SOCIAL BONDING HAPPENS IN TIME: INTERPERSONAL SYNCHRONISATION IN THE SILENT DISCO

Joshua Michael Silberstein Bamford
Master’s Thesis
Music, Mind and Technology
Department of Music, Art and Cultural Studies
31 May 2017
University of Jyväskylä

JYVÄSKYLÄN YLIOPISTO

Tiedekunta – Faculty Humanities	Laitos – Department Music, Art and Cultural Studies
Tekijä – Author Joshua Michael Silberstein Bamford	
Työn nimi – Title Social bonding happens in time: Interpersonal synchronisation in the silent disco.	
Oppiaine – Subject Music, Mind & Technology	Työn laji – Level Master's Thesis
Aika – Month and year May 2017	Sivumäärä – Number of pages 50

Tiivistelmä – Abstract

Dance is a fundamentally social activity. Studies have begun to examine the role of movement in music for conveying emotional states, potentially revealing a useful mechanism for the communication of emotions, while other studies have found that joint synchrony increases interpersonal affiliation. However, music and movement studies have focused on individuals and comparatively few studies have involved multiple simultaneous participants. The aim of the proposed research is to examine the importance of synchrony in a dance setting for building interpersonal affiliation. This was tested using a Silent Disco scenario, in which participants heard the music in slightly different timing to each other. Participants were drawn from the population of a Finnish university, and were able to self-select partners. In a within-subjects design, it was found that pairs experienced a greater sense of interpersonal affiliation while in the synchronous condition than in the asynchronous conditions. Self-reported results were supported by behavioural measurements of interpersonal affiliation. Further analysis found a positive relationship between Trait Agreeableness and self-reported affiliation in the synchronous condition. These findings are discussed in the context of current research around synchrony and social bonding, and provide new insights into the role of synchrony in social dancing or therapeutic settings. It may be concluded that shared experiences are more effective at bringing us together when they are shared in time.

Asiasanat – Keywords

Synchronisation, movement, music, embodied cognition, social, dance

Säilytyspaikka – Depository	
Muita tietoja – Additional information	

Acknowledgements

Firstly, I wish to thank my supervisors, Birgitta Burger and Petri Toiviainen, for sharing their time and expertise with me over the past two-and-a-half years. I have always looked forward to our conversations which, despite the best of intentions, inevitably stray far beyond the scope of my thesis. The work you do is incredible, and I have no idea how lucky I am. Thanks to Mikko Leimu for assisting with some of the intricacies of the MoCap lab, and to Markku Pöyhönen for just making things work. Thank you also to Marc Thompson, for everything he has done in coordinating the MMT programme, and to Geoff Luck for a brief conversation at a conference in Perth, which ultimately resulted in me applying to study in Jyväskylä. To my fellow MPT students, thank you for being my companions on this journey. In particular, a big thank you to Susan Johnson (and again to Birgitta Burger), and everyone on the SysMus16 committee for agreeing to host a conference with me. To everyone else in the department, staff and students, thank you for talking, singing, dancing, playing and generally being such good company. The Musica building is a wonderful place. Special thanks to everyone in JYY, UniSounds, Music-Kuoro, Sinfis, Pedaali, Trioli, IDESCO, ESN or any of the other student organisations that tried to distract me from finishing this thesis. I'm not sure if I got here despite, or because, of you. Thank you to Daniel Bowling, Tecumseh Fitch, and the Cognitive Biology department at the University of Vienna, for an inspiring semester on exchange and for giving me a bird's eye view of musical behaviour. On a more personal note, my sincere thanks to Fabienne Saurer for always being there, even when you can't be, and to the Marttila family for adopting me in Finland. Thank you to my biological family in Australia, for both your unending support, even when I said I wanted to move to Finland for study, and for being a wonderful source of inspiration in how to avoid getting a real job. To my Grandfather, thank you for the shoes. To Jyväskylä, thanks for being "home" for a while.

"And those who were seen dancing were thought to be insane by those who could not hear the music." - Friedrich Nietzsche (a man who clearly appreciated the silent disco)

CONTENTS

1 INTRODUCTION

An ever-increasing body of literature has explored the relationship between music and movement. People have a general capacity for rhythmic entrainment, and will often move spontaneously to music (Chen, Zatorre, & Penhune, 2006). There are also individual differences in the way people move to music (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010), and respond emotionally to music (Thompson, McIlwain, Eerola, & Vuoskoski, 2012). The combination of music and movement also appears to have a profound social bonding effect.

Dance may be considered the expression of music through movement. A broad definition is used for the purpose of this thesis, in which any auditory stimulus with a regular pulse or beat may be considered music. Any movement which is rhythmic in nature, and which is produced with the intention of synchrony with music, may then be considered dance. This definition is contingent upon intention, not actuality, as an individual may intend to dance in time with a beat, but fail to do so for any number of reasons (some of which will be the topic of this thesis). Success in rhythmic entrainment through dance is reliant upon sensorimotor synchronisation to a rhythmic stimulus.

It is also of vital importance to define what true synchrony is. The literature on synchronisation and entrainment has, to date, used these terms almost interchangeably. More problematic is that, in some studies, “synchronisation” may not always be used to mean truly simultaneous, time-locked movement, but more general behavioural matching or imitation occurring in a roughly similar period of time (Richmond, 2017). This thesis adopts the model proposed by Bernieri and Rosenthal (1991), and considers interpersonal coordination as an umbrella term for joint action between individuals. Two sub-types of interpersonal coordination then exist: interactional synchrony, the true synchrony in which actions occur simultaneously in time, but do not have to be identical in nature; and behaviour matching, a kind of imitation in which the nature of the actions performed by individuals is similar, but they need not occur at exactly the same time (Bernieri & Rosenthal, 1991). Synchronisation must involve deliberate intention to coordinate timing with another actor, and requires an ability to match perception and action, predict the movement of an external actor and adapt to it (Keller, Novembre, & Hove, 2014).

To move in time, we must perceive the timing of a stimulus and coordinate a motor response; a complex skill in which individuals may perform differently.

It can be argued that synchronisation requires a form of empathy, an important process by which we can perceive emotion, both in other people, and in music. Empathy is the capacity for one to take the perspective of another, and individual differences may be measured in the Trait Empathy construct (Baron-Cohen & Wheelwright, 2004). Individual differences in Trait Empathy have been studied extensively, and new research is starting to understand the neurological mechanisms behind this. Music, movement and emotion appear to have much in common, perhaps including some underlying mechanisms which get to the core of why we have music in the first place.

This thesis aims to examine the role of synchrony in social bonding. It is grounded in theories describing the evolution of music, and considers music's role in communicating emotion as well as bringing people together. While music is an undeniably social activity, the mechanisms through which we synchronise movement with others, and exactly what this means for social interaction through music, are poorly understood. Through the following pages, an account of embodied musical empathy will be given, alongside an overview of literature examining the role of music and dance activity in facilitating social bonding. These threads are brought together in an experiment demonstrating the importance of interpersonal synchrony to the social bonding experience of dancing.

1.1 Embodied Empathy and Mirror Neurons

The idea that perceiving movement is integral to empathy has existed within the psychology literature since Goldman (1989) proposed the Simulation Theory of Empathy: that one perceives the mental states of others by simulating the other's state in one's own mind. Many authors have since explored theories of emotion that emphasise the importance of motor imitation to the process of empathy (Decety & Ickes, 2011; Iacoboni, 2009; Ramachandran, 2000). This has since gained support from research into the Mirror Neuron System (MNS), which may be the neural mechanism through which imitation and mental simulation occur (Gallese & Goldman, 1998). The implication is that simulation of mental states may first be enabled by simulation of physical movement; the way we move may be a window into who we are.

The MNS, first discovered in monkeys, refers to a system of neurons that activate whenever perceiving another performing an action (Rizzolatti & Craighero, 2004). Research into the MNS in humans has been controversial, as monkey experiments have involved detailed observations of individual mirror neurons; experiments that are difficult to replicate in human subjects (Rizzolatti & Craighero, 2004). Nevertheless, authors such as Rizzolatti (2005) have put forward a strong case for the existence of mirror neurons in humans, with neuroimaging studies finding activation in homologous areas of the human motor cortex to those regions associated with the MNS in monkeys. The Simulation Theory of Empathy proposes that we mentally simulate the actions of others in our own motor cortices, using the Mirror Neuron System, in order to understand those actions and empathise with the other.

1.2 Music, Movement and Empathy

Music undoubtedly carries emotional information, and the process of perceiving emotion in music may be indistinct from the general process of empathy. Certainly, there is an increasing amount of research that considers both music and empathy to be fundamentally embodied experiences (Leman, 2007). Juslin and Västfjäll (2008) have outlined the possible mechanisms by which music may convey emotion, in a seminal theoretical paper. One of the six mechanisms they propose is Emotional Contagion: an automatic internal mimicry of perceived emotion in music, which induces the emotion in the listener. The authors suggest this mechanism is fundamentally linked with motor processing through the Mirror Neuron System. Overy and Molnar-Szakacs (2009), have expanded on this with the Shared Affective Motor Experience (SAME) theory, which proposes that music implies movement, and that the perception of movement in turn conveys emotion. On the other hand, Livingstone and Thompson (2009) have suggested that music, as a behaviour, could not exist if humans did not have a capacity for empathy; again, the Mirror Neuron System is the suggested mechanism at the core of both empathising and musical behaviour. Although much of this research has been theoretical, many authors are now suggesting that motor processing is important to both the perception of emotional states, and the appreciation of music.

If the Mirror Neuron System is being used by musical, movement and emotion perception, then it might be expected that there is some transfer between these abilities. Indeed, studies have suggested that Emotional Intelligence and Agreeableness (both traits which are related to Trait Empathy) may be associated with greater rhythmic entrainment ability (Luck, 2011; Petrides, Niven, & Mouskounti, 2006). In a partial replication of the study by Luck (2011), a positive relationship was found between Trait Empathy and the time taken for participants to establish synchronised movement with a musical pulse (Bamford, 2013; Bamford & Davidson, 2017). Furthermore, relationships have been observed between rhythmic perception, as measured on the Profile of Music Perception Skills (PROMS), and Trait Empathy (Strauß & Zentner, 2015). While these studies provide interesting observations of individual differences, they have mostly only studied subjects in isolation and ignored the fact that both empathising and dancing are fundamentally social activities: we usually either perform for, or with, others.

1.3 Evolution of Social Dancing

There have been a small number of previous studies that have suggested that the movement in music is not only responsible for conveying emotion, but also has an integral social function. Natural selection theory suggests that only behaviours which increase the chance of survival of the individual (and their genes) are likely to continue in a population. Music and dance have costs, in terms of time and energy; therefore, if we loudly move in synchrony together, there must be a good evolutionary reason for it. The capacity for rhythmic entrainment is also a complex cognitive ability, which may rely on many underlying mechanisms evolved for other purposes (Phillips-Silver, Aktipis, & Bryant, 2010). Many researchers have put forward one of two possible social functions of music and dance: either helping us find a mate, or helping us form groups.

1.3.1 Sexual Selection

Traits that improve the chance of an individual attracting a mate, and thus passing on one's genes, may be considered sexually selected for. Often, these traits are considered aesthetically pleasing, but otherwise useless (Prum, 2012). The dominant theory explanation for sexual selection, since the theory was first proposed by Darwin, is that sexually selected traits are markers of general fitness precisely because they handicap their owners (Zahavi, 1975). It is difficult to maintain the most beautiful plumage, or to sing the best song, when there are other, more pressing matters relating to immediate survival; thus, only the toughest animals can afford these things, giving rise to this handicap signalling theory. The alternative theory of index signalling has proposed that sexually selected for traits may serve as an honest signal of fitness, not because they are a handicap, but because they are related to other traits which do have survival function, and are very difficult to fake (Biernaskie, Grafen, & Perry, 2014). Dancing behaviour could potentially fit into either of these theories, although human research has been quite limited.

It is possible that dancing behaviour is either a costly signal, in both time and energy, that only fit individuals can afford, or that is an index of some other adaptive traits such as motor coordination, and thus performs a sexual selection function. Indeed, it has been noted that dancefloors serve as platforms for courtship behaviour (Hendrie, Mannion, & Godfrey, 2009). Unfortunately, early success in this line of research was marred with controversy, as an important paper examining the relationship between dancing ability and genetic fitness was found to be the product of scientific fraud (for an account, see: Palestis, Trivers, & Zaatari, 2014); that does not disprove the theory that dancing ability is sexually selected for, however. Some newer studies have now emerged, claiming that particular movements by human females during dance may be perceived as more attractive by human males; in this case the authors suggest that these movements may be an index signal of motor control and hip structure which may indicate general fitness and fertility (McCarty et al., 2017). Music and dance may well be methods by which individuals can display their fitness to potential mates. The evidence, however, is still limited at this stage, and so other evolutionary mechanisms must be considered.

1.3.2 Group Bonding

The other key theory as to why humans have music and dance is that it serves to bind groups together. This is the more controversial idea from an evolutionary perspective, as the precise mechanism through which group bonding behaviour may provide an evolutionary benefit is still under debate.[1]

Some authors have suggested that music is a necessary extension of social grooming behaviour seen in other primates (Dunbar, 2010, 2012). In other species, individuals will groom each other to establish social order, but this becomes impractical as group sizes increase. Humans may have overcome this limitation by evolving synchronous musical behaviour as a way of efficiently socially grooming many conspecifics simultaneously, and thus binding together larger groups than would ever be possible otherwise.

It has been suggested that synchronous activity focuses participants on others in the group, while transcending differences between individuals (McFerran, 2013); one sees others as bodies in motion, and focus on the motor processes of entraining with that motion, rather than focusing on other traits that may mark the other as different to the self. Furthermore, some have proposed that moving in synchrony serves to blur the psychological divide between the self and the other (Tarr, Launay, & Dunbar, 2014). In addition, by dancing in synchrony with another or a group, it may serve as a coalition signalling mechanism (Hagen & Bryant, 2003); others from outside the group may perceive those who are moving together as being affiliated. This assertion is supported by perceptual experiments suggesting that synchrony functions as a gestalt grouping principle, implying that bodies moving in synchrony are grouped together and perceived as a whole by onlookers (Rideaux, Badcock, Johnston, & Edwards, 2016). In this way, dancing behaviour may build group cohesion, while also serving display that cohesion to others.

[1] It is beyond the scope of this thesis, but the precise evolutionary mechanisms through which group bonding provides an advantage should be kept in mind. Traditionally, all adaptations function either through natural or sexual selection. When considering social behaviours, various alternatives such as kin selection, group selection and reciprocal altruism exist. The viability of these hypotheses is hotly contested. Nevertheless, it stands that many species, particularly our own, exhibit pro-social behaviours, seemingly with the intent of binding a group together, and this observation cannot be ignored.

1.4 Music/Dance and Group Bonding

A few experimental studies have indeed found that synchronous movement promotes pro-social behaviour, builds affiliation and perhaps even enhances empathy. Indeed, it is possible that shared empathy through music and dance may be central to the social cohesion effect of these activities. Behrends, Müller and Dziobek (2012) have suggested that regular dancing may actually increase one's empathic ability. They assert that dance therapy may be used to train empathy in those with Autism spectrum disorders, who are usually considered to be deficient in empathy, and that the higher order processing required for dance would make this kind of therapy more effective than a simpler imitation task (Behrends et al., 2012). Berrol (2006) similarly suggests that Dance/Movement Therapy, a very specific type of arts therapy, may develop empathetic abilities. One must consider that theories of Dance/Movement Therapy may be specific to clinical populations, in this case those on the Autism spectrum. However, as Autism is a spectrum disorder, with many people exhibiting Autistic traits without actually being diagnosed as Autistic, it's possible there are more general applications to non-clinical populations. Nevertheless, both the theories presented by Behrends, Müller and Dziobek (2012) and Berrol (2006) are based upon the idea that synchronous movement may be an empathic process, although they do not suggest any specific mechanisms, nor do they test this theory themselves.

While there has been some research on imitation and social affiliation (Lakin & Chartrand, 2003), it is only very recently that true synchronisation has been examined in detail. Hove and Risen (2009) were amongst the first to study the importance of synchronous movement in an experimental setting. They found that, in a finger tapping scenario, a participant would develop a greater sense of affiliation towards the experimenter when both were tapping in synchrony (Hove & Risen, 2009). In a study by Cirelli, Einarson and Trainor (2014), music was played to infants and an experimenter would move either in or out of synchrony with the infant's spontaneous movement. Infants who experienced the synchronous movement were subsequently more likely to help the experimenter by picking up dropped pens (Cirelli et al., 2014). A similar study found that participating in a shared musical activity increased helping behaviour between 4 year old children, when compared to a control condition (Kirschner & Tomasello, 2010). Not only does this demonstrate a relationship between cooperation and synchronous movement, but it also suggests that this behavioural mechanism exists from a very young age.

Another study by Tarr, Launay, Cohen and Dunbar (2015) measured pain threshold as well as self-reported social bonding in High School aged children. This was based on the theory that endorphins released during exercise have a social bonding effect, which may explain the effect of synchronous movement on social bonding (Dunbar, 2010; Tarr et al., 2014); endorphins also increase pain tolerance, meaning that pain threshold can be used as a proxy measurement.[2] The effect of exercise was only half the story, as an independent effect was found of the degree of synchrony between participants on both pain threshold and self-reported social bonding.

A number of more recent studies have further supported the synchrony-bonding observation. Listening to a rhythmic stimulus may improve motor coordination between individuals, perhaps through entrainment of movement to that rhythm (Lang et al., 2016). It is likely that improved coordination with a partner may then lead to more positive feelings about that partner. Furthermore, the synchrony-bonding effect is not limited by line of sight, as synchronising movement with the sounds of another person will increase feelings of affiliation towards them, even if they cannot be seen (Launay, Dean, & Bailes, 2014). Not only do we experience greater affiliation with a partner when moving in synchrony, but this also increases our self-esteem, perhaps through experiencing a kind of social reinforcement or approval (Lumsden, Miles, & Macrae, 2014). Importantly, the synchrony-bonding effect scales well with increasing group size (Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016). This is consistent with the social grooming hypothesis which supposes music to be a more efficient alternative to the one-on-one social grooming behaviour exhibited in many of our primate cousins. All of these studies indicate an effect of synchrony on social bonding, however they are few in number, and it is difficult to adequately control conditions so that the role of synchrony can be appropriately identified. Clearly, new methods are required for further study.

[2] There may be two separate hormonal systems for social bonding: both endorphins, which also increase pain threshold, and oxytocin. Exactly how these two systems interact to mediate social bonding is still up for debate (Dunbar, 2010).

1.5 The Silent Disco

The concept of a silent disco is a twist on a traditional party in which, rather than having a speaker system, only the participants with headphones can hear the music ('Silent disco', 2015). This creates a distinct in-group and out-group, whereby only those actively participating may hear the music and experience entrainment with other participants (Cummins, 2009). Some silent disco events even have multiple DJs running multiple channels such that not every participant is even listening to the same music.[3] The result is that the shared group experience of dancing together is separated from the experience of rhythmic entrainment with other dancers.

The situation created by the silent disco provides an opportunity to study the importance of rhythmic entrainment in the experience of synchronous activity. Reddish, Fischer and Bulbulia (2013) first alluded to this research paradigm by using a four-way wired headphone splitter, delivering metronome beats at either synchronous or asynchronous tempi, to which participants had been instructed to move in time to, with prescribed movements. In a test of cooperation afterwards, participants were more likely to donate more money to benefit the whole group when they had been moving in synchrony, as compared with the asynchronous condition (Reddish et al., 2013). This study suggests a role for synchronous movement in promoting prosocial behaviour, in line with previous research, but more importantly establishes the idea of using headphones to manipulate synchrony between individuals, and thus helping to pave the way for the silent disco paradigm.

Woolhouse, Tidhar and Cross (2016) began investigating this by getting two groups of participants to dance in a room together, while each group was listening to different music in a 2 channel silent disco scenario. Afterwards, each participant was asked to recall certain features of the other participants, and it was found that memory for those in the same group was better than for those of the other group (Woolhouse et al., 2016). It is important to note that this study

[3] For example, the Silent Disco at Fringe World in Perth, Western Australia ('Fringe World Silent Disco', 2015). In this case, all participants were given wireless-headphones, each with the option of 3 channels. The headphones included lights which changed colour depending on the channel selected. Footage from this event can be found here: https://youtu.be/6RKCaHn5LHg

presented the different groups with entirely different music, so it is impossible to determine whether the observed effects resulted from asynchronous movement or an asynchrony in the affective qualities of the music. Nevertheless, the findings of Woolhouse, Tidhar and Cross (2016) are consistent with much of the previous literature, suggesting that synchronous movement may have an important social function, however memory for others cannot be directly equated with increased feelings of social affiliation.

The silent disco paradigm has already been employed as a method to examine the role of synchrony in social bonding. Tarr, Launay and Dunbar (2016) found an effect of synchrony on both a questionnaire measure of social closeness and on pain threshold. In this experiment, four participants formed a test group, and each group was placed into either a synchronous, partially synchronous or asynchronous group, and participants were taught specific dance routines. The synchronous and partially synchronous conditions had participants listening to the same music, but with different choreographic instructions, while the asynchronous condition had randomised the presentation of musical stimuli between participants. Interestingly, it was the partially synchronous condition that was most detrimental to social bonding (Tarr et al., 2016). However, by using pre-choreographed movements, this study did not allow for spontaneous movement as one would find on a social dance floor. Furthermore, the definition of synchrony in this study was really a type of temporal locked behavioural imitation; participants were instructed to either perform the same or different actions, but the timing of movements was always constant. Nevertheless, these previous studies do demonstrate the potential of the Silent Disco paradigm as a method for testing social synchronisation.

1.6 The Present Study

Much of the research explored here is theoretical; providing fertile grounds to be experimentally tested. The few empirical studies to have explicitly studied interpersonal synchrony and affiliation have demonstrated a synchrony-bonding effect, but have a range of limitations that prevent us from drawing concrete conclusions about the mechanisms through which synchrony causes social bonding. This is unsurprising, as both synchrony and social bonding are notoriously difficult to study: measurements must be timed carefully, so as to not interrupt synchronous movement, methods of measuring social bonding are often unreliable, and analysing the movement of multiple bodies in any detail is quite complex. Nevertheless, the idea that music and dance bring people together is certainly not a new one. It provides a strong argument for the existence of music from both an evolutionary perspective (when considering the reasons for music to have evolved as a behaviour) and from a modern practical standpoint (as music continues to bond groups together, be they religious groups or music fans at a rock concert). It seems as though there is ample scope for more empirical research.

The few empirical studies that do exist present interesting methodological options for the present study. Measuring affiliation or pro-social attitudes/behaviour is challenging. It can be accomplished either by asking participants to self-report, with a questionnaire, or by observing and measuring behaviour, as Cirelli and colleagues (2014) have done. Previous studies, such as that by Hove and Risen (2009), have looked at interpersonal synchronisation, but these studies have usually been between a participant and an experimenter who may intentionally move in, or out, of synchrony with the participant. The Silent Disco provides a way to induce synchronous or asynchronous movement between two or more participants. This allows interpersonal synchrony to be studied in a more naturalistic setting.

The present study aimed to investigate the role of interpersonal synchrony in social bonding through dance. It replicates some of the methodology from Hove and Risen (2009) although in a dance context, rather than with finger tapping, thus enhancing external validity. This was done using a Silent Disco scenario, similar to that used by Woolhouse, Tidhar and Cross (2016), although with only two participants listening to stimuli in either synchronous or asynchronous conditions, and with the nature of the musical stimulus being kept constant between individuals in the dyad, except for a difference in timing (tempo-stretched or phase-shifted). Unlike the experiment by Tarr and others (2016), the present study allows participants to dance freely rather than to choreographed movements, again, to maintain a more naturalistic setting. The present study thus builds upon the silent disco paradigm, as used in these previous studies.

All the dyads in the present study danced in all conditions, in a within-subjects design. It was hypothesised that participants would indicate higher levels of satisfaction with their social interaction in the synchronous condition than in either of the asynchronous conditions (tempo-shifted or phase-shifted), on a self-report questionnaire. Additionally, behavioural measures of interpersonal affiliation, collected through motion capture, are expected to support self-reported affiliation, as participants should look towards each other more and stand closer to each other in the synchronous condition compared to the asynchronous conditions. Furthermore, individual differences in Trait Empathy and Agreeableness are taken into consideration, to find possible interactions with performance on the dancing task.

2 METHOD

2.1 Participants

Participants were recruited through online advertisements on Facebook and mailing lists. Most participants were current international students at the University of Jyväskylä, between the ages of 19 and 31 (Mean=25.17), and all had completed at least a High School level of education. There were 24 pairs. Participants self-selected their partner for the silent disco activity, ensuring that all participants were dancing with someone they were comfortable with. This resulted in 20 Female-Female pairs, 3 Male-Female, and 1 Male-Male. All participants were asked to complete the battery of personality measures, as well as questions about music and dance experience. 62% of participants had received some kind of formal dance training, and reported enjoying dancing (Mean=8.3, on a scale of 10). Prior music and dance experience was collected to help explain individual differences in dance behaviour, should outliers have emerged from the data.

2.2 Materials

All participants completed a questionnaire battery as part of recruitment. This battery included the Empathy Quotient 8-item version (EQ-8), Toronto Empathy Questionnaire (TEQ), the Big Five Inventory (BFI), the Ollen Musical Sophistication Index (OMSI) in addition to demographic questions about education and dance experience (see Appendix 1). The EQ-8 is a shortened form of the Empathy Quotient (Baron-Cohen & Wheelwright, 2004), developed by Loewen, Lyle and Nachshen (2009). The BFI is a 44-item measure of the Big Five, included to gain some general insight into participants' personalities (John & Srivastava, 1999). The OMSI is a quantifiable measure of musical sophistication, without relying solely upon asking for the level of the participants' formal music education, and will be used to control the sample (Ollen, 2006). There is no equivalent to the OMSI for dancing sophistication, so general questions about dance training and regularity of social dancing were used for the same purpose.

The study was completed in a motion capture lab, equipped with an 8 camera, Qualisys Oqus 5+, optical motion-capture system, recording at 120 frames per second. Participants all wore 28 reflective markers each for a total of 56 markers per pair. Each participant also wore a pair of wireless headphones to isolate the musical stimuli between participants.

The musical stimuli were created from 30 second excerpts of six songs. Of these, there were three Motown songs and three electronic dance tracks, of a range of tempi from 90 to 140bpm. Each piece had high pulse clarity and percussiveness, with a strong bass, as these features produce the most regularity in music induced movement (Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2012). It was important that participants wanted to move to the music, thus providing their partner with a strong visual stimulus of the beat that they hear; as such, this experiment could be considered to be testing the effect of incongruent auditory (the music) and visual (the movement of the partner) stimuli. Each of the six excerpts was manipulated in two separate ways: the tempo was stretched by 5% towards 120bpm, or a delay of a quarter-of-a-beat was added to the start of the track. 120bpm was chosen as an ideal average tempo, based on previous research (McKinney & Moelants, 2006). This made for a total of 18 stimuli: the six originals, six tempo stretched versions, and six phase shifted versions. Stimuli were played using a Max/MSP patch which randomised their presentation order and controlled timing of playback. The complete list of stimuli can be found in Appendix 2.

A self-report questionnaire was also included, to assess how participants felt during the task. This consisted of five questions about their experience while dancing, and was administered at the end of each condition. Their response was recorded on a 10-point Likert scale. The questions are included in Appendix 3.

2.3 Procedure

Individual participants were recruited online, and asked to bring a partner with whom they were comfortable dancing. Each pair came into the motion capture lab and were assigned the experimental conditions in random order. Each of the three conditions consisted of 12 musical stimuli, playing the six 30s tracks twice. This allowed for counter-balancing the tempo shifted stimuli. In the ‘Synchronised’ condition, both participants had the same stimuli, hearing both original and tempo shifted versions at the same time. The ‘Tempo’ condition presented the original track to one participant, while the other heard the tempo shifted version of that same track; the reverse would also occur, so neither was only getting tempo shifted tracks. Finally, the 'Phase' condition only included songs in their original tempo, but for one participant the stimulus would begin 90º behind the other; again, this was counter-balanced so that both participants would experience being earlier and later for each stimulus.

At the start of the study, both participants were informed that the study was about social interaction on the dance floor, and instructed to move freely to the music that they heard. They were told that they would both be hearing the same music, and that the headphones were simply being used as a side project, to test whether they worked for stimulus presentation in a motion capture setting, for the sake of future research. At the end of the 12 stimuli of each condition, the participants were asked firstly to stand comfortably while the system recalibrated, and then to step towards a computer one at a time to complete a short questionnaire about their experience during the task. Once both participants completed the questionnaire, they would then be asked to step back onto the floor for the next condition. Once the pair completed all three conditions they were debriefed; first being asked what they thought the study was about, as participants were provided very little background to the study, and then being informed of its true aims.

After the lab experiment, all participants were given the personality questionnaire battery, including the EQ-8, TEQ, BFI, OMSI, and demographic questions. This was completed online.

2.4 Motion Capture Analysis

Motion capture data was exported from Qualisys Track Manager software and imported into MATLAB for analysis with the MoCap Toolbox developed by Burger and Toiviainen (2013). Recordings were made for each trial presented to each dyad. These were trimmed to retain only the recording from 10 seconds after the initial presentation of the stimulus, until the end of the stimulus 20 seconds later. The first 10 seconds were removed to give participants time to find the beat after stimulus presentation. As recordings were made at 120 frames-per-second, and were trimmed to 20 seconds, this gave 2,400 frames per trial. Since the stimulus order was randomised, and conditions counterbalanced, all recordings had to be reordered such that conditions were arranged in order: synchrony, tempo-stretch, phase-shift. A marker-to-joint conversion was then performed to find the centre point between head markers of each participant; this gave a central marker for use in later analysis.

Measures of interest could then be investigated. Interpersonal distance was calculated between the central head markers of both participants in the dyad at each frame of the recording using *mcdist* in the MoCap Toolbox, as illustrated in Figure 1. This resulted in 2,400 measurements, from which both a mean and variance were calculated for each trial. The mean distance, and variance of distance were then averaged between the 12 trials of each condition, leading to one mean distance and one variance of distance score per condition for each dyad. These scores were then used in statistical analysis to find the effect of each condition on distance.

FIGURE 1. The measurement of interpersonal distance.

Relative head orientation was calculated with *mcorientation* in the MoCap Toolbox,[4] by using the front-left and front-right head markers of each participant in the dyad. This gives a measurement of the degree to which participants are facing each other, with 0° being face-to-face. As with the distance measurement, this was done for every one of the 2,400 frames, from which a mean and variance of relative head orientation was calculated per trial. Subsequently the means of these scores was found per condition, which were then used in statistical analysis to find the effect of each condition on both mean relative head orientation, and variance of relative head orientation.

[4] *mcorientation* is not available in the current release (v1.5) of the MoCap Toolbox as it is still under development. It may be included in future versions of the MoCap Toolbox.

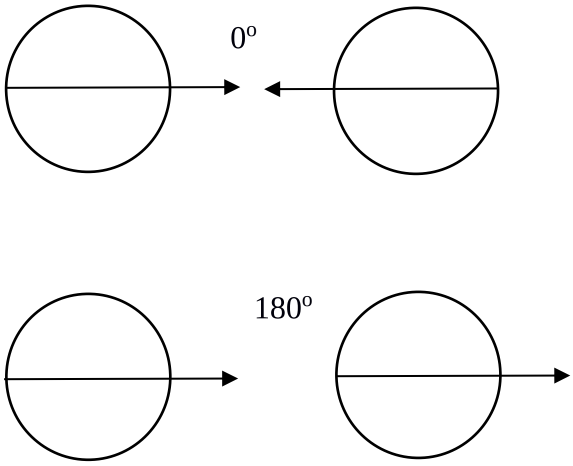

FIGURE 2. The measure of relative head orientation.

3 RESULTS

Both the results from the questionnaire data and some initial observations from the Motion Capture data are presented here. Firstly, differences in self-reported response to the task are presented, between the three within-subjects synchrony conditions. Secondly, these responses are broken down further, looking at correlations between subjective responses and personality traits. Statistical analysis was done in the PAST statistics package (Hammer, Harper, & Ryan, 2001). Finally, some simple measurements of distance and relative head orientation between participants are presented, as behavioural measurements of affiliation and coordination within each dyad.

3.1 Effect of Synchrony on Self-Reported Experience

As the questionnaire yielded ordinal data, non-parametric statistics were used. A repeated-measures Friedman's test found a significant effect of synchrony condition on the response given by participants (N = 48) to the question: "how would you rate your interaction with your partner?", $X^2(2) = 7.1979$, $p < .05$. Post-hoc analysis using Bonferroni corrected Wilcoxon signed-rank tests revealed a significant difference between the Synchronised and Phase conditions, $W = 433$, $z = 2.818$, $p < .05$, with a moderate effect size, $r = .288$, but no difference between the other conditions. Descriptive statistics for the responses to all questions may be found in Table 1. Although this first question was most relevant to the study, repeated-measures Friedman tests were also run on the other questions, finding no significant differences between conditions.

3.2 Personality

Correlations were conducted between the self-reported rating of partner interaction during the task and personality measures from the TEQ, EQ-8 and BFI. These are shown in Table 2. Only the question about partner interaction was chosen, given the observed effect on responses to this question of synchrony, to determine whether there was a possible interaction with personality.

TABLE 1. Descriptive statistics for answers to the post-task questionnaire.

	Synchronised			Tempo-stretched			Phase-shifted		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
"How would you rate the interaction between yourself and your partner?"	7.87	9	2.07	7.29	7.5	1.93	7.17	8	2.37
"How much did you enjoy this task?"	8.12	8.5	1.64	8.29	9	1.56	7.77	8	2.20
"How comfortable did you feel during the task?	8.54	9	1.64	8.54	9	1.40	8.52	9	1.44
"How much did you enjoy the music?"	6.77	7	2.01	6.79	7	2.17	6.46	7	2.40
"Did you feel anxious or nervous during the task?"	1.95	2	1.43	1.93	2	1.06	1.91	1	1.29

A significant correlation was found between the two measures of Trait Empathy: the TEQ and EQ-8, $r_\tau = .504$, $p < .01$, thus validating the measures against each other. Both measures of Trait Empathy also demonstrated a correlation with the Agreeableness scale of the BFI. The TEQ was found to correlate with Openness as well, while the EQ-8 correlated with Extraversion.

Several other interesting correlations emerged during follow-up analysis of the personality data. Agreeableness was found to have a positive correlation with the subjective interaction rating, meaning participants who scored higher on Agreeableness tended to rate the interaction as better. This correlation was strongest in the Synchronous condition, $r_\tau = .451$, $p < .01$, compared to the two asynchronous conditions, indicating a possible interaction effect between dancing in synchrony and high Agreeableness on the perception of others. Weaker, positive correlations were observed between the interaction rating and both EQ-8, $r_\tau = .387$, $p < .05$, and Openness, $r_\tau = .396$, $p < .05$, and ratings on the Synchronous condition.

TABLE 2. Kendall's Tau correlations between personality traits (BFI, TEQ and EQ-8) and self-reported rating of partner interaction across the three conditions (Synchronised, Tempo and Phase). Significance values are uncorrected for multiple tests.

	Extra.	Agree.	Consci.	Neuro.	Open.	TEQ	EQ-8
Agree.	.0846						
Consci.	.509**	.250					
Neuro.	.0443	-.350*	-.263				
Open.	.112	-.012	.237	0.117			
TEQ	.314	.484**	.298	.106	.440*		
EQ-8	.438*	.390*	.285	-.056	.287	.504**	
Sync.	.016	.451**	.072	.003	.396*	.282	.387*
Tempo	.034	.379*	.120	.001	.178	.151	.289
Phase	-.162	.302	.0210	.077	.137	.210	.286
All Conditions	-.095	.401*	.0831	.041	.217	.224	.351*

*$p < .05$, **$p < .01$

3.3 Behavioural measures of social bonding

Following pre-processing of the motion capture data, as described in section 2.4, both relative head orientation and interpersonal distance were analysed as behavioural measures of social bonding. Due to technical problems in some of the recordings, a smaller sample of 15 dyads were used for motion capture analysis ($N = 15$).

3.3.1 Relative head orientation

Through motion capture analysis, relative head orientation scores (both mean and variance) were calculated for each dyad, in each condition. The data for mean and variance of relative head orientation both conformed to the assumptions of normality and homogeneity, and thus parametric statistics were used. A repeated-measures ANOVA revealed a significant effect of condition on the mean relative head orientation, $F(2, 42) = 3.907$, $p < .05$, as shown in Figure 3. Post-hoc Tukey's HSD revealed the significant effect was between the Synchrony and Phase-shift conditions, $p < .05$. Similarly, an effect was found on the variance of relative head orientation with a repeated-measures ANOVA, $F(2, 42) = 4.106$, $p < .05$. As shown in Figure 4, the Synchrony condition resulted in less variance in relative head orientation than the Phase-shift condition, a difference which was found to be significant in a Tukey's HSD post-hoc test, $p < .05$.

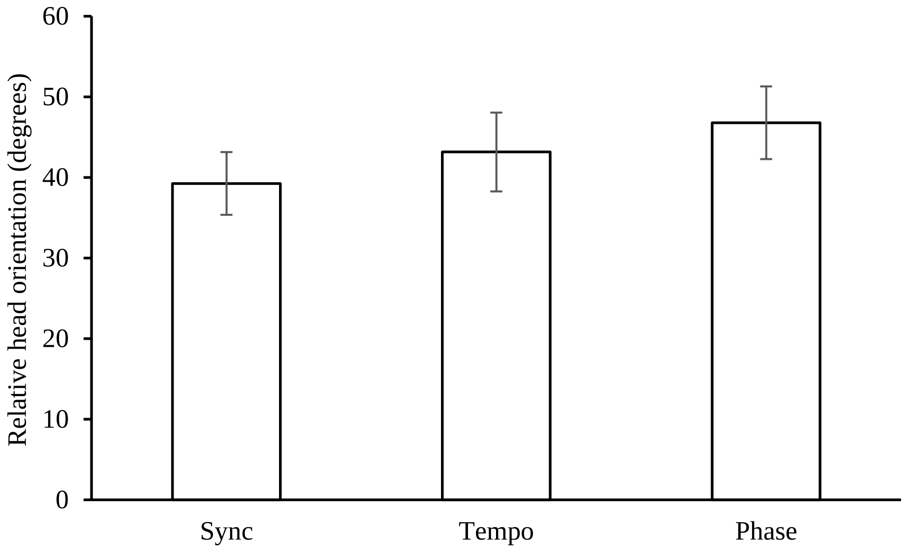

FIGURE 3. Mean relative head orientation of all trials and dyads between synchronous and asynchronous conditions. Error bars show standard error.

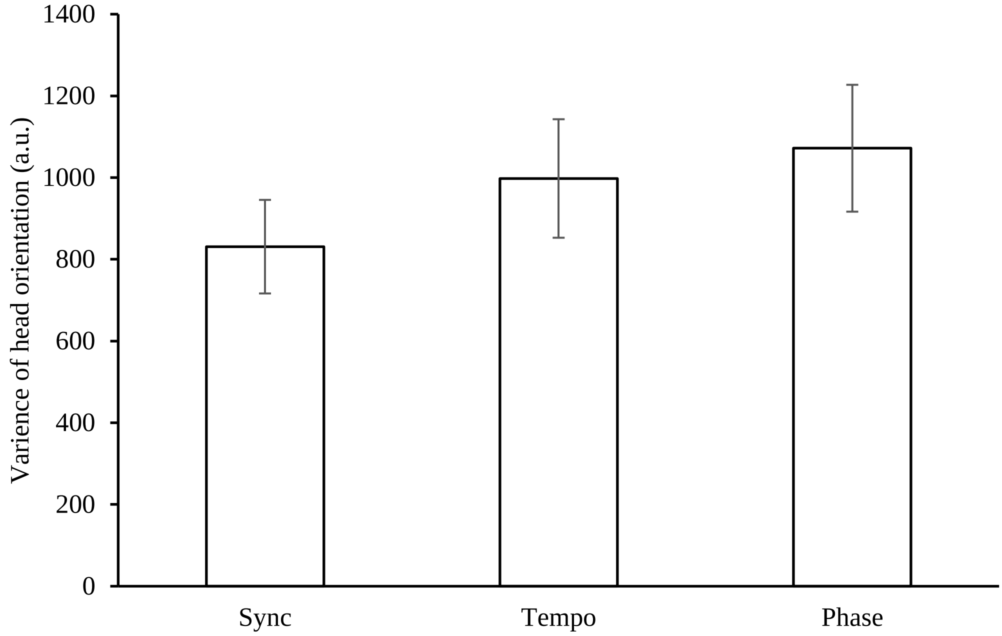

FIGURE 4. Mean variance of relative head orientation within each trial, across all dyads, compared between synchronous and asynchronous conditions. Error bars show standard error.

3.3.2 Interpersonal distance

As described in section 2.4, mean interpersonal distance and variance of interpersonal distance were calculated for each trial for each dyad. The assumptions of homogeneity and normality were met by the data, and thus parametric statistics were used. A repeated-measures ANOVA testing the effect of condition on mean interpersonal distance found no significant effect (shown in Figure 5), as was the case for variance in interpersonal distance (shown in Figure 6). Nevertheless, there was a slight trend for interpersonal distance to be greater in the Phase-shifted condition.

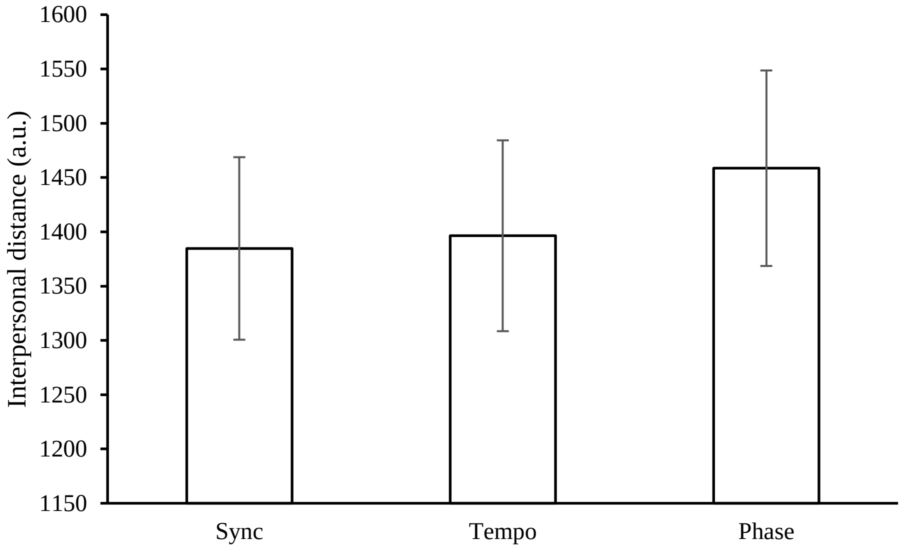

FIGURE 5. Mean interpersonal distance of all trials and dyads between synchronous and asynchronous conditions. Error bars show standard error.

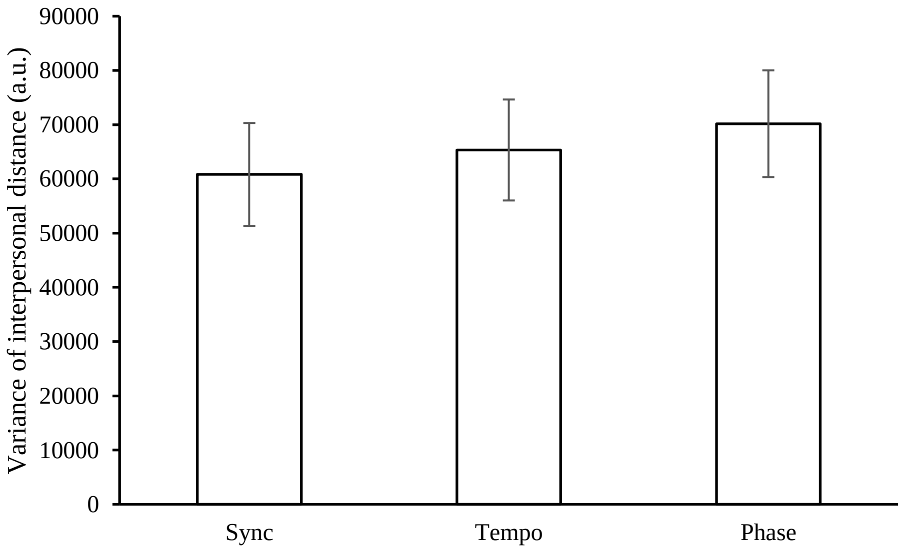

FIGURE 6. Mean variance of interpersonal distance within each trial, across all dyads, compared between synchronous and asynchronous conditions. Error bars show standard error.

4 DISCUSSION

4.1 The Present Study

The present study investigated the social bonding effect of different degrees of synchrony in free spontaneous movement to music within dyads. This attempted to maintain maximum ecological validity with the social dance floor, allowing creativity and expression between dancers, while still being able to experimentally manipulate how synchronised the dancers were. The primary hypothesis, that interpersonal synchrony would have a positive effect on feelings of social affiliation on the dance floor, appears to be supported by the data. Participants did report a better interaction with their partner when they were both listening to the same music, in the same time. This effect seemed more pronounced for those who scored higher on Agreeableness, in an exploratory analysis of individual differences. Furthermore, the self-report data was supplemented by behavioural measures of affiliation, with participants looking towards each other more in the synchronous condition than the asynchronous conditions. In both self-reported and behavioural measures, it appears that the phase-shifted condition caused the most disruption to social bonding.

4.1.1 Synchrony

Each dyad was placed in three different conditions in the Silent Disco paradigm: synchronous, tempo-stretched, and phase-shifted. As was expected, the condition allocated to the pair had a significant effect on how they rated the interaction with their partner. The effect of being out of phase seemed to be the most pronounced, with this significantly impacting upon their experience of dancing with their partner. It is worth noting that with the Tempo condition, subjects would, at least sometimes, find the beat falls in synchrony, while the Phase condition would always be out of phase. Therefore, it may be that Tempo stretching could be considered a transient Phase-shift. Having a dance partner always slightly behind, or ahead of the beat may be worse than a partner who drifts in and out of phase. This implies that the positive experience of synchrony does not hinge upon matching the other person’s tempo, but rather it is the coincidence of movement that is important. In the tempo shifted condition, some beats will still coincide occasionally, allowing the participants a transient synchrony, while the phase shift will never allow for coincidence of movement on the beat. This suggests that for synchrony to be perceived and appreciated, very tight beat matching is required, and certainly a 90-degree phase shift is already beyond an acceptable deviance from the beat.

Unexpectedly, there was no effect of synchrony on any of the other self-report measures of the task experience. One may have predicted that enjoyment of the music may be influenced by social interaction while listening to it, but ratings of musical enjoyment remained unaffected by the movements of the partner. This is, however, consistent with the findings of Tarr and others (2016), who similarly found that synchrony only influenced social bonding, but not personal enjoyment of the music.

4.1.2 Personality

There were some expected correlations within the personality traits measured. Previous studies have found a relationship between Trait Empathy and the Agreeableness factor of the Big Five (Bamford & Davidson, 2017; Del Barrio, Aluja, & García, 2004). This was replicated here, finding a strong positive relationship between Agreeableness, EQ-8 and TEQ. It is particularly encouraging that the EQ-8 and TEQ share a strong positive relationship, as they purport to measure the same construct and include very similar items. Finding these relationships, should reinforce their validity as Trait Empathy measures, and is consistent with previous research suggesting that Trait Empathy may be considered an aspect of Agreeableness.

Positive, but relatively weaker, relationships were also observed between the EQ-8 and Extraversion, and between the TEQ and Openness. This may indicate that these other factors of the Big Five reflect other aspects of Empathy; specifically, some questions in the Empathy questionnaires may be interpreted as a kind of 'openness to emotion', which could be related to a general 'openness to experience'. Some previous research also suggests that the Big Five themselves are not entirely unrelated factors (Anusic, Schimmack, Pinkus, & Lockwood, 2009; Digman, 1997). Indeed, the present study did observe relationships between Agreeableness and Neuroticism, as well as Conscientiousness and Extraversion. Care must be taken, however, in interpreting relationships within the Big Five in a relatively small sample.

4.1.3 Personality and Synchrony

Given that personality data had been collected, it was possible to investigate how self-reported ratings of the task experience were influenced by personality. The most interesting relationship was between Agreeableness and self-reported partner interaction. It would not be surprising if Agreeableness had a general relationship with ratings, as Agreeable people may simply be more likely to want to give positive evaluations of others. However, when comparing the conditions, Agreeableness and partner rating showed the strongest positive relationship for the Synchronous condition; in the tempo-shifted condition, the relationship between Agreeableness and partner rating was weaker, and in the phase-shifted condition it was non-significant. This suggests, perhaps, that those who score higher on Agreeableness are particularly sensitive to others moving in synchrony with themselves.

Smaller, but still significant relationships were observed between self-reported interaction rating and both EQ-8 and Openness score. High Empathy may predispose one towards being more attentive to synchrony of movement with another, and thus to rating the interaction with synchronous partners more positively. Previous studies have also suggested that people who are high on Empathy may also be better at synchronising with others (Keller et al., 2014), and with music (Bamford & Davidson, 2017), so it is possible that these participants rated the interaction with their partner well because their own ability actually resulted in a better interaction. As already discussed, a positive relationship had been observed between Empathy and Openness, so this may be expressed through similar behaviour when asked to rate the interaction with their dance partners.

One must be careful drawing conclusions from these personality findings, as these relationships were observed post-hoc. They were the result of many correlations, which were exploratory in nature and not testing any specific hypothesis. The probability of false-positives increases with the number of tests conducted. There is also a danger in developing theories from data observations and then using that same data to support the theory, in that the theory may not generalise beyond those specific observations. However, future experiments could be designed to specifically test the hypothesis that Agreeable people are more sensitive to perceiving synchrony with others.

4.1.4 Behavioural measures

Analysis of the behavioural measures of social bonding (relative head orientation and interpersonal distance) revealed mixed results. Previous research has suggested that people stand closer to those they feel affiliated to (Snyder & Endelman, 1979), so the distance between participants during the dance task may indicate feelings of social affiliation which would reinforce the questionnaire results. It was hypothesised that a significant effect would be found of synchrony on interpersonal distance, however this was not the case. It is possible that the sample used in the behavioural measurements was too small to find a significant effect, although there was a trend in the right direction, with dyads tending to stand closer to each other when presented with synchronous music.

Relative head orientation did reveal a significant effect, which was very encouraging. The mean relative head orientation was lower during the Synchrony condition that the Phase-shifted condition, implying that participants within the dyad were looking at each other or close to each other for more of the time while in the Synchrony condition. Furthermore, the variance in relative head orientation was lower in the Synchrony condition than in the Phase-shifted condition, indicating that participants were not looking around as much, and maybe kept their heads in more of a fixed position, while dancing in Synchrony. This finding may support the suggestion of Woolhouse, Tidhar and Cross (2016) that people focus more attention on others who are dancing in time with themselves. Although eye-tracking would be more precise, head orientation does give an indication of where attention is directed and, in the case of the Synchrony condition, attention of the participants seemed to be directed towards each other for much of the time.

In addition to the quantified behavioural measures, some observations from observing the motion capture recordings can also be made. There appeared to be three different styles of managing asynchrony with a partner: Leading, in which the individual stays with their own beat but tries to dance with their partner; Following, in which the individual sacrifices their own beat for the sake of dancing with their partner; and Ignoring, in which the individual simply disregards the other person entirely, sometimes turning their back or looking away. It is possible that the style of managing asynchrony that a participant adopted may be predicted by their personality traits, or the sense of affiliation they feel with their dance partner. Individual differences in movement were not analysed as part of this study, although it is possible future analysis of the data could investigate this.

4.2 Implications

The present study sits amongst a small selection of previous studies. Research into the synchrony-bonding effect have found an effect of interpersonal synchrony on social bonding or pro-social behaviour, but have been more strictly controlled, involving finger tapping or simple movements (eg. Cirelli et al., 2014; Hove & Risen, 2009), or used a different definition of synchrony. The work by Tarr and others (2016) also found an effect of synchrony on social bonding in a dance setting, however both their measurement of social bonding and manipulation of interpersonal synchrony were quite different in nature to the present study. Their 'partial synchrony' condition presented the music in the same time, but instructed participants with different choreography, while the 'no synchrony' condition presented participants with entirely different musical stimuli. By prescribing choreography to participants, Tarr and others (2016) may not have in fact been measuring the effect of true, temporal synchrony, but that of behavioural matching or imitation.

While interpersonal synchrony has been less studied, there is comparatively more research on imitation and social bonding. It is generally found that behavioural imitation creates social affiliation (Lakin & Chartrand, 2003). Casual observations of people, when moving freely on a dance floor, reveal imitation in abundance. Dancing is a creative enterprise, and dancers gain the approval of their co-dancers through imitation of movements.

Creativity may be important in social bonding through dance. A study on group singing by Sanfilippo (2015), found that both acting in synchrony with others, while also maintaining creative expression through limited degrees of improvisation, yielded a far greater social bonding effect that all singing in unison. The same may be true for dancing; social bonding may occur best when dancers can create and imitate, in synchrony.

Shared creativity cannot be the only factor, however. We may receive validation from our co-dancers when they imitate us, and the exchange of movement ideas allows for a collaborative space in which both actors have agency. Regardless, even without behavioural imitation or the possibility for creativity, the social bonding effect from synchronous action still holds, as demonstrated in other research. For example, rowers feel more strongly affiliated after rowing together (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010), and previously mentioned studies have used far more controlled synchronous action of bouncing or finger tapping (eg. Cirelli et al., 2014; Hove & Risen, 2009). This highlights the complexity of synchronous movement as it appears in the real world, and thus it may be that no single mechanism is entirely responsible for the pervasiveness of synchronous movement in human culture.

The potential implications of this area of research are great, although somewhat beyond the scope of this study. Understanding how dance enables social bonding has implications for our understanding of the function of music-dance throughout our evolutionary history. There are also possibilities to gain greater understanding of the neurological structures behind social cognition. Finally, there may be applications in social policy and in therapy, if it is possible to increase social connectedness, pro-social behaviour, or even empathy, through dance.

4.2.1 Evolution of Music-Dance

There are many competing theories explaining the existence of musical behaviour in humans. Some authors assert that music is a by-product of cognitive abilities developed for other purposes (Pinker, 2003). On the other hand, adaptionist theories suggest that music may either be a result of sexual selection, being used as a marker of general genetic fitness, or natural selection, through enabling greater cohesiveness within groups (Dunbar, 2012). The findings of the present study would support the idea that music serves, or has served, an evolutionary function through aiding group cohesion.

The present study observed that synchrony changed the experience of participants in the dance setting. This indicates that synchrony of movement, an ability which is present in relatively few species, has a role to play in social interaction. Synchrony is used in a few very specific contexts in human behaviour: coordinating movement to amplify strength in lifting or pulling tasks, and through music and dance. While the purpose of the former is self-evident, music and dance have less obvious functions. Given the social benefits of synchronous action, and their importance to successful group music-dance, it may be that the purpose of music is to bind us together. However, the neurological processes behind this are not yet clear.

4.2.2 Neurological Theories of Synchronisation and Social Bonding

The brain is the source of behaviour, so it is possible that neuroscience may elucidate the present findings: particularly the relationship between Agreeableness/Empathy and perception of social interaction. There may be neurological differences between highly Agreeable or Empathetic people and others, which may serve to illuminate the reasons behind their greater sensitivity to interpersonal synchrony. Previous studies have found relationships between Trait Empathy and neurological structures, in particular the midcingulate cortex and adjacent dorsomedial prefrontal cortex (Eres, Decety, Louis, & Molenberghs, 2015), while others have found correlations between the Agreeableness trait and posterior cingulate cortex (DeYoung et al., 2010). These studies simply describe trends in personality and brain structure, but could be theoretically linked to behavioural functions.

It has been suggested that imitation and empathy are both reliant upon a Mirror Neuron System (MNS) in the pre-motor cortex (Kaplan & Iacoboni, 2006). The Shared Affective Motion Experience (SAME) theory proposes that the MNS is important in music perception as well, allowing us to effectively empathise with music through the perception of movement implied in sound (Overy & Molnar-Szakacs, 2009). As would be expected if a common neural mechanism, such as the MNS, were involved in both musical (specifically rhythmic) perception and empathy, a relationship has been observed between rhythmic perception and measures of Trait Empathy (Bamford & Davidson, 2017; Strauß & Zentner, 2015). It is possible that the MNS is important to both musical perception and empathy, and thus may also be involved in social interaction through music.

In dance, as a social setting, one synchronises not only with the music but also with other dancers. Tarr and others (2014) assert that one of the mechanisms through which social bonding occurs is by blurring the differentiation between the self and the other. It is possible that a neural mechanism behind this is the MNS, which is thought to mirror observed actions of others in one’s own motor cortex. While the present study involved no neuroimaging, it fits into a picture created by the literature which suggests related processes in social bonding, empathy and synchronised movement through dance. This is, however, still a speculative interpretation, and must be treated with caution until further research is done.

4.2.3 Practical Applications

Understanding the mechanisms of social dance is not a purely academic pursuit; this line of research may reveal real-world benefits. Music and dance have always been important parts of society, and understanding their connection to social bonding places greater value on their role within our culture. There is potential for this knowledge to be applied in therapeutic or community programmes. Two of the most promising prospects would be through using dance to improve empathy in individuals, and as a tool to bridge cultural divides.

Empathy is of great importance to society at large, but particularly for certain clinical populations. There are disorders which are considered to be largely caused by a deficiency in empathy, such as Autism Spectrum Disorders (Baron-Cohen & Wheelwright, 2004), and it is possible that music-based interventions may hold some promise in enhancing the quality of life of these individuals. Indeed, a number of studies have looked at enhancing empathy through musical and dance training with a good degree of success (Behrends et al., 2012; Greenberg, Rentfrow, & Baron-Cohen, 2015; Rabinowitch, Cross, & Burnard, 2013). This would provide support for Dance/Movement Therapy (D/MT) as an intervention, which involves movement to music, along with a therapist or in a group. As Vuoskoski (2015) points out, an integral part of the emotional content, as well as the social bonding potential, of music may be in the rhythm. If this is the case, then training in embodying rhythm through dance may exercise underdeveloped neural pathways that are integral for empathy. Alternatively, it may be the mirroring of others, the behavioural matching, in D/MT that exercises our empathetic circuits (McGarry & Russo, 2011). In either case, there is an argument to be made in favour of D/MT as a method to enhance empathy.

There is a tendency to assume that more Empathy is generally a good thing, and argue that it may increase morality of society more broadly. We must be careful about over-generalising in this regard, however, as there is only limited evidence to suggest that higher empathy actually makes us better people (Lamm & Majdandžić, 2015). It has been suggested that there are two distinct Empathy systems: empathetic ability and empathetic propensity. Empathetic ability may represent the potential for someone to take another's perspective, while empathetic propensity reflects how willing someone is to take the perspective of another. An example of how these two systems may work against each other is that psychopaths may be perfectly capable of empathy, it is just that they choose not to empathise (Keysers, 2017). Thus, efforts to increase Trait Empathy will only be meaningful interventions if willingness to empathise is developed as well.

Dance may go beyond enhancing Trait Empathy as individuals, as the social bonding effect may bring us closer together with others. As demonstrated in this and previous studies, synchronous movement promotes pro-social behaviour and increases feelings of affiliation (Cirelli et al., 2014; Hove & Risen, 2009; Kirschner & Tomasello, 2010). Some research suggests that this may be applied to bring a therapist and client closer together, as people who have just performed a synchronous action (in this case, moving cups) are more open about sharing their emotional state with another (Koole, 2017). This could also be applied to bridging divisions between culture in a similar manner to Clarke, DeNora and Vuoskoski (2015), who used exposure to a culture's music to reduce prejudice towards that culture. Pierre Dulaine has attempted this already, through bringing his Dancing Classrooms project to both Israel and Northern Ireland with the idea of bringing children from different cultures together to dance, breaking down barriers in the process (Nabatoff, 2014).[5] With greater understanding of the process of social bonding through dance, this may justify pursuing similar projects in the future.

4.3 Limitations

As with so much psychology research, the present sample was drawn from a limited pool of university students, and thus results should be treated with caution when trying to generalise outside that population (Peterson, 2001). Although ecological validity was aimed for, the setting of the present study was nevertheless somewhat unnatural; participants did comment that the music became boring after some time, and that the lighting should have more accurately imitated a night club. External validity was, on the whole, better than similar studies, as

[5] While there is little objective evidence to support the success of this, there was a documentary made of the Dancing in Jaffa project: http://www.dancinginjaffa.com/
And for more information on Dancing Classrooms, see: http://www.dancingclassrooms.org/

participants were allowed to move freely. There was no prescribed choreography, or limitation in the range of movement (such as in finger tapping studies), allowing participants to be creative, imitate and synchronise with each other at will. However, this came at some expense to internal validity, as it was difficult to control all the factors. A difference was observed dependent on the timing of musical stimulus presentation but a more controlled study would be required to separate the factors of creativity, synchrony and imitation, and determine exactly why these results have been observed.

Testing dyads rather than individuals was also a potential source of uncontrolled variables. Participants were allowed to self-select their partner, which served to partially control the pairings; it could be assumed that all participants were matched with someone with whom they were already comfortable dancing. From general observation, there were a range of differences in the way pairs interacted, independent of the silent disco condition they were in. Unfortunately, detailed information about the nature of their relationship was not collected from the outset. Future studies would be well advised to include a social closeness questionnaire as an initial measure, with questions about how well the participants knew each other, for how long, and how often they may see each other. Most pairs were Female-Female, and were mostly good friends who had known each other for at least a number of months. There were, however, a few Female-Male romantic partners, as well as one Male-Male pair of friends. Gender interactions were not accounted for specifically in the present study, although neither did the less common pairings (Female-Male and Male-Male) present themselves as outliers. Detailed motion capture data was collected, and would allow more detailed analysis of behavioural differences between pairs and individuals (on the basis of personality) which have not yet been accounted for in the present study.

4.4 Further Study

As previously mentioned, there is scope for further analysis of the data collected in the present study. Individual differences in movement and gestures could be investigated. It would also be possible to analyse synchronisation of movement, to determine whether subjects were dancing in time with the music, or with their partner, in the asynchronous conditions. Interpersonal synchronisation may be a predictor for subjective ratings of the interaction with their partner.

Different styles of adapting to asynchronous stimuli may also emerge, as participants are forced to either dance with their partner or with the beat they hear, and this may be related to individual differences in personality. In addition, it may be possible to investigate whether the quality of gesturing changed between conditions, or whether participants imitated each other's gestures more in the synchronous condition than asynchronous conditions. These would all be interesting avenues for future analysis of the present data, however future studies into social bonding and interpersonal synchronisation could also include some different measurements.

Future studies could include a greater range of social bonding measurements that do not rely upon self-report and compare them against each other, as many of these measurements have not been validated. Previous studies have used other objective measures of social bonding following synchronous action, such as pain threshold, or subsequent pro-social behaviour. Pain threshold is used as a proxy measurement for endorphin release, which is then a proxy measurement for social bonding, based on the theory that endorphins are related to social bonding (Tarr et al., 2014). While this theory may have merit, there are obviously confounding factors that could also be involved in endorphin release, and pain is really a highly subjective measurement, relative to the individual. More direct measures of endorphin levels are difficult to collect, as they may be highly invasive. Oxytocin has also been suggested as a neuro-hormonal mechanism for social bonding, and thus measuring oxytocin in the brain may also reflect success of social bonding, however it is similarly problematic to measure. Purely behavioural measures such as pro-social or helping behaviour have also been utilised in the literature (Cirelli et al., 2014; Hove & Risen, 2009). However, to equate pro-social behaviour with affiliation between individuals relies upon the assumption that we always wish to help those we feel closest to. This may not always be the case, as it is possible we are more helpful towards those we want to get close to, than those whose friendship we already have. Other studies have used emotion sharing as a measure after synchronous activity (Koole, 2017), but again this cannot be directly equated with social affiliation, although the authors do note that we usually share emotions more openly with close friends. Finally, social memory after synchronous activity has been used in previous research (Woolhouse et al., 2016). It is similarly intuitive to assume that if we remember people better after dancing with them, then we would feel closer to them, but again, this is an assumption, and it may also be the case that we have a better memory for our enemies than our friends. Ultimately, it would be beneficial to compare this range of potential bonding measures to each other, in order to validate that they really may be used to measure the same psychological construct, that is, the extent to which one feels socially bonded to another.

The present study was limited in its scope, and in light of the current results, future studies could be designed to further disentangle role of synchrony from other factors. The present study suggests that synchronised movement may foster social bonding; however, it did not control for imitation of movement, or personal expression/creativity. The study by Tarr and others (2016) would suggest that synchronisation with imitation of movements creates the greatest social bonding effect, however that study limited the creativity of participants, which may be an important factor. It may be that shared creativity, imitation, synchronised movement, or some combination of these create the greatest social bonding effect in a dance scenario, however, the existing research does not sufficiently separate these factors.

Future research into social bonding and synchrony may also benefit from neuroimaging. It is difficult to conduct movement studies while also collecting functional neuroimaging data, as movement is limited by most neuroimaging methods. Any study of this kind would likely have to be restricted to finger tapping, sacrificing ecological validity. However, it would be valuable to better understand which brain mechanisms are being activated during the process of interpersonal synchronisation.

5 CONCLUSIONS

The present study explored the importance of interpersonal synchrony in building feelings of affiliation in a social dance setting. It suggests that synchrony is an important factor in the experience of interacting with a partner on the dance floor, by using the silent disco scenario to control the timing of musical stimuli between partners, and thus controlling their degree of synchrony. While in the synchronous condition, participants self-reported having a better experience interacting with their partner than in the two asynchronous conditions. Self-report measures were reinforced by behavioural measures of social affiliation, with participants seemingly directing more attention towards each other during the synchrony condition. Furthermore, personality measurements indicate that people who were high on Agreeableness were more sensitive to synchronous movement, rating their experience of this condition as better than their less Agreeable peers. It is possible to analyse this data further, and future research could examine the styles adopted by participants when their partner is dancing to a different beat: to lead, to follow, or to ignore; this may also be related to personality differences or social bonding.

As much of the background literature is theoretical, with few studies specifically testing interpersonal synchronisation and affiliation, the present study adds empirical weight to the theory that music and dance serve a purpose in building social cohesion. This has implications for dance and music therapy, as it emphasises the importance of interpersonal synchrony in the therapeutic process, for building affiliation between therapist and client, or between clients in a group setting. Furthermore, it supports an argument for rhythmic art forms (music and dance) as community building projects to enhance social cohesiveness. Three factors that may contribute to the social bonding effect of dance are identified: shared creativity, imitation of gesture, and synchrony of movement. More research is required to fully understand the role of these three factors, however the present study supports the assertion that interpersonal synchrony leads to a greater sense of affiliation than simply sharing the experience of dancing (but not in time). This has implications for some of our theoretical constructs surrounding the mechanisms and functions of music in a social setting. It may be that moving in time through music in dance is a uniquely powerful way of bringing people together.

References

Anusic, I., Schimmack, U., Pinkus, R. T., & Lockwood, P. (2009). The Nature and Structure of Correlations Among Big Five Ratings: The Halo-Alpha-Beta Model. *Journal of Personality*, *97*(6), 1142–1156.

Bamford, J. M. S. (2013). *Moving in Character: Investigating the relationship between music, movement and empathy* (Unpublished Honours Thesis). University of Western Australia, Perth, Western Australia.

Bamford, J. M. S., & Davidson, J. W. (2017). Trait Empathy associated with Agreeableness and rhythmic entrainment in a spontaneous movement to music task: Preliminary exploratory investigations. *Musicae Scientiae*, 1029864917701536. https://doi.org/10.1177/1029864917701536

Baron-Cohen, S., & Wheelwright, S. (2004). The Empathy Quotient: An Investigation of Adults with Asperger Syndrome or High Functioning Autism, and Normal Sex Differences. *Journal of Autism & Developmental Disorders*, *34*(2), 163–175.

Behrends, A., Müller, S., & Dziobek, I. (2012). Moving in and out of synchrony: A concept for a new intervention fostering empathy through interactional movement and dance. *The Arts in Psychotherapy*, *39*(2), 107–116. https://doi.org/10.1016/j.aip.2012.02.003

Bernieri, F. J., & Rosenthal, R. (1991). Interpersonal coordination: Behavior matching and interactional synchrony. In R. S. Feldman & B. Rim (Eds.), *Fundamentals of nonverbal behavior* (pp. 401–432). Paris, France: Editions de la Maison des Sciences de l'Homme.

Berrol, C. F. (2006). Neuroscience meets dance/movement therapy: Mirror neurons, the therapeutic process and empathy. *The Arts in Psychotherapy*, *33*(4), 302–315. https://doi.org/10.1016/j.aip.2006.04.001

Biernaskie, J. M., Grafen, A., & Perry, J. C. (2014). The evolution of index signals to avoid the cost of dishonesty. *Proceedings of the Royal Society B: Biological Sciences*, *281*(1790), 20140876–20140876. https://doi.org/10.1098/rspb.2014.0876

Burger, B., Thompson, M. R., Luck, G., Saarikallio, S., & Toiviainen, P. (2012). Music moves us: Beat-related musical features influence regularity of music-induced movement. In *The 12th International Conference on Music Perception and Cognition and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music*. ICMPC-ESCOM Thessaloniki. Retrieved from http://icmpc-escom2012.web.auth.gr/sites/default/files/papers/183_Proc.pdf

Burger, B., & Toiviainen, P. (2013). MoCap Toolbox - A Matlab toolbox for computational analysis of movement data. Presented at the 10th Sound and Music Computing Conference, SMC 2013, Stockholm, Sweden, Logos Verlag Berlin. Retrieved from https://jyx.jyu.fi/dspace/handle/123456789/42837

Chen, J. L., Zatorre, R. J., & Penhune, V. B. (2006). Interactions between auditory and dorsal premotor cortex during synchronization to musical rhythms. *NeuroImage*, *32*(4), 1771–1781. https://doi.org/10.1016/j.neuroimage.2006.04.207

Cirelli, L. K., Einarson, K. M., & Trainor, L. J. (2014). Interpersonal synchrony increases prosocial behavior in infants. *Developmental Science*, *17*, 1–9. https://doi.org/10.1111/desc.12193

Clarke, E., DeNora, T., & Vuoskoski, J. (2015). Music, empathy and cultural understanding. *Physics of Life Reviews*, *15*, 61–88. https://doi.org/10.1016/j.plrev.2015.09.001

Cohen, E. E. A., Ejsmond-Frey, R., Knight, N., & Dunbar, R. I. M. (2010). Rowers' high: behavioural synchrony is correlated with elevated pain thresholds. *Biology Letters*, *6*(1), 106–108. https://doi.org/10.1098/rsbl.2009.0670

Cummins, F. (2009). Rhythm as an affordance for the entrainment of movement. *Phonetica*, *66*(1–2), 15–28.

Decety, J., & Ickes, W. (2011). *The social neuroscience of empathy*. MIT Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=KLvJKTN_nDoC&oi=fnd&pg=PR5&dq=%22bibliographical+references+and%22+%22B.+van+Baaren,+Jean+Decety,+Ap+Dijksterhuis,+Andries+van+der+Leij,+and+Matthijs+L.%22+%22978-0-262-01297-3+(hardcover+:+alk.+paper)+1.+Empathy.+2.+Neurosciences.+3.%22+&ots=gD83cXpm3Z&sig=p2ceW6NKfFLGer2UdKtw352mpvw

Del Barrio, V., Aluja, A., & García, L. F. (2004). Relationship Between Empathy and the Big Five Personality Traits in a Sample of Spanish Adolescents. *Social Behavior & Personality: An International Journal*, *32*(7), 677–682.

DeYoung, C. G., Hirsh, J. B., Shane, M. S., Papademetris, X., Rajeevan, N., & Gray, J. R. (2010). Testing Predictions From Personality Neuroscience: Brain Structure and the Big Five. *Psychological Science*, *21*(6), 820–828. https://doi.org/10.1177/0956797610370159

Digman, J. M. (1997). Higher-Order Factors of the Big Five. *Journal of Personality and Social Psychology*, *73*(6), 1246–1256.

Dunbar, R. I. M. (2010). The social role of touch in humans and primates: behavioural function and neurobiological mechanisms. *Neuroscience & Biobehavioral Reviews*, *34*(2), 260–268.

Dunbar, R. I. M. (2012). On the Evolutionary Function of Song and Dance. In N. Bannan (Ed.), *Music, Language, & Human Evolution* (pp. 201–214). Great Britain: Oxford University Press.

Eres, R., Decety, J., Louis, W. R., & Molenberghs, P. (2015). Individual differences in local gray matter density are associated with differences in affective and cognitive empathy. *NeuroImage*, *117*, 305–310. https://doi.org/10.1016/j.neuroimage.2015.05.038

Fringe World Silent Disco. (2015). Retrieved 28 February 2015, from http://www.fringeworld.com.au/program/event/5059922e-7d61-424b-9db8-de1092f982ab/

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences*, *2*(12), 493–501. https://doi.org/10.1016/S1364-6613(98)01262-5

Goldman, A. I. (1989). Interpretation Psychologized. *Mind & Language*, *4*(3), 161–185. https://doi.org/10.1111/j.1468-0017.1989.tb00249.x

Greenberg, D., M., Rentfrow, P. J., & Baron-Cohen, S. (2015). Can Music Increase Empathy? Interpreting Musical Experience Through The Empathizing–Systemizing (ES) Theory: Implications For Autism. *Empirical Musicology Review*, *10*(1).

Hagen, E. H., & Bryant, G. A. (2003). Music and Dance as a Coalition Signaling System. *Human Nature*, *14*(1), 21–51.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, *4*(1), 9.

Hendrie, C. A., Mannion, H. D., & Godfrey, G. K. (2009). Evidence to suggest that nightclubs function as human sexual display grounds. *Behaviour*, *146*(10), 1331–1348.

Hove, M. J., & Risen, J. L. (2009). It's All in the Timing: Interpersonal Synchrony Increases Affiliation. *Social Cognition*, *27*(6), 949–960.

Iacoboni, M. (2009). Imitation, Empathy, and Mirror Neurons. *Annual Review of Psychology*, *60*(1), 653–670. https://doi.org/10.1146/annurev.psych.60.110707.163604

John, O. P., & Srivastava, S. (1999). The Big Five trait taxonomy: History, measurement, and theoretical perspectives. *Handbook of Personality: Theory and Research*, *2*(1999), 102–138.

Juslin, P. N., & Vaestfjaell, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences*, *31*(5), 559–575.

Kaplan, J. T., & Iacoboni, M. (2006). Getting a grip on other minds: Mirror neurons, intention understanding, and cognitive empathy. *Social Neuroscience*, *1*(3–4), 175–183. https://doi.org/10.1080/17470910600985605

Keller, P. E., Novembre, G., & Hove, M. J. (2014). Rhythm in joint action: psychological and neurophysiological mechanisms for real-time interpersonal coordination. *Phil. Trans. R. Soc. B*, *369*(1658), 20130394. https://doi.org/10.1098/rstb.2013.0394

Keysers, C. (2017). Vicarious Activations, Emotional Contagion, and Prosocial Behaviour. Presented at the 2nd International Convention of Psychological Science, Vienna, Austria.

Kirschner, S., & Tomasello, M. (2010). Joint music making promotes prosocial behavior in 4-year-old children. *Evolution and Human Behavior*, *31*(5), 354–364. https://doi.org/10.1016/j.evolhumbehav.2010.04.004

Koole, S. L. (2017). The Rhythm of Relating: Movement Synchrony Facilitates Emotional Sharing. Presented at the 2nd International Convention of Psychological Science, Vienna, Austria.

Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science (Wiley-Blackwell)*, *14*(4), 334–339.

Lamm, C., & Majdandžić, J. (2015). The role of shared neural activations, mirror neurons, and morality in empathy – A critical comment. *Neuroscience Research*, *90*, 15–24. https://doi.org/10.1016/j.neures.2014.10.008

Lang, M., Shaw, D. J., Reddish, P., Wallot, S., Mitkidis, P., & Xygalatas, D. (2016). Lost in the Rhythm: Effects of Rhythm on Subsequent Interpersonal Coordination. *Cognitive Science*, *40*(7), 1797–1815. https://doi.org/10.1111/cogs.12302

Launay, J., Dean, R. T., & Bailes, F. (2014). Synchronising movements with the sounds of a virtual partner enhances partner likeability. *Cognitive Processing*, *15*(4), 491–501. https://doi.org/10.1007/s10339-014-0618-0

Leman, M. (2007). *Embodied Music: Cognition and Mediation Technology*. MIT Press.

Livingstone, R. S., & Thompson, W. F. (2009). The emergence of music from the Theory of Mind. *Musicae Scientiae*, *13*(2 suppl), 83–115.

Loewen, P. J., Lyle, G., & Nachshen, J. S. (2009). An eight-item form of the Empathy Quotient (EQ) and an application to charitable giving. Retrieved from http://individual.utoronto.ca/loewen/Research_files/Eight%20Question%20ES_final.pdf

Luck, G. (2011). Influence of the Big Five on Synchronisation with Music. Presented at the Power of Music, UWA, Perth, Western Australia.

Luck, G., Saarikallio, S., Burger, B., Thompson, M. R., & Toiviainen, P. (2010). Effects of the Big Five and musical genre on music-induced movement. *Journal of Research in Personality*, *44*(6), 714–720. https://doi.org/10.1016/j.jrp.2010.10.001

Lumsden, J., Miles, L. K., & Macrae, C. N. (2014). Sync or sink? Interpersonal synchrony impacts self-esteem. *Frontiers in Psychology*, *5*, 1064. https://doi.org/10.3389/fpsyg.2014.01064

McCarty, K., Darwin, H., Cornelissen, P. L., Saxton, T. K., Tovée, M. J., Caplan, N., & Neave, N. (2017). Optimal asymmetry and other motion parameters that characterise high-quality female dance. *Scientific Reports*, *7*, 42435. https://doi.org/10.1038/srep42435

McFerran, K. (2013, May 26). Striking a chord: what can music really do for students? Retrieved 27 May 2013, from http://theconversation.com/striking-a-chord-what-can-music-really-do-for-students-14121?utm_source=feedly&utm_medium=feed&utm_campaign=Feed%3A+conversationedu+%28The+Conversation%29

McGarry, L. M., & Russo, F. A. (2011). Mirroring in Dance/Movement Therapy: Potential mechanisms behind empathy enhancement. *The Arts in Psychotherapy*, *38*(3), 178–184. https://doi.org/10.1016/j.aip.2011.04.005

McKinney, M. F., & Moelants, D. (2006). Ambiguity in Tempo Perception: What Draws Listeners to Different Metrical Levels? *Music Perception: An Interdisciplinary Journal*, *24*(2), 155–166. https://doi.org/10.1525/mp.2006.24.2.155

Nabatoff, D. (2014, August 4). Dancing With the Enemy. Retrieved 17 April 2016, from http://www.huffingtonpost.com/diane-nabatoff/dancing-with-the-enemy_b_5114145.html

Ollen, J. E. (2006). *A criterion/related validity test of selected indicators of musical sophistication using expert ratings* (PhD Thesis). Ohio State University, USA.

Overy, K., & Molnar-Szakacs, I. (2009). Being Together in Time: Musical Experience and the Mirror Neuron System. *Music Perception*, *26*(5), 489–504. https://doi.org/10.1525/mp.2009.26.5.489

Palestis, B., Trivers, R., & Zaatari, D. (2014). Symmetry and Dance: A Case of Scientific Fraud. *The Winnower*. https://doi.org/10.15200/winn.140076.67602

Peterson, R. A. (2001). On the Use of College Students in Social Science Research: Insights from a Second-Order Meta-analysis. *Journal of Consumer Research, 28*(3), 450–461.

Petrides, K. V., Niven, L., & Mouskounti, T. (2006). The trait emotional intelligence of ballet dancers and musicians. *Psicothema, 18*(Suplemento), 101–107.

Phillips-Silver, J., Aktipis, C. A., & Bryant, G. A. (2010). The Ecology of Entrainment: Foundations of Coordinated Rhythmic Movement. *Music Perception: An Interdisciplinary Journal*, *28*(1), 3–14. https://doi.org/10.1525/mp.2010.28.1.3

Pinker, S. (2003). *How the Mind Works*. Great Britain: Penguin UK.

Prum, R. O. (2012). Aesthetic evolution by mate choice: Darwin's really dangerous idea. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1600), 2253–2265. https://doi.org/10.1098/rstb.2011.0285

Rabinowitch, T.-C., Cross, I., & Burnard, P. (2013). Long-term musical group interaction has a positive influence on empathy in children. *Psychology of Music*, *41*(4), 484–498. https://doi.org/10.1177/0305735612440609

Ramachandran, V. S. (2000). Mirror neurons and imitation learning as the driving force behind 'the great leap forward' in human evolution. *Edge Website.* Retrieved from http://www.cultivosurbanos.org/wp-content/uploads/2012/06/Ramachandran-VS-Mirror-neurons-and-imitation-learning-as-the-driving-force-behind-the-great-leap-forward-in-human-evolution.pdf

Reddish, P., Fischer, R., & Bulbulia, J. (2013). Let's Dance Together: Synchrony, Shared Intentionality and Cooperation. *PLoS ONE*, *8*(8), e71182. https://doi.org/10.1371/journal.pone.0071182

Richmond, J. (2017). Coming to terms with entrainment and rhythmic synchronisation. *Australian Music & Psychology Society Newsletter*, *6*, 5.

Rideaux, R., Badcock, D. R., Johnston, A., & Edwards, M. (2016). Temporal synchrony is an effective cue for grouping and segmentation in the absence of form cues. *Journal of Vision*, *16*(11), 1–12. https://doi.org/10.1167/16.11.23

Rizzolatti, G. (2005). The mirror neuron system and its function in humans. *Anatomy and Embryology*, *210*(5–6), 419–421. https://doi.org/10.1007/s00429-005-0039-z

Rizzolatti, G., & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience*, *27*(1), 169–192.

Sanfilippo, K. (2015). Creating Together: How improvisation in music affects social bonding. Presented at the The 8th International Conference of Students of Systematic Musicology, Leipzig, Germany.

Silent disco. (2015). In *Wikipedia, the free encyclopedia*. Retrieved from http://en.wikipedia.org/w/index.php?title=Silent_disco&oldid=647878595

Snyder, C. R., & Endelman, J. R. (1979). Effects of degree of interpersonal similarity on physical distance and self-reported attraction: A comparison of uniqueness and reinforcement theory predictions. *Journal of Personality, 47*(3), 492–505. https://doi.org/10.1111/j.1467-6494.1979.tb00628.x

Strauß, H., & Zentner, M. (2015). Objectively assessed musical ability and empathy: An analysis based on two multicomponential measures. Presented at the 4th International Conference on Music and Emotion, Geneva.

Tarr, B., Launay, J., Cohen, E., & Dunbar, R. I. M. (2015). Synchrony and exertion during dance independently raise pain threshold and encourage social bonding. *Biology Letters*, *11*(10), 20150767. https://doi.org/10.1098/rsbl.2015.0767

Tarr, B., Launay, J., & Dunbar, R. I. M. (2014). Music and social bonding: 'self-other' merging and neurohormonal mechanisms. *Frontiers in Psychology*, *5*. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4179700/

Tarr, B., Launay, J., & Dunbar, R. I. M. (2016). Silent disco: dancing in synchrony leads to elevated pain thresholds and social closeness. *Evolution and Human Behavior*, *37*(5), 343–349. https://doi.org/10.1016/j.evolhumbehav.2016.02.004

Thompson, W. F., McIlwain, D., Eerola, T., & Vuoskoski, J. (2012). Who Enjoys Listening to Sad Music and Why? *Music Perception*, *29*(3), 311–321.

Vuoskoski, J. K. (2015). Music, Empathy, and Affiliation: Commentary on Greenberg, Rentfrow, and Baron-Cohen. *Empirical Musicology Review*, *10*(1–2), 99–102.

Weinstein, D., Launay, J., Pearce, E., Dunbar, R. I. M., & Stewart, L. (2016). Singing and social bonding: changes in connectivity and pain threshold as a function of group size. *Evolution and Human Behavior*, *37*(2), 152–158. https://doi.org/10.1016/j.evolhumbehav.2015.10.002

Woolhouse, M. H., Tidhar, D., & Cross, I. (2016). Effects on Inter-Personal Memory of Dancing in Time with Others. *Auditory Cognitive Neuroscience*, 167. https://doi.org/10.3389/fpsyg.2016.00167

Zahavi, A. (1975). Mate selection—A selection for a handicap. *Journal of Theoretical Biology*, *53*(1), 205–214. https://doi.org/10.1016/0022-5193(75)90111-3

Appendix 1 – Demographic Questions

Age?

Sex?

What is your home country?

In which country do you live currently?

What is the highest level of education you have completed?

- Secondary school
- Bachelor’s degree
- Master’s degree
- Doctoral studies

Have you taken formal dance classes?

If so, what styles and for how long?

How often do you go dancing?

- Almost never
- A few times a year
- Once a month
- A few times a month

- Once a week
- A few times a week

How much do you enjoy dancing?

- Scale from 1 - 10

Any other comments about your dance experience?

How would you describe your engagement with music?

- Non-musical
- Music listener
- Amateur musician
- Semi-professional musician
- Professional musician

If you have learned an instrument, which instruments and for how long?

Any other comments about your musical experience?

Appendix 2 – Stimulus Track List

Title	Artist	Original BPM	Stretched BPM
Get Ready	The Temptations	130	123.5
In the Midnight Hour	Wilson Pickett	115	121.675
My Girl	The Temptations	105	110.25
Sandstorm	Darude	135	128.25
DOTA	Basshunter	140	133
Prototype	ThisNameIsAFail	125	118.75

Appendix 3 – Task experience questions

Please respond to all questions with a ranking from 1 to 10, where 10 is the most positive evaluation.

How much did you enjoy this task?

How comfortable did you feel during the task?

How would you rate the interaction between yourself and your partner?

Did you feel anxious or nervous during the task?

How much did you enjoy the music?

Do you have any other comments?