Launay, Tarr, & Dunbar, 2016).

Religion, storytelling, laughter and language are all suggested to have had a role in enabling our ancestors to effectively cooperate in achieving a shared goal (Harari, 2014; Tomasello, 2009). Likewise, it has been argued that music, particularly moving to music, contributes to our ability to socially bond and this has played an important role in human evolution (e.g. Brown, 2000; Cross & Morley, 2009; Dunbar, 2012). The rationale for this arises in part from the observation that music and dance exist across all known cultures and play a key role in social events such as rituals, sports, and ceremonies (McDermott & Hauser, 2005). Only humans sing and dance without the purpose of attracting mates (however, see Miller, 2000) and this is facilitated by our ability to *entrain*, which Cross (2001) has defined as the ability to expect future rhythmic events and synchronise with others. Though a

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few case reports have suggested that other animals may also acquire the capacity to synchronise to an external meter (e.g. chimpanzees: Hattori, Tomonaga, & Matsuzawa, 2013; cockatoos: Patel, Iversen, Bregman, & Schulz, 2009), the flexible expansion of this attribute to a large group level is thought to be specific to humans.

Numerous studies have highlighted the prosocial (i.e. an elicited interest to understand and relate to others) effects of synchrony, suggesting that it provides benefits for people to effectively cooperate and resolve internal conflicts. Empirical evidence has demonstrated that interpersonal synchrony can increase likeability of a partner (Hove & Risen, 2009), encourage trust in the behaviour of others (Wiltermuth & Heath, 2009), blur boundaries between the self-and-other (Tarr, Launay, & Dunbar, 2014) and foster cooperation (Reddish, Fischer, & Bulbulia, 2013). Furthermore, it has also been shown that the prosocial effect of synchrony extends beyond the performance group. Reddish, Tong, Jong, Lanman, and Whitehouse (2016) compared participants from two rival universities in Singapore and demonstrated that groups which moved in synchrony had higher proportions of participants willing to take the time to complete a survey requested by members from the other university, implying that synchrony can lead to *generalised prosociality* (Reddish, Bulbulia, & Fischer, 2014).

While some studies have provided evidence that interpersonal synchrony can act as a technology to socially bond, Hagen and Bryant (2003) have argued for a different evolutionary function for synchronous movement. They proposed that the collective movement of a group, facilitated by music and dance, at least partly serves as a mechanism for *coalition signalling* to outsiders. They argued that for a large number of individuals to demonstrate coalition to a passive observer, performing movement together and singing, as a technology, broadcasts the group's ability to cooperate effectively. Projecting the capability to cooperate as a group has two obvious benefits that can lead directly to the group's survival. One is the increased capacity to form cooperative alliances with other equally united groups. The other is sustaining an advantage during territorial defence by demonstrating fitness to intimidate and outperform other competitive groups. Military marches, for example, are carried out to demonstrate the army's strength and solidarity by synchronising footsteps, often accompanied by a marching band to provide an external meter. Similarly, before entering a sports match, New Zealand rugby teams perform a *haka*, a national sporting ritual, to project the masculinity and unity of their team through synchronous dancing and chanting while facing the opponent team (Jackson & Hokowhitu, 2002).

In support of Hagen and Bryant's (2003) view, Fessler and Holbrook (2014) provided empirical evidence by having participants walk either in synchrony or non-synchrony with a partner and then rate the formidability (i.e. powerfulness) of presented antagonist images. Participants who walked in synchrony with a partner envisioned the antagonist to be less formidable than the participants who walked in non-synchrony, which implies that moving in synchrony may raise one's fighting capacity. A subsequent study requiring participants to passively listen to audio stimuli of soldiers' footsteps indicated that the soldiers were envisaged to be larger in size (estimation of height and weight) and more muscular when the heard footsteps were synchronised (Fessler & Holbrook, 2016). Similarly, Lakens (2010) used pairs of stick figures and videotaped people waving with various degrees of synchrony to reveal that maximally synchronous movements were judged to have the greatest entitativity (i.e. seen as a single unit).

In light of the existing literature, it seems likely that physically synchronised action between people is associated with social bonding, and the degree to which movements are perceived to be synchronised also influences perceived bondedness and formidability to a passive observer. Nevertheless, the extent to which a group's collective movement is better at signalling their social closeness versus their formidability to a passive observer has not been empirically examined. Moreover, literature emphasising either social bonding or formidability overlooked the distinction between movement in unison (e.g. marching) against movement that is coordinated but not completely synchronised (e.g. non-unison dance). In fact, a vast majority of the work in this area has focused almost entirely on completely synchronised physical motor interaction between partners (e.g. Kokal, Engel, Kirschner, & Keysers, 2011; Tarr, Launay, & Dunbar, 2016; Wiltermuth & Heath, 2009), imagined as one of the figures in the scene (Stupacher, Maes, Witte, & Wood, 2017), interacting with a virtual partner (Launay, Dean, & Bailes, 2013, 2014; Tarr, Slater, & Cohen, 2018), or in a passively observing context (Lakens, 2010; Miles, Nind, & Macrae, 2009). Yet music and dance rarely involve complete synchrony, and a recent study (von Zimmermann, Vicary, Sperling, Orgs, & Richardson, 2018) suggests that distributed coordination of group movement has more influence on pro-social behaviour than synchrony itself.

In the present studies, we aimed to address these gaps in the literature by examining the extent to which a group's movement indicates its closeness and formidability. To do this, we employed a novel approach of using dancing virtual avatars to control for the group's size, clothing, appearance, and facial expressions to eliminate confounds related to social cues. We distinguished the dance movements as unison movement (i.e. making the same movements at the same time) and coordinated movement (i.e. making different movements coupled in time), and further divided them into temporally aligned movement (to represent good performance) and misaligned movement (to represent bad performance). Participants passively observed virtual avatars and rated the perceived closeness and formidability of groups.

We predicted that groups moving in unison and coordinated movement would demonstrate a contrasting pattern of results. In line with Fessler and Holbrook (2016) and Lakens (2010), we predicted that moving in unison could make a group to appear as one large single unit, making this an effective means to signal a strong coalition (e.g. in a military march) and lead to greater perceived formidability (i.e. fighting capacity). By contrast, in accordance with von Zimmermann et al. (2018), we predicted that coordinated movement may be more strongly related to pro-social behaviour because such complex and contingent movements would require more effort and attention to others to successfully achieve a collective goal than synchronised movement. Complex contingent movements could also indicate that the group has practiced for longer to refine the performance. This perceived time investment could indicate a more closely bonded ground, or a group that has become bonded through time spent practising together. In light of these predictions, we proposed the following three hypotheses:

H1. Both closeness and formidability ratings will be higher for the groups that align movements compared to groups that misalign movements. Participants will perceive the performers to be more connected to one another if the performance is more temporally aligned.

H2. When the movements are misaligned, participants will give equally low ratings for both closeness and formidability, regardless of whether the movement is unison or coordinated. However, the two ratings will be different when the movements are aligned, indicating an interaction between movement type and temporal alignment of movements.

H3. When the movements are aligned, participants will rate unison movement as more formidable than coordinated movement, whereas they will rate coordinated movement as more socially bonded than unison movement.

To test these hypotheses, we used a single dance move extract in Study 1 to design the unison movement stimuli and pairs of two extracts that are locked-in-time to generate coordinated movements. In Study 2, we mirror-mapped the choreography of an existing boyband on to the virtual avatars to raise the ecological validity and realism. Additionally, we compared these results with conventionally used point-light-display (PLD) figures to validate the robustness of using virtual avatars, and whether the avatars could be seen as better representation of real people than PLD. In the context of social judgments, research has shown that using human-like avatars is a more ecologically valid approach compared with conventionally used PLD figures (Narang et al., 2017). Ideally, figures that look closer to human beings would better represent realistic physical movement and allow viewers to engage as though they are watching real people (however, for a review on the *uncanny valley* hypothesis, see Kätsyri, Förger, Mäkäräinen, & Takala, 2015).

2. Study 1

2.1. Methods

2.1.1. Participants

G*Power was used a-priori to calculate the number of participants required to achieve 95% power when conducting repeated measure MANOVA with eight variables (two dependent measures × two levels of movement type × two levels of movement quality). To detect a minimal effect of 0.20, 76 participants were required. Initially, we recruited 95 participants from the Amazon Mechanical Turk (MTurk) survey platform in exchange for monetary compensation. Six multivariate outliers were removed assessed by the probability of Mahalanobis distance below .001, and two univariate outliers were removed assessed by studentised residual values ± 3. The age of the remaining 87 participants (37 females) ranged from 20 to 60 (M = 34.15, SD = 12.0) with all MTurk participants having approval ratings over 95% assessed by their previous works. Although we have not recorded demographic data, a recent survey (Difallah, Filatova, & Ipeirotis, 2018) revealed that the majority of MTurk participants are from the United States (75%), with India (16%) being the second largest population. Ethics approval was obtained from the ethics committee of Goldsmiths, University of London. Participants signed an electronic informed consent prior to taking part in the study.

2.1.2. Stimuli

We created a set of 40 unique virtual avatars using Character Creator (ver. 2.3.2420.1; Reallusion, 2018) with varied facial shape, skin colour, and hair to represent diverse ethnic groups (see Fig. 1). All other features such as clothing, facial expression, height and body size (depending on gender) were controlled. Of this set, we randomly mixed-matched four male and three female avatars to form 60 unique groups (seven avatars in each group). We then imported these avatars into iClone 7 (ver. 7.22.1724.1; Reallusion, 2018) for animating motion and rendering.

We animated the dance motions using two commercially available motion capture libraries titled 'A&M Mocap Motion Series - Music Video Dance Vol.1' and 'A&M Mocap Motion Series - Street Dance Vol.1' (A&M Mocap, 2018). We selected 15 repetitive motions from these libraries and segmented them into short clips of seven-second sequences. All of these dance routines were matched in-time since the tempo of the music that originally accompanied the dance was identical (125 bpm).

The stimulus set was divided into four conditions, following a 2 × 2 design of movement type (unison vs. coordinated) against movement quality (aligned vs. misaligned). To produce the aligned coordinated movements, we coupled two sets of dance routines to form partially synchronised dance where three avatars in the group performed one routine and four performed the other. To produce the aligned unison movements, we used an identical dance routine performed by all avatars in the group.

To create a matched set of aligned and misaligned performances, we applied an equal degree of jitter to the aligned performance clips to generate a new set of misaligned stimuli. We used a trial and error method to determine the optimal amount of jitter to produce movements that looked poorly aligned but could still be perceived as 'trying to achieve the same goal'. Ultimately, an ideal compromise was made by delaying the frame rate of six avatars from the baseline (0 frame) by 6, 12, 20, 27, 34, and 41 frames; consequently, no more than two movements were perfectly aligned at any point while retaining sufficient order.

Next, we integrated a total of 60 dance motions (15 per conditions) with the set of avatar groups, resulting in distinctive dances performed by unique dance groups. The positioning and physical size manipulation of male and female characters were counterbalanced. For each group, characters were given a random size variation from baseline (100%) following the criteria: females as either 93, 95, or 97%; and males as either 98, 99, 100, or 102%. Since no two characters in the group had the same size, we could keep the average size of the dance group constant across stimuli. The final stimulus clips were rendered at 60 frames per second with frame size 1920 × 1080 in 'MOV' format.

To check that the perceived complexity of the dance performances was matched across the unison and coordinated movement conditions, we conducted a pilot test through MTurk (N = 30). We randomly presented a set of 60 stimuli to evaluate how good the dancing was perceived to be (five-point scale). By interpreting the box plot of each stimulus, we flagged 6 clips that were inconsistent with the rest and with large standard deviation. We excluded these clips along with the matched pair, resulting in a total of 48 clips with 12 in each condition (see https://osf.io/n6ebs/ for all stimulus clips). Re-analysing the remaining set confirmed that the quality of individual clips roughly matched for between-movement-types while being significantly different for within-movement-types. Therefore, we could be confident

Fig. 1. Still shot of groups of seven avatars performing coordinated movement.

that any contrasting ratings would be influenced by the type of movements and their temporal alignment, not by specific aspects of the dance movements involved.

2.1.3. Procedure

We conducted a 2 × 2 repeated measure design between movement type (unison vs. coordinated) and movement quality (aligned vs. misaligned, manipulated with jitter) through Qualtrics online survey platform. On the first page, we briefly described the study, stating that we had recorded the movements from real dancers and used unique virtual avatars to represent individual dancers. This was to encourage participants to engage with the virtual avatars as unique groups of real people. We then presented the stimuli of 48 video clips at random and instructed participants to watch the clip and answer four questions on the following page. The clips were embedded from Youtube with the control bar and title of the video removed. The questions included two items each as measures for perceived closeness and formidability, and all questions were answered on a five-point scale. As a measure of closeness, we adapted the Inclusion of Other in the Self (IOS) scale by Aron, Aron, and Smollan (1992) with pairs of circles gradually merging to one, and a text item, 'how much do you think people in the video like one another?'. For formidability measures, we adapted Fessler and Holbrook's (2016) item for estimating physical size represented by black and white human figure increasing in size, and a text item, 'how formidable (e.g. powerful, daunting) do you think the people in the video are?' (see Appendix A for pictorial items). Questionnaire items for both closeness and formidability demonstrated good reliability across the two studies reported in this article (for closeness Cronbach's α ranged from 0.81 to 0.86 and for formidability α ranged from 0.79 to 0.88). Thus, a pictorial and a text questionnaire item were combined across the two studies by computing a mean for each of the dependent variables (closeness and formidability). Finally, we debriefed the participants and thanked them for their contribution.

2.2. Results

Data were missing (3%) completely at random with equal distribution across the questionnaire items and were replaced with the series mean. Responses for each question item were combined to produce mean variables of four conditions for the two dependent measures of closeness and formidability ratings. Both mean ratings of closeness and formidability were normally distributed assessed by Normal Q-Q plot. A two-way (movement type: unison vs. coordinated; movement quality: aligned vs. misaligned) repeated measure MANOVA was conducted to assess differences in the ratings of closeness and formidability. Using Pillai's trace, there was a significant main effect of movement quality on ratings of closeness and formidability ($V = 0.24$, $F(2, 85) = 13.55$, $p < .001$), as well as a main effect of movement type ($V = 0.43$, $F(2, 85) = 32.08$, $p < .001$), and an interaction ($V = 0.19$, $F(2, 85) = 10.21$, $p < .001$).

This was followed by two separate 2 × 2 ANOVA tests for the ratings of closeness and formidability to identify where the differences arose (see Fig. 2). For closeness rating, there was a significant main effect of movement quality ($F(1, 86) = 57.54$, $p < .001$, $\eta_p^2 = 0.401$), a main effect of movement type (F (1, 86) = 26.22, $p < .001$, $\eta_p^2 = 0.234$), and an interaction ($F(1, 86) = 19.13$, $p < .001$). After adjusting p-values for multiple comparison following the Benjamini and Hochberg's (1995) method using 'p.adjust' function in R (Bolar, 2019), both movement types had higher closeness ratings when they were aligned than when they were misaligned: aligned unison ($M = 3.80$, $SD = 0.68$) vs. misaligned unison ($M = 3.03$, $SD = 0.66$), $t(86) = 7.75$, $p < .001$; aligned coordinated ($M = 3.52$, $SD = 0.52$) vs. misaligned coordinated ($M = 2.94$, $SD = 0.71$), $t(86) = 6.96$, $p < .001$. Unison movement was rated higher than coordinated movement when both of these movement types were aligned ($t = 5.47$, $p < .001$), and also when they were misaligned ($t = 2.87$, $p = .01$).

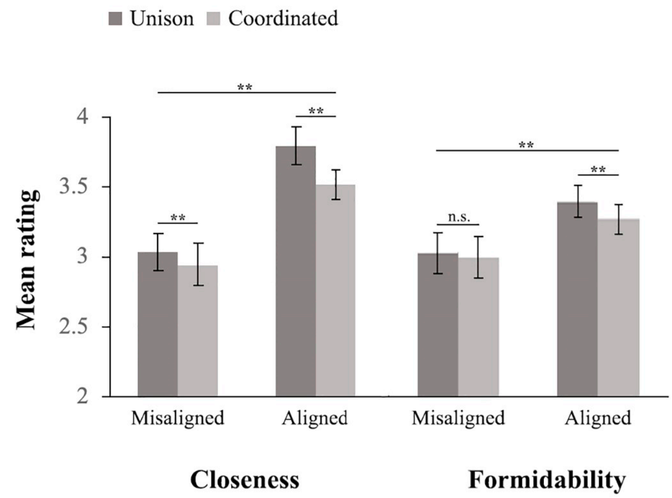

Fig. 2. Mean ratings on perceived closeness and formidability for movement type × movement quality. Error bars represent 2SE. Asterisks represent statistical significance with adjusted p-values for multiple comparisons following the Benjamini and Hochberg (1995) method. * < .05, ** < .01, and n.s. > .05.

Likewise, for formidability rating, there was also a significant main effect of movement quality ($F(1, 86) = 32.05$, $p < .001$, $\eta_p^2 = 0.272$), a main effect of movement type (F (1, 86) = 17.04, $p < .001$, $\eta_p^2 = 0.165$), and an interaction ($F(1, 86) = 9.95$, $p = .002$, $\eta_p^2 = 0.104$). Both movement types had higher formidability ratings when they were aligned than when they were misaligned: aligned unison ($M = 3.40$, $SD = 0.55$) vs. misaligned unison ($M = 3.03$, $SD = 0.68$), $t(86) = 5.66$, $p < .001$; aligned coordinated ($M = 3.27$, $SD = 0.51$) vs. misaligned coordinated ($M = 3.00$, $SD = 0.69$), $t(86) = 5.28$, $p < .001$. Unison movement was rated higher than coordinated movement when both movement types were aligned ($t(86) = 4.50$, $p < .001$), while the two movement types revealed no significant differences when they were misaligned ($p = .17$).

Furthermore, when comparing the patterns of the two dependent measures, closeness had higher ratings than formidability only when the movements were aligned (unison movement, $t(86) = 5.54$, $p < .001$; coordinated movement, $t(86) = 4.29$, $p < .001$), while there was no significant difference in the ratings when the movements were misaligned (unison movement, $p = .93$; coordinated movement, $p = .34$).

2.3. Summary

As we hypothesised, participants perceived the groups to be more socially bonded and formidable when groups temporally aligned movements than when they misaligned movements (H1). Moreover, as predicted, the differences in the ratings of closeness and formidability were greater between the movement types when groups aligned movements. However, while we predicted that movement type (unison vs. coordinated) would have no impact when movements are misaligned, this was true only for the formidability ratings, but not for the closeness ratings (H2). Participants gave higher ratings for unison versus coordinated on both closeness and formidability, contradicting our hypothesis that coordinated movement would be rated higher on closeness than unison movement (H3). We speculated that this unexpected finding might be related to a lack of realism and the oversimplified coordinated movement stimuli that combined only two dance extracts. As a result, participants could have perceived the two dance extracts to be unrelated to each other, weakening the perception of the group's intention to achieve a collective goal. Thus, in Study 2, we adopted movements performed by an existing boyband to raise the ecological validity and incorporated more complex forms of coordination.

3. Study 2

In this study, we determined whether the findings of Study 1 would also be replicated in the context of more ecologically valid stimuli by adopting the dance movements from a presently active boyband as basis for the motions of virtual avatars. At the same time, we took the opportunity to generate an analogous set of stimuli using point-light-display (PLD) movement to ascertain the generalisability of the findings to this newly adopted form of movement representation. Additionally, we asked participants whether virtual avatars and PLD figures are seen as closely realistic to human movement.

3.1. Methods

3.1.1. Participants

To examine interactions between the results of virtual avatars and PLD figures using a within-between ANOVA with a minimum of 0.10 effect, G*Power (version 3, Faul, Erdfelder, Buchner, & Lang, 2009) calculated that 138 participants were required to achieve 95% power. We recruited 166 MTurk participants with approval ratings over 95% in exchange for monetary compensation. Following the same screening process as Study 1, eight multivariate and three univariate outliers were excluded, with additional criteria to screen anyone who participated in the previous study. The remaining 151 participants (90 females), with age ranging from 18 to 76 ($M = 38.5$, $SD = 13.8$), were randomly assigned to one of two conditions to either watch clips of virtual avatars ($n = 75$) or PLD figures ($n = 76$).

3.1.2. Materials

As the basis for designing the stimuli, we used short Youtube videoclips of groups of seven people performing a dance cover of the song ‘Dope’ by a South Korean boyband (BTS, 2015, track 5). First, we identified the parts of the choreography that are either performed in unison movement or coordinated movement. This resulted with a total of 20 dance templates roughly 5 – 7 s in length that have distinctive qualities of unison or coordinated movement.

As with Study 1, we validated the quality of each stimulus through MTurk ($N = 30$) and excluded 2 sets of matched pairs. Of the remaining 16 stimuli, virtual avatars and PLD clips were designed by extracting matched choreography templates from an open-source motion capture file[2] of the song (see https://osf.io/n6ebs/ for full matched stimuli set). We represented virtual avatars as unique groups as with Study 1, whereas PLD figures were identical in appearance (see Fig. 3).

3.1.3. Procedure

The experiment employed a 2 × 2 × 2 mixed design: between-group (watching virtual avatars vs. PLD figures) × movement type (unison vs. coordinated) × movement quality (aligned vs. misaligned). This study's procedure was almost identical to Study 1's but with several adjustments to improve on experimental control. We repeated the clips twice with one-second gaps (indicated by a black screen) and disabled the button to proceed to the next page until the video ended. This was done to prevent participants from skipping the video too quickly and to limit the number of times participants could repeat the clip. Additionally, we trimmed the video clips to stop slightly before the performance ended because we were concerned about the performers being perceived as unnatural in the misaligned condition when their movement stopped.

To match the seven-point Inclusion of Other in Self scale (Aron et al., 1992), we developed seven-point scales for closeness and formidability (see Appendix A). In addition, we added two items at the end for each condition to estimate how well the non-human figures represented real people. The two novel questions were ‘how well do you think the animated avatars/stick figures represent real people?’ and ‘could you engage with the avatars/stick figures as though they were real people?’ ($\alpha = 0.70$), with the response given on a scale of 1 (not at all) to 5 (very much).

3.2. Results

Both mean ratings of closeness and formidability were normally distributed assessed by Normal Q-Q plot, and there was homogeneity of variances ($ps > .05$). Fig. 4 illustrates the mean ratings of closeness and formidability separated as (a) virtual avatar and (b) PLD group. Descriptive statistics and t-statistics are reported in Appendix B.

First, a three-way (group: virtual avatars vs. PLD figures; movement type: unison vs. coordinated; movement quality: aligned vs. misaligned) mixed MANOVA was conducted to assess whether there are differences in the ratings of closeness and formidability. Using Pillai's trace, there was a significant main effect of movement quality on ratings of closeness and formidability ($V = 0.35$, $F(2, 148) = 39.88$, $p < .001$), a main effect of movement type ($V = 0.093$, $F(2, 148) = 7.61$, $p = .001$), and an interaction ($V = 0.16$, $F(2, 148) = 14.40$, $p < .001$). There was a significant between-group difference ($V = 0.06$, $F(2, 148) = 4.41$, $p = .014$) and a three-way interaction between group × movement type × movement quality ($V = 0.06$, $F(2, 148) = 4.65$, $p = .011$), but no two-way interactions between group × movement type ($p = .98$) or group × movement quality ($p = .21$).

These interactions suggested that the results of virtual avatars and PLD figures have parallel profiles, but there is an overall group mean difference. Thus, we assessed between-group effects and only closeness ratings were significantly different between avatars and PLD ($F(2, 148) = 8.85$, $p = .003$, $\eta_p^2 = 0.56$), while formidability rating did not reach significance ($p = 14$). Subsequent independent sample t-tests revealed that PLD figures had higher closeness ratings than avatars across all conditions ($ps < .05$), except the misaligned unison movement condition ($p = .08$).

Next, we examined whether the results of virtual avatars and PLD figures directly replicate the patterns of Study 1 (shown in Fig. 2). Within-group contrasts showed that, for closeness ratings, there was a main effect of movement quality ($F(1, 148) = 71.19$, $p < .001$, $\eta_p^2 = 0.32$), a main effect of movement type ($F(1, 148) = 14.00$, $p < .001$, $\eta_p^2 = 0.086$), and an interaction ($F(1, 148) = 24.29$, $p < .001$, $\eta_p^2 = 0.14$). After adjusting for p-values, results of virtual avatars and PLD showed completely converging patterns: aligned movements compared to misaligned movements had higher closeness ratings ($ps < .001$), unison movement had higher ratings than coordinated movement when they were aligned ($ps < .01$), but revealed no differences between ratings when they were misaligned ($ps > .20$).

Likewise, for formidability ratings, there was a main effect of movement quality ($F(1, 148) = 70.12$, $p < .001$, $\eta_p^2 = 0.32$), a main effect of movement type ($F(1, 148) = 8.12$, $p = .005$, $\eta_p^2 = 0.05$), and an interaction ($F(1, 148) = 18.88$, $p < .001$, $\eta_p^2 = 0.11$). Aligned movements compared to misaligned movements had higher formidability ratings ($ps < .01$), unison movement had higher ratings than coordinated movement when they were aligned ($ps < .05$), but revealed no differences between movement types when they were misaligned ($ps > .83$).

As with Study 1, the comparison of the two dependent measures showed that closeness ratings were higher than formidability ratings only when movements aligned ($ps < .05$), but not when misaligned ($ps > .20$).

Lastly, an independent sample t-test was conducted in response to the questions ‘how well do you think the animated avatars/stick figures represent real people?’ and ‘could you engage with the avatars/stick figures as though they were real people?’ combined as one variable. It

[2] The dance motions for ‘Dope’ by BTS is opensource and available at: https://bowlroll.net/file/153696.

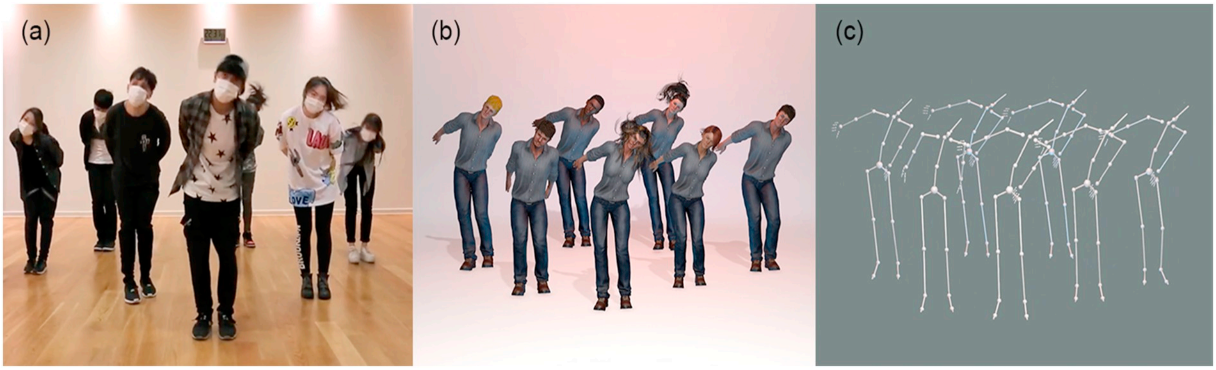

Fig. 3. Still shots of aligned unison movement of (a) showing a group of people performing the choreograph that served as the basis for mapping motion capture to (b) virtual avatars and (c) PLD figures.

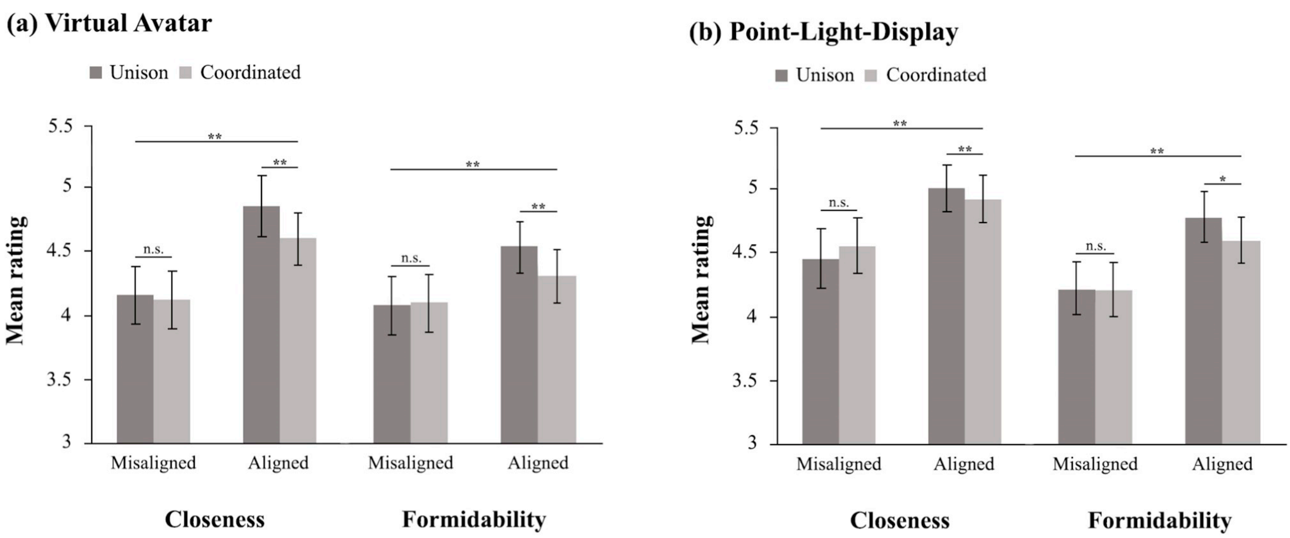

Fig. 4. Mean perceived closeness and formidability ratings of movement type × movement quality when stimuli presented as (a) virtual avatars and (b) PLD figures. The error bars represent 2SE. Asterisks represent statistical significance with adjusted *p*-values for multiple comparisons following the Benjamini and Hochberg (1995) method. * < .05, ** < .01, and n.s. > .05.

revealed that virtual avatars ($M = 3.28$, $SD = 0.84$) were judged as better representation of real people compared to PLD figures ($M = 2.94$, $SD = 1.01$), $t(149) = 2.23$, $p = .03$, $d = 0.37$.

3.3. Summary

Study 2, which incorporated higher levels of ecological validity and more complex forms of coordination, revealed almost identical results to those seen in Study 1. The only difference in the pattern of results between the two studies was that both virtual avatars and PLD figures groups showed no differences in the ratings for temporally misaligned movements in Study 2, whereas there was a significant difference for closeness ratings in Study 1. Moreover, we observed converging patterns of results when an independent participant group watched PLD figures perform the same dance. This strongly corroborates and replicates our previous finding that perfectly aligned unison movement may be a more effective mechanism than coordinated movement to signal a group's close bonds and fitness. Furthermore, the replication of previous results using new stimulus sets and the converging results with the PLD figures suggest virtual avatars are a robust method to study collective movement perception.

4. Discussion

In the present studies, we sought to investigate the extent to which different movement types, performed as either aligned or misaligned, influences a group's perceived closeness and formidability. Differentiating from previous studies that used stick figures (e.g. Miles et al., 2009) or human clips (e.g. Study 4, Lakens, 2010) to study perception of group movement, we developed a novel set of stimuli by representing groups formed of seven individuals with virtual avatars. By using realistic visuals with movements finely mapped from motion capture data of real dancers in Study 1, we presented short clips of virtual avatar groups displaying unison movement or coordinated movement with varying degrees of temporal alignment. In Study 2, we used novel stimuli with choreography taken from an existing boyband to replicate the results of Study 1 in a more ecologically valid setting and tested for generalisability with PLD figures in a between-group design.

In line with our first hypothesis (H1) that participants would give higher ratings of closeness and formidability for aligned movement than misaligned, our studies consistently showed that participants perceive groups that aligned movement as considerably more closely bonded and formidable than those that misaligned movement. Aligned group movement not only gave the impression of the merging of self-and-other between group members (Tarr et al., 2014), but also led the groups to appear physically larger on average when body height and weight were controlled (Fessler & Holbrook, 2016). This supports previous findings that better temporal alignment of movements between group members increase perceived social bonds (e.g. Miles et al., 2009;

Stupacher et al., 2017) and level of formidability (e.g. Fessler & Holbrook, 2016; Hagen & Bryant, 2003).

Our second hypothesis (H2) was that the difference in the ratings of closeness and formidability would only emerge when groups aligned movements, but not when they misaligned movements. Both studies demonstrated that the ratings of closeness and formidability were similar when movements misaligned but significantly different and with larger effects when movements aligned. Study 2 supported our hypothesis that the ratings of closeness and formidability would not differ when the movements were misaligned, whereas Study 1 showed a small but significant difference between the two ratings (implying that people can distinguish the two). Nonetheless, considering that the more ecologically valid and refined stimuli of Study 2 showed the same results between avatars and PLD, we interpret the discrepancies from Study 1 as a minor effect. Overall, the patterns in both studies imply that the type of movement a group performs influences the impression of that group's closeness and formidability, only when groups are performing well together.

When movements were aligned, perceived ratings for closeness were higher than formidability for both unison and coordinated movements. It may be unsurprising, however, that the closeness ratings were higher than those for formidability given that we used dance movements, which may be perceived as more social than other kinds of coordinated movement. We may have found a different pattern if we incorporated movements such as those used in military training. Thus, future research comparing perceived social bonds and formidability could look to include a wide variety of group collective activities (e.g. rituals, sports, and military training) to test the influence of performance context.

Our third hypothesis (H3) made the most specific predictions that coordinated movement would be a better mechanism to demonstrate a group's closeness than unison movement, while unison movement would leave a stronger impression of formidability than coordinated movement. In both studies, participants rated groups that performed unison movement as closer to one another and more formidable than groups that performed coordinated movement. This aligns with Fessler and Holbrook's (2016) findings which used auditory stimuli, and we corroborate their findings by replicating their results using visual stimuli. However, it contradicts our hypothesis that coordinated movement may be a better indicator of a group's close bonds than unison movement. In Study 1 we suspected that the unexpected results might have arisen because the stimuli were too simplistic in their coordination However, we observed the same pattern in the subsequent study when we incorporated a more complex coordination from the choreography of an existing dance group, with these presented as both virtual avatars and PLD figures.

It remains surprising that participants judged unison movement as more closely bonded when a more complex and contingent coordinated movement would demand more practice, conscious attention to others, and effective cooperation. Besides, stronger relationship quality has been associated with the amount of time spent together (Sutcliffe et al., 2012), and our prediction was that coordinated movement would infer this more so than unison movement. Although there are several possible explanations, a point of interpretation could derive from Lakens (2010) finding that revealed completely synchronised action to be maximally entitative. A group that appears more entitative would be perceptually similar and be observed as a single unit, thus blurring the boundaries between the group and the individuals. This would suggest that previous results relating synchronisation to social bonding may come from the perceived entitativity of the group, rather than from a perception that the group members have spent time together to develop complex coordination. An alternative view is that participants may have seen completely synchronised movement between relatively large groups of people as requiring similar or even greater effort to fine-tune their movements to appear 'moving as one team'. To address this issue, it would be worth further investigation into the perceived number of hours or the amount of effort a group would have spent on preparing movements, which may reveal a direct link with the closeness rating.

Our stimulus set was derived from the choreography of an existing song, with a musical beat providing the metrical framework for the groups to align movements. However, we muted the audio for greater experimental control, allowing us to focus on only the factors of interest. Our design is therefore limited in drawing a direct link with the real example of musical interaction, and future experiments could use musical stimuli to examine the interplay between music and movement to provide stronger empirical evidence on the broad question of music and dance and their functions. In a recent finding, Stupacher et al. (2017) showed that musical *groove* (comparable to coordinated movement), but not a metronome (comparable to unison movement), strengthens the felt pro-social behaviour when moving in synchrony. This provides preliminary indication that musical beat or harmonic complexity may have an influence on how a group bonds when moving to music.

Another limitation in our studies was that it largely targeted WEIRD (Henrich, Heine, & Norenzayan, 2010) participants and it is yet unknown whether the current findings are generalisable to a wider population. According to Markus and Kitayama (1991), individuals from more communal cultures such as those in Asian and African regions put primary focus on the interpersonal relationship within communities and relate others as part of self, whereas those from North American regions tend to focus more on the self (for a cultural comparison with an African community, see Constantine, Gainor, Ahluwalia, & Berkel, 2003; and for Japanese, see Kitayama, Markus, Matsumoto, & Norasakkunkit, 1997). Therefore, we may speculate that the perception of the social measures may be influenced by the culture and environment, which calls for a cross-cultural validation. Future work could compare two or more cultures by applying relevant self-construal measures such as the Individualism and Collectivism (INDCOL) scale (Triandis & Gelfand, 1998), to assess the extent to which the current findings are generalisable.

Similarly, following the methods outlined here, it is possible to further investigate how the degree of complexity and the average size of exerted movements, or group size can influence the perception of a group. As discussed previously, the effect of synchronised interaction has been widely studied but overlooked other forms of joint actions: small (e.g. finger tapping, Launay et al., 2013; walking, Wiltermuth & Heath, 2009) versus large physical movement (e.g. dancing, Tarr, Launay, & Dunbar, 2016) have not been empirically compared, and to best of our knowledge, only a single study has compared group size (small vs. mega choir communities, Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016). In a similar vein, while our studies restrict collective movement to the context of dance, other physical activities that involve effective cooperation such as sport can be further researched and compared. In fact, synchrony in music has been compared to rowing (Vuoskoski & Reynolds, 2019), and synchronised rowing has been shown to elevate pain-threshold (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010) in the same way as a performance of music and dance (Tarr, Launay, Cohen, & Dunbar, 2015; Tarr, Launay, & Dunbar, 2016). It may also be interesting to compare other visible features against types of movements such as matched versus unmatched clothing (i.e. uniforms) and gender balance of the group. This would reveal the relative role of group movement compared with other indicators of group identity. To incorporate such study designs, using virtual avatars may possibly be the ultimate tool to help address these existing questions empirically.

In our studies, virtual avatars gave consistent results regarding social closeness and formidability judgements in the context of group movement. Notably, Study 2 demonstrated a convergence of ratings between virtual avatars and matched stimuli of PLD figures dancing to the same song, revealing parallel profiles. Participants also viewed virtual avatars as a better representation of real people in comparison with the conventionally used PLD, indicating that virtual avatars are a robust and promising tool to implement in research involving complex physical interactions. Interestingly, however, PLD figures had higher closeness ratings across all conditions. One possible explanation for this observation could be that participants had a negative perception of the more human-like avatars than the PLD figures, in line with the uncanny valley hypothesis (Kätsyri et al., 2015). Alternatively, the virtual avatars with no facial expression could have communicated an unwillingness or lack of desire to perform as a group, leading them to be perceived as a less socially bonded group. To address whether virtual avatars or PLD figures are the better substitutes for real people, future research should make a direct comparison of the results of avatars and PLD with people.

Our current findings support both coalition signalling and social bonding hypotheses by demonstrating that well-aligned group movement can signal a group's internal social bonds (e.g. Wiltermuth & Heath, 2009) and, at the same time, broadcast formidability to a passive observer (e.g. Hagen & Bryant, 2003). Nevertheless, the question of which of these two theories is more relevant remains and should be further examined in a varied social context and validated cross-culturally. Our findings appear to show that coordinated movement may be a less effective signalling tool compared with unison movement, for both social closeness and formidability, which implies that groups should completely synchronise in order to maximally indicate their social bonds and formidability. Overall, we provide the first empirical comparison of formidability and social bonding theories relating to collective movement in the context of dance. We used a novel and ecologically valid method to strengthen the view that music and dance could have evolved to provide unique social selection benefits, not only to promote relationships within the group but also to broadcast the group's internal bond and fitness to outsiders.

CRediT authorship contribution statement

Harin Lee: Conceptualization, Methodology, Software, Visualization, Investigation, Formal analysis, Writing - original draft. **Jacques Launay:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision. **Lauren Stewart:** Conceptualization, Methodology, Writing - review & editing, Supervision.

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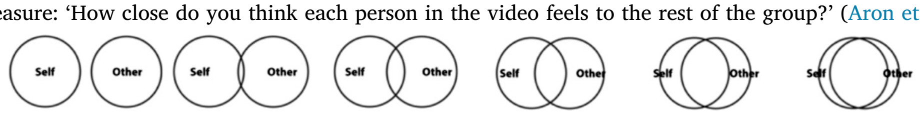
Declaration of competing interest

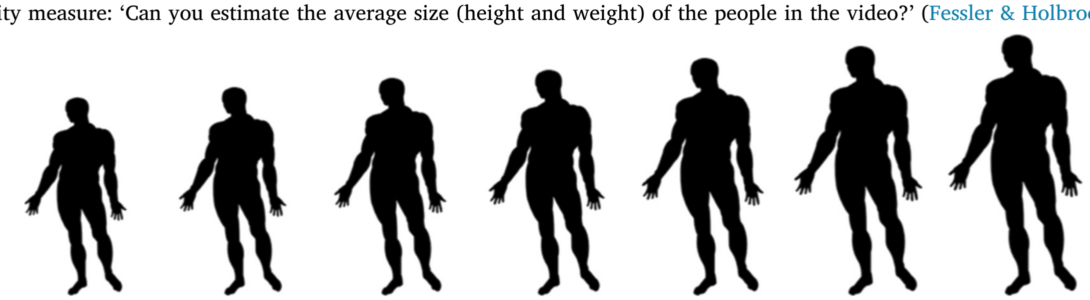
Authors have no competing interests to declare.

Appendix A. Pictorial questionnaire items

Closeness measure: 'How close do you think each person in the video feels to the rest of the group?' (Aron et al., 1992).



Formidability measure: 'Can you estimate the average size (height and weight) of the people in the video?' (Fessler & Holbrook, 2016).



Appendix B. Descriptive and *t*-statistics of Study 2

Table B.1
Mean closeness and formidability ratings of virtual avatar and PLD groups.

		Virtual avatar (n = 75)		PLD (n = 76)	
		M	SD	M	SD
Closeness	Aligned-Coordinated	4.60	0.88	4.93	0.84
	Aligned-Unison	4.85	1.01	5.33	0.96
	Misaligned-Coordinated	4.12	0.98	4.56	0.96
	Misaligned-Unison	4.16	0.97	4.45	1.01
Formidability	Aligned-Coordinated	4.31	0.92	4.60	0.79
	Aligned-Unison	4.54	0.87	4.78	0.88
	Misaligned-Coordinated	4.10	0.96	4.22	0.93
	Misaligned-Unison	4.08	1.00	4.22	0.90

Table B.2
Pairwise *t*-statistics of closeness and formidability ratings on virtual avatar and PLD groups.

Dependent measures	Group	Pairs	M_{diff}	SE	t	Sig
Closeness	Virtual avatar	Aligned-Uni vs. Misaligned-Uni	0.683	0.127	5.39	< .001
		Aligned-Coord vs. Misaligned-Coord	0.479	0.092	5.18	< .001
		Aligned-Uni vs. Aligned-Coord	0.248	0.072	3.44	.002
		Misaligned-Uni vs. Misaligned-Coord	0.045	0.064	0.70	.582
	PLD figure	Aligned-Uni vs. Misaligned-Uni	0.873	0.137	6.34	< .001
		Aligned-Coord vs. Misaligned-Coord	0.375	0.086	4.38	< .001
		Aligned-Uni vs. Aligned-Coord	0.398	0.088	4.53	< .001
		Misaligned-Uni vs. Misaligned-Coord	−0.100	0.074	−1.35	.196
Formidability	Virtual avatar	Aligned-Uni vs. Misaligned-Uni	0.468	0.079	5.90	< .001
		Aligned-Coord vs. Misaligned-Coord	0.210	0.066	3.16	.004
		Aligned-Uni vs. Aligned-Coord	0.234	0.057	4.10	< .001
		Misaligned-Uni vs. Misaligned-Coord	−0.024	0.053	−0.46	.710
	PLD figure	Aligned-Uni vs. Misaligned-Uni	0.555	0.093	5.95	< .001
		Aligned-Coord vs. Misaligned-Coord	0.387	0.064	6.07	< .001
		Aligned-Uni vs. Aligned-Coord	0.180	0.070	2.59	.016
		Misaligned-Uni vs. Misaligned-Coord	0.011	0.062	0.18	.859
Closeness × Formidability	Virtual avatar	Closeness vs. Formidability of Aligned-Uni	0.305	0.126	2.43	.027
		Closeness vs. Formidability of Misaligned-Uni	0.090	0.104	0.87	.519
		Closeness vs. Formidability of Aligned-Coord	0.291	0.105	2.77	.012
		Closeness vs. Formidability of Misaligned-Coord	0.021	0.102	0.21	.835
	PLD figure	Closeness vs. Formidability of Aligned-Uni	0.545	0.118	4.61	< .001
		Closeness vs. Formidability of Misaligned-Uni	0.227	0.103	2.20	.037
		Closeness vs. Formidability of Aligned-Coord	0.326	0.104	3.14	.003
		Closeness vs. Formidability of Misaligned-Coord	0.338	0.104	3.24	.003

Note. *p*-values were adjusted for multiple comparisons following Benjamini and Hochberg (1995) method. Abbreviations: Uni = Unison, Coord = Coordinated.

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2020.103093. All stimuli used for the experiments can be found at https://osf.io/n6ebs/.

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