

Dance and Social Bonding: Synchrony and the Endogenous Opioid System

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“as the dancer loses himself in the dance, as he becomes absorbed in the unified community, he reaches a state of elation in which he feels himself filled with energy or force immediately beyond his ordinary state”

- Alfred Radcliffe-Brown, writing on dancers of the Andaman Islanders (1922, p. 252)

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Abstract

Dance – movement to music – is a ubiquitous and ancient human activity, which may serve important adaptive functions. In this thesis I focus on the suggestion that dance may encourage social bonding amongst co-actors by stimulating the production of endorphins in the Endogenous Opioid System (EOS).

Studies have demonstrated that performing similar movements in a predictable, rhythmic fashion makes dyads feel more socially close, likely due to a merged sense of ‘self’ and ‘other’. Synchronising movements with other people has also been investigated with regard to its neurochemical effect. People performing exertive synchronised movements in a social context experience increased pain threshold (a proxy measure of endorphin release by the EOS) compared to those performing the same movements alone or out of synchrony.

This thesis brings together these two bodies of literature to address a number of outstanding questions regarding the effects of dance in a naturalistic context (i.e. groups rather than dyads moving to music rather than a metronome). Firstly, does dance make people feel more socially bonded? Secondly, what role does exertion play in the relationship between synchrony, social bonding and endorphin release? Thirdly, what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with this social bonding and endorphin release? Finally, does endogenous opioid uptake mediate the social bonding effects in dance?

In experiment 1, I compare participants’ self-reported closeness and generosity in an economic game before and after either a real-world dance class or gym session and find that either activity can have an effect on some measures of social bonding between strangers. In experiment 2, conducted in Brazil, I find both synchrony and exertion have significant and independent main effects on self-reported bonding amongst non-strangers, and on pain threshold (a proxy measure of endorphin levels). The subsequent two experiments are laboratory-based studies in the UK, and utilise silent disco technology to better manipulate the audio-visual experience of synchrony between strangers, and Actiwatches to measure exertion. Participants in synchrony with one another experience elevated pain threshold and higher levels of social bonding and in experiment 4, naltrexone- (an endorphin antagonist) treated participants experience suppressed analgesic effects, confirming that exertive synchronous movement activates the EOS.

In conclusion, this thesis presents novel research on and preliminary support for the endorphin-mediated social bonding hypothesis of dance. The results lay the foundation for further investigation into the complex neurohormonal underpinnings of these human social behaviours, and contribute to our understanding of the atavistic nature of group dance.

Glossary

ASD – Autism Spectrum Disorder

ASC – Autism Syndrome Condition

BOTSA – Brain Opioid Theory of Social Attachment

CCK – Cholecystokinin

DA - Dopamine

dACC – Dorsal anterior cingulate cortex

EOS – Endogenous Opioid System

HPA – Hypothalamic-Pituitary-Adrenal

IOS – Inclusion of Other in Self

MEA – Motion Energy Analysis

MLM – Multilevel Linear Modelling

NAcc – Nucleus Accumbens

OR – Opioid Receptors

PANAS – Positive And Negative Affect Scale

PET – Positron Emission Tomography

PIT – Pain Threshold Test

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Chapter I – Introduction¹

I.1 Aims and approach of the thesis

Dance is a ubiquitous and ancient human activity, which involves synchronised movement to music and fellow dancers. Around the world, people sing, make music, and dance (Blacking, 1973; Brown, 1991; Lomax, 1968; Nettl, 1983, 2000), activities often conducted in a group setting and accompanied by strong emotions (Ehrenreich, 2008). The aim of this thesis is to contribute towards an understanding of why dance exists as such an important and widespread activity for our species. Ethnographers have detailed the great diversity of meanings and importance of dance and music making (e.g. Durkheim, 1915; Ehrenreich, 2008; Hanna, 1977). However, empirical investigation into the various hypotheses regarding the functions of dance are lacking (for a review of the shortcomings of anthropological research, see: Bulbulia & Reddish, 2013). This thesis employs experimental methods to test one popular explanation for the ubiquity of dance: the social bonding hypothesis.

I.1.1 The social bonding hypothesis of dance

It has been suggested that a key function of music and dance during their development and spread amongst human populations was their capacity to create and strengthen social bonds between interacting group members. This forms the basis of the social bonding hypothesis, which postulates that dance is an effective tool in establishing and maintaining social bonds so as to increase cooperation and prosocial behaviours between group members (Anshel & Kipper, 1988; Chanda & Levitin, 2013; Freeman, 2000; Huron, 2001; Kirschner & Tomasello, 2010; Kokal,

¹ Sections of this introductory chapter are published in Tarr, Launay & Dunbar (2014).

Engel, Kirschner, & Keysers, 2011; McNeill, 1995; Reddish, Fischer, & Bulbulia, 2013; Roederer, 1984).

Evidence that social bonding is signalled by and arises from various music-based activities has been provided by, *inter alia*, ethnographers (Durkheim, 1915; Radcliffe-Brown, 1922), historians (e.g. McNeill, 1995), ethnomusicologists (Brown, 2000; Clayton, Sager, & Will, 2005), biomusicologists (Hagen & Bryant, 2003), and experimental researchers (Kirschner & Tomasello, 2010; Wiltermuth & Heath, 2009). In this thesis, music is included in the conceptualisation of dance (explored in detail in ‘Coupled concepts: music and dance’, pg. 13).

Dance involves participants synchronising their movements to a predictable, rhythmic beat, and to each other. The vast majority of empirical research contributing to an understanding of how dance bonds us has focussed on operationalising the conditions and effects of synchrony on interpersonal closeness. This literature has demonstrated that performing similar movements in a predictable, rhythmic fashion makes individuals feel more socially close, likely due to action-perception networks facilitating a merged sense of ‘self’ and ‘other’ (e.g. Demos, Chaffin, Begosh, Daniels, & Marsh, 2012; Hove & Risen, 2009; Lumsden, Miles, & Macrae, 2014; Miles, Nind, & Macrae, 2009). With but a few exceptions (e.g. Kirschner & Tomasello, 2010; Reddish et al., 2013; Wiltermuth & Heath, 2009), these studies almost exclusively have focussed on pairs of people (dyads) moving to metronome beats. In this thesis I aim to contribute to the literature by investigating the effect of synchrony on social bonding using a more ecologically valid operationalisation of dance, where groups of people make expressive movements to actual music.

In addition, it is key to take into account the neurochemical effects associated with acting in synchrony. People performing exertive synchronised movements, such as rowing, in a social context experience increased analgesia (i.e. higher pain threshold) compared to those performing

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the same movements alone (Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010; Sullivan & Rickers, 2013) or out of synchrony (Sullivan, Rickers, & Gammage, 2014). In these studies, pain threshold was used as a proxy measure of endorphins, which are released by the Endogenous Opioid System (EOS). The EOS is a collection of opioid receptors and associated peptides which are involved in pain and pleasure pathways (Janal, Colt, Clark, & Glusman, 1984; Leknes & Tracey, 2008), and mood (Zubieta et al., 2001). The EOS is activated during exercise (e.g. Boecker et al., 2008), and primate social grooming, which underlies the formation of social bonds (e.g. Keverne, Martensz, & Tuite, 1989). Due to its role in bonding, and its stimulation during exertive synchronous activities, it has been hypothesised that the EOS may underpin the bonding that arises during an exertive synchronous activity such as dance (Dunbar, 2012b). However, empirical investigation into this hypothesis is limited (thus far only: Dunbar, Kaskatis, MacDonald, & Barra, 2012), and an empirical investigation into both the bonding effects and EOS activation during synchronous movement to music during dance is still lacking. The integration of methods used in the synchrony, EOS, and social bonding literature, is an additional contribution of this thesis.

I explore the hypothesis that dance may encourage social bonding amongst co-actors by stimulating the production of endorphins in the Endogenous Opioid System. This thesis aims to provide two novel contributions to the literature (discussed in more detail in ‘Contribution of this thesis’, pg. 52): 1) an empirical investigation into both social bonding effects as well as EOS activation following group synchrony; and 2) an ecologically valid paradigm of dance, which has groups of participants perform actual dance movements to popular music. These contributions are encapsulated in the following four questions addressed by this thesis.

Firstly, does dance make people feel more socially bonded? Secondly, what role does exertion play in the relationship between synchrony, social bonding and endorphin release?

Thirdly, what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with this bonding during group dancing? Finally, does endogenous opioid (specifically endorphin) uptake mediate the social bonding effects in dance?

1.1.2 The scope of the thesis

Dance: a case of ‘musicking’

Dance is a complex sensorimotor activity. It demands synchronisation to external stimuli, such as a rhythmic beat in music (auditory stimulus), and/or cues provided by surrounding dancers (visual stimulus). The resulting synchronised movement involves body-wide coordination and navigation of spatial patterns (Brown, Martinez, & Parsons, 2006b). Although this thesis is predominantly concerned with the social bonding effects of dance, I subscribe to a coupled concept of music and dance, similar to the concept of ‘musicking’ described by Christopher Small (1998). As a result, although I provide a brief definition of the defining elements of dance and music in ‘What is dance?’ (pg. 10), for the majority of this thesis I when using the word ‘dance’, I am referring to dance/music as a combined concept (justified in further detail in ‘Coupled concepts: music and dance’, pg. 13).

Why dance?

Many of the aspects of dance and musical activities which contribute to making people feel socially close are not specific to music and dance-based activities. For example, sharing attention with co-actors (e.g. Reddy, 2003), working towards similar goals (e.g. Tomasello et al., 2005), and experiencing a sense of positivity after successful co-engagement (e.g. Isen, 1970) occur in a range of human activities. This thesis does not postulate that dance and music are the only means by which individuals form social bonds, and nor is bonding likely to be the only explanation for why

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humans have such an immense and widespread aptitude and appreciation for these activities. However, the performance and perception of music are arguably among the most cognitively demanding and complex sensorimotor behaviours undertaken by humans (Zatorre, Chen, & Penhune, 2007). Coupled with dance, these activities make a unique set of demands on the brain and nervous system.

In the context of other similarly complex human activities (e.g. group sport), dance is notable for two reasons. Firstly, it can involve and induce emotive responses in both performers (Kleber, Birbaumer, Veit, Trevorrow, & Lotze, 2007) and audience members (Blood, Zatorre, Bermudez, & Evans, 1999; Blood & Zatorre, 2001; Menon & Levitin, 2005; Stevens et al., 2009; Vines, Krumhansl, Wanderley, Dalca, & Levitin, 2011). Unlike sport, dance involves responding directly and purposefully to music and provides expressive, communicative elements. Body movement conveys an immense amount of information about an individual, as evidenced by motion perception studies on human gait as a cue for youth and gender (Kozlowski & Cutting, 1977), and immunocompetence (Hausdorff et al., 2001). Furthermore, observers are remarkably good at extracting emotive information from mimes and dancers, illustrating the expressive, nonverbal communicative and emotive capacity of such performances (Walk & Homan, 1984).

Secondly, dance tends to be performed and/or enjoyed in a group, and is fundamentally cooperative in nature (Brown & Volgsten, 2006; Sebanz, Bekkering, & Knoblich, 2006; Tomasello, Carpenter, Call, Behne, & Moll, 2005). Gathering for rhythmic singing and dancing is commonplace cross-culturally (Ehrenreich, 2008; Farnell, 1999; Sachs, 1937). Additionally, dance involves both synchronisation with music, and with fellow dancers, thereby demanding a spatial-temporal and interpersonal coordination that is rare in other social contexts (Blacking, 1995).

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The evolutionary and cognitive mechanisms facilitating our predisposition for this complex, social, emotive, and strikingly widespread synchronous activity is a deeply interesting topic.

Investigation into the underpinnings of music-based activities such as dance offers unprecedented insights into human cognitive function and evolution.

The ubiquity, antiquity and diversity of dance

Dance and music are fundamental and ancient forms of human expression, of which three striking features emerge: the ubiquity, antiquity, and diversity of these art forms.

Most, if not all, human cultures boast various activities which might be considered forms of music and dance (Blacking, 1973; Brown, 1991; Lomax, 1968; Sachs, 1937). Like language, art and laughter, the performance, aptitude and appreciation of dance are cross-culturally ubiquitous, thereby forming an important part of what make us distinctly human (Björn Merker, Madison, & Eckerdal, 2009; Nettl, 2000; Patel et al., 2008; Phillips-Silver et al., 2011; Trehub, 2003).

Furthermore, our tendency to create and engage in such performances is likely to have been part of human society for some time. A wealth of documentation ranging from cave paintings, to Egyptian hieroglyphics to records from ancient Olympic games to religious texts attests to the importance of dance in recorded human history (Björn Merker et al., 2009; Nettl, 2000). Among the oldest known instruments are the Slovenian and German bone “flutes”, dated to approximately 50,000 – 35,000 years ago (Adler, 2009; Kunej & Turk, 2000). Furthermore, as outlined by the body-percussion hypothesis (reviewed ‘Human ‘musicking’’, pg. 13), our first ‘instrument’ was most likely our body, which far preceded any constructed instruments, such as flutes.

Finally, the stylistic and socio-contextual details of music and dance, and the role they play in ritual, religion, and human expression generally, differs vastly across cultures (Brown, 2000). In

light of this vast diversity, many researchers argue that an assessment of music and dance's functionality is specific for each culture in question. This analysis, mostly employed by cultural anthropologists, provides a deeply valuable appreciation of the diversity of these human cultural practises (e.g. Ehrenreich, 2008; Kaeppler, 1978), and possible hypotheses for their function in society (Durkheim, 1915; J L Hanna, 1987; Radcliffe-Brown, 1922). However, the present thesis is concerned more with the underlying mechanisms and fundamental elements underpinning the long and ubiquitous history of music and dance. Beneath the immense variability in these behaviours is the curious fact that all human societies engage in dance and musical performances at all, and this thesis takes an experimental approach which involves isolating and measuring elements of dance, and its effects.

1.1.3 An experimental approach: operationalising the constructs

This thesis poses a series of questions and experimentally testable, falsifiable hypotheses regarding how dance might bond us socially. This empirical approach involves the isolation and manipulation of specific variables of interest (independent variables), and the measurement of the effect of this manipulation on other (dependent) variables.

One method of empirically investigating the bonding effects of dance, and music-based activities generally, is comparing the musical activity in question to a 'control' activity which is not usually culturally defined as musical (e.g. Anshel & Kipper, 1988). I employ this method in the first study in this thesis (Chapter 2). However, operationalising dance in a meaningful and empirically useful manner (and choosing a relevant control activity) is challenging, due to the fact that dance is such a diverse and complex behaviour. One solution is the isolation and progressive manipulation of a particular element of dance in a series of experiments. In this thesis, similar to others interested in dance (e.g. Reddish et al., 2013), I focus on the fact that almost all forms of dance

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involve matching movements in time, or synchronising. The manipulation of synchrony, and its effect on bonding is a prominent area of research, and a review of this literature forms a significant portion of this introductory chapter. In this thesis, I use a series of manipulations of synchrony in Chapters 3 – 4.

As I am specifically interested in the possible role of endorphins in the bonding that arises during synchrony in dance, I also face the challenge of measuring of EOS activation. The most accurate method of measuring activity in the EOS is via Positron Emission Tomography (PET) scans (e.g. Mueller et al., 2010), fMRI (Wager et al., 2004) , or direct measure of endorphin levels in spinal fluid extractions (e.g. Dearman & Francis, 1983). As these methods are costly and invasive, indirect proxy measures of pain (outlined and justified in further detail in ‘The EOS and (physical) pain’, pg. 26), and the manipulation of the EOS using opioid interventions such as agonists or antagonists (see ‘Opioid interventions and social behaviour’, pg. 24) are preferable. In this thesis, I utilise a proxy measure of EOS activation (pain threshold) in Chapters 3 – 5, and administer an endorphin antagonist in Chapter 5.

Finally, operationalizing ‘social bonding’ is notoriously challenging (Launay et al., in press). In this thesis, the term ‘social bonding’ refers to the psychological experience of increased social (i.e. inter-personal) closeness, which may be reflected in prosocial (cooperative) behaviours (see ‘What is social bonding?’, pg. 18). In Chapters 2 – 5, I use a number of self-report questions to determine the degree of psychological closeness to others (e.g. other participants in the testing group). These questions include verified scales widely used in the literature (particularly studies investigating the link between synchrony and bonding). An additional method of measuring prosociality is via cooperative behaviour in economic games (e.g. Launay, Dean, & Bailes, 2013; Wiltermuth & Heath, 2009). These games generally involve constructed situations in which

participants are presented with a series of rules regarding the allocation of money between participants. Economic theory predicts that self-interested (and rational) individuals will choose to keep rather than share the money. Consequently, the amount of money donated to another individual/public pot is taken as a measure of generosity or cooperation, which in turn can be interpreted as an indication of how socially bonded individuals feel. I use a range of different economic games in Chapters 2 and 4, and the details of each are described in the introduction section of each chapter.

1.1.4 Outline of the literature review

This introductory chapter begins by reviewing the question ‘what is dance?’ and outlining the relevant elements of music, dance, and a coupled concept of music and dance (‘musicking’). Following this, synchrony is defined in relation to dance, which includes a review of emotion in musicking.

Having established working definitions of these elements, the next section provides an outline of what is meant by the term ‘social bonds’, a review of the social brain hypothesis, and an introduction to the EOS as a mechanism by which social bonding occurs. In a review of evidence for the role of the EOS in social bonding, I explore the social behaviours (grooming) of our primate cousins, and the Brain Opioid Theory of Attachment (BOTSA). Additionally, the role of the EOS in pain management, and the link between social and physical pain is reviewed. The idea that humans may have relied upon dance as a means of bonding with multiple individuals simultaneously is then introduced, a description of the theoretical explanations of the functionality of dance and music is discussed, including the various evolutionary hypotheses for why these behaviours occur, and a review of the evidence in support of the social bonding hypothesis specifically.

Following this I discuss the mechanisms by which dance/music might foster social bonds, including ‘self-other matching’, experiments linking synchrony and social bonding, and evidence to suggest the possible role of the EOS in this bonding.

Finally, I outline the existing gaps in the literature, the contributions offered by this thesis, and introduce the data chapters and the questions each aim to answer regarding dance and social bonding, and the effects of synchrony and the EOS.

1.2 What is dance?

Before moving forward, it is necessary to establish working definitions of the relevant terms. In this thesis, dance is broadly defined as movement to music and as such it is important to first define the elements of music.

1.2.1 Elements of music

Music is an auditory form of emotional communication (Meyer, 1956), and its production involves the organisation of sound in relation to various basic elements which can be generally delineated along the lines of rhythm, tone and affect (Jackendoff & Lerdahl, 2006). These different elements may be of varying importance in a particular style of music, depending on the cultural and historic context.

Rhythm consists of a series of auditory pulses, or ‘beats’ (Phillips-Silver et al., 2011). Musical time is organised according to rhythmic beats (Zatorre et al., 2007), and ‘tempo’ refers to the rate of rhythmic beat. A regular set of evenly spaced sounds is termed ‘isochronous’ (iso = equal; chronos = time), and the capacity to pick up and entrain to an isochronous beat is the basis of our ability to synchronise to music (Phillips-Silver et al., 2011).

The tonal elements of a piece of music are based on an organisation of pitch, usually to produce a melody (a succession of notes arranged in a particular order and temporal manner). Pitch is determined by the speed of vibration from the source of the sound (Kennedy & Kennedy, 2007; Zatorre et al., 2007). A metronome beat or the beat of single drum can be distinguished from a beat embedded in musical stimuli, based on the fact that the former lacks variation in tone and/or the presence of a melody. In this thesis, the term ‘music’ is used in reference to a form of organised sound that does not only consist of only a rhythmic beat, but rather the additional elements of tone, dynamics and affect.

Musical affect refers to the interaction of music with emotion (Jackendoff & Lerdahl, 2006), discussed in more detail in ‘Emotion and ‘musicking’, (pg. 17). Whilst the various elements of rhythm, tone and affect can be perceived separately (Zatorre et al., 2007), these elements interact to create a musical percept (Jones, Moynihan, MacKenzie, & Puente, 2002), an appreciation of which essentially constitutes musicality. In dance, musicality plays a central role in a performer’s fine-tuned synchrony with the musical stimulus and emotive quality of movement.

1.2.2 Elements of dance

Dance to music involves coupling between auditory processing (i.e. the identification of a musical pattern), and some spatial-temporal motor response (or spatial patterning: Naveda & Leman, 2010). This coupling is the basis of synchronisation during dance. The organisation of body movements into a spatial pattern is an important component of dance (Brown et al., 2006b). This patterning of movement forms part of the ‘spatial cognition’ employed when dancing, and includes two sets of awareness: 1) an awareness of the egocentric space, or a kinaesthetic and/visual map (Haggard & Wolpert, 2005); and 2) a map of the body and its movement in exocentric space (Longstaff, 2000).

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Egocentric awareness involves continual reassessment of the coordinated motor (i.e. movement) response to music. This awareness arises via proprioceptive feedback from muscles that forms a kinesthetic map, allowing an accurate and constantly updated consciousness of body positioning in space (Hänggi, Koeneke, Bezzola, & Jäncke, 2010). Exocentric awareness refers to the dancers' perception of their movements in the performance space or stage area (Hänggi et al., 2010), and when dancing with others, an exocentric awareness contributes to interpersonal synchrony during dance.

An additional element of dance is its communicative capacity for expression, often, but not always, captured during dance performances through the stylisation of gestures (Brown & Parsons, 2008). The representational capacity afforded by the confluence of movement and music is celebrated in many dance styles, cultures and story-telling rituals. Arguably, gestural representation, or at least the use of music and dance to express and communicate, provides the basis for an important distinction between human dance, and other synchronised human activities (such as drill marching), as well as synchronised behaviours performed by other animals.

Dance to music, rather than a metronome

Movement in dance involves more than scaled up toe-tapping in time to a metronome or single-drum beat. Dance gestures are often influenced by the hierarchical arrangement of strong and weak beats (or measures) of a musical item (Brown et al., 2006b). For example, we don't march or samba to a waltz because the musical rhythm in each style of music suggests different emphasis in movement. In a waltz, the first beat is stressed, and the following two beats are weaker. Similarly, the first step is largest, and the subsequent two steps are much more subdued and smaller (Brown et al., 2006b). Our ability to entrain movement to music should therefore not be conflated with synchronising to a metronome alone.

1.2.3 Human ‘musicking’

As described by Christopher Small, “*music is not a thing...[it’s] an activity, something that people do*” (Small, 1998, p. 2). He describes a novel verb, ‘to music’, i.e. to engage in ‘musicking’, as “*take[ing] part, in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, by providing material for performance (what is called composing), or by dancing*” (Small, 1998, p. 9). This thesis subscribes to this conceptualisation of musicking, and specifically a coupled concept of music and dance.

Coupled concepts: music and dance

There is a strong case to be made that an evolutionary analysis of music and dance should view these behaviours as a single, or at very least intrinsically interlinked, concept (Bellah, 2003; Cross, 1999, 2001; Freeman, 2000). Indeed, in many cultures, music and dance are considered indistinguishable (Arom, 1991; Blacking, 1995; Merriam, 1964), and some languages do not have separate words to describe them (Gourlay, 1984). Whilst there has been widespread investigation into the cognitive, neurobiological function, psychology, anthropology and possible evolutionary origins of music and human musicality (Cross & Morley, 2008; Freeman, 2000; McDermott & Hauser, 2005; McDermott, 2008; Patel, 2003; Trehub, 2003), research into the drivers and mechanisms of a co-evolution of music and dance is less well explored. However, music and dance likely share a coupled evolutionary history (e.g. Kornysheva, von Cramon, Jacobsen, & Schubotz, 2010). Indeed, at the most fundamental level, it is not possible to create sound, and by extension music of any form, without movement. This forms the basis of the ‘body percussion hypothesis’, which postulates that dance evolved with music as a way of generating rhythm and sound (Cummins, 2009).

The body percussion hypothesis

The notion that dance originated as a sounding phenomenon is supported by anthropological evidence from societies where dance is often performed as a means of creating music, and rarely in the complete absence of music or song (e.g. Kaepler, 1978). Bells, shakers, heels etc. attached to the body create sounds with each step or movement, and in many cultures, dancers clap, snap and stomp whilst dancing, creating, or at least adding, to the musical stimuli (Brown & Parsons, 2008; Dunbar, Kaskatis, et al., 2012; Kirby, 1936). Indeed, the separation of ‘performers’ and ‘audience’ is a fairly recent tradition (Cross & Morley, 2008). Given that most dance is performed to musical rhythms, which facilitates synchronisation among dancers (Steven Brown, Martinez, & Parsons, 2006b; Cummins, 2009; Merker et al., 2009), it is justifiable to define dance as having a musical component. A coupled music-dance concept is also supported by neurological evidence regarding our auditory-motor systems, and the fact that music (literally) moves us (e.g. Eitan & Granot, 2006), often instinctively, from a very young age (e.g. Zentner & Eerola, 2010).

Coupled auditory-motor systems

Humans have tightly coupled auditory-motor systems (Naveda & Leman, 2010; Zatorre et al., 2007). Listening to musical stimuli increases activity in a number of motor regions of the brain (Blood & Zatorre, 2001; Levitin & Menon, 2003), which initiates physical movement (Janata & Grafton, 2003; Janata, Tomic, & Haberman, 2012; Koelsch & Siebel, 2005; Madison, Gouyon, Ullén, & Hörnström, 2009; Madison, 2006). At a neurological level, certain elements of music are particularly good at inducing a motor response, for example preferred tempo (Kornysheva et al., 2010). At a higher-level, the ability of music to induce body-movement and dance has been described as ‘groove’ (e.g. Janata et al., 2012; Madison, 2006), and certain musical styles with

particular musical elements appear better at inducing groove (e.g. songs with medium degrees of syncopation: Witek, Clarke, Wallentin, Kringelbach, & Vuust, 2014).

Instinctive entrainment

The ability to perceive a beat emerges from an early age (e.g. Phillips-Silver & Trainor, 2005), as does spontaneous movement in response to music (e.g. Kirschner & Tomasello, 2009; Zentner & Eerola, 2010). Preverbal infants (from as young as 5 - 24 months) are more likely to entrain rhythmically to music (or other rhythmically regular sounds) than to speech (Zentner & Eerola, 2010). As such, humans appear to have an innate capacity to perceive and synchronise to a rhythmic pattern (Patel, Iversen, Chen, & Repp, 2005), and the ability to spontaneously (and even unconsciously) ‘entrain’ to an external beat, particularly beats embedded in music (Demos et al., 2012), seems to be a culturally ubiquitous skill (Brown & Jordania, 2011; Clayton et al., 2005).

This ability is a fundamental element of our aptitude for music and dance (Brown et al., 2006b; Cummins, 2009; Björn Merker et al., 2009), and although the capacity (and tendency) to entrain is not limited exclusively to humans (Patel, Iversen, Bregman, & Schulz, 2009), it is widely considered an important defining characteristic of our species (Brown, Martinez, & Parsons, 2006a; Björn Merker et al., 2009; Patel et al., 2008; Trehub, 2003). Due to this strong relationship between movement and music, even from early stages of our development, it is reasonable to consider music and dance as two aspects of the same phenomenon.

1.2.4 Synchrony, temporal entrainment and musicking

Dance demands spatial-temporal and interpersonal coordination, and various forms of ‘synchrony’ (Blacking, 1995). Whilst dancing, the musical beat and tempo act as a scaffold for matching movement accurately: participants have the opportunity to synchronise ‘temporally’ (i.e.

‘entrain’ to the musical beat), and ‘behaviourally’ (match movements with fellow dancers). In this manner, synchronisation can involve both similarity of timing and forms of behaviour produced by one or multiple individuals (Jackendoff & Lerdahl, 2006).

Principles of entrainment

When an oscillating object (an ‘oscillator’) maintains a rhythmic movement in the presence of another oscillator, the two rhythms fall into a constant relationship with each other (Huygens, 1673/1986), which is termed ‘entrainment’ (Clayton, Sager & Will 2004). When two rhythms are tightly entrained, the objects are said to be acting in ‘synchrony’ (Huygens, 1673/1986).

Temporal synchrony is the entrainment of movement to the musical tempo and beat (Jackendoff & Lerdahl, 2006), i.e. being ‘in time’ with the music. When multiple individuals act simultaneously, this is termed ‘social entrainment’ (Phillips-Silver, Aktipis, & Bryant, 2010) or interpersonal synchrony, during which the precise timing and coordination of movement coinciding with another’s timing of movement constitutes temporal synchrony (Bernieri & Rosenthal, 1991; Grammer, Kruck, & Magnusson, 1998). Although there are various types of temporal synchrony (e.g. in-phase or anti-phase), the present thesis is concerned with the simple manipulation of whether participants are temporally synchronised in general. Social entrainment can involve not just temporal synchrony, but also the execution of similar (i.e. matched) movements at the same time, or ‘behavioural synchrony’ (Cohen et al., 2010; Miles, Griffiths, Richardson, & Macrae, 2010).

Terms used in this thesis: ‘Synchrony’ and ‘partial synchrony’

In this thesis, temporal synchrony is a minimal condition for the definition of dance, but behavioural synchrony may also occur. In the literature review that follows, the term synchrony is

used as a blanket term to describe either temporal or behavioural synchrony, and where necessary the details are clarified. However, in the data chapters that follow (Chapters 2, 3, 4 and 5), I use the term ‘synchrony’ to refer to occasions when the most complete form of synchrony was possible (i.e. matched timing and matched movements between participants: behavioural synchrony), and ‘partial synchrony’ to refer to situations where only temporal synchrony occurs (i.e. matched timing but mismatched (non-identical) movements). ‘Asynchrony’ indicates occasions where neither temporal nor behavioural synchrony occurs.

1.2.5 Emotion and ‘musicking’

The effect that music has on mood and emotion is a primary (self-reported) motivator behind our desire to engage in music based activities (Juslin & Laukka, 2004). In adults, music evokes emotions via core brain regions generally involved in processing affect (for a recent review see: Koelsch, 2014), such as limbic areas (e.g. amygdala) and the orbitofrontal cortex (Blood et al., 1999; Blood & Zatorre, 2001; Koelsch, Fritz, von Cramon, Müller, & Friederici, 2006). Even newborns experience limbic responses to music, indicating that the neural architecture of music processing (and associated emotions) does not rely on exposure, we are born with it (Perani et al., 2010). Furthermore, music has the capacity to activate neural pathways for reward and motivation (including the Nucleus Accumbens (NAcc), see: Koelsch, 2014 for more details), which partially explains a continued desire to engage with music, a pleasurable and stimulating stimulus. Furthermore, activity in the hippocampal formation occurs even when people tap in time with a virtual partner (Fairhurst, Janata, & Keller, 2013), and some patients with lesions in this area of the brain reportedly find dissonant music pleasant (Gosselin et al., 2006).

1.3 What is social bonding?

In this thesis, the term ‘bonding’ is used interchangeably with that of ‘social bonding’, and refers to the psychological experience of increased social (i.e. inter-personal) closeness, which may be reflected in prosocial (cooperative) behaviours.

Understanding social bonding, and how and why animals cooperate and behave socially is one of the greatest conundrums in the biological and social sciences (Darwin, 1871; Hamilton, 1964). Primate sociality (particularly that of anthropoid primates, such as humans) is characterised by interpersonal relationships which involve a high degree of conspecific behavioural and psychological coordination (Dunbar, 1988, 2010; Fedurek & Dunbar, 2009; Keverne et al., 1989). These ‘social bonds’ exist between non-sexual partners and non-kin, but the intensity and persistence of these bonds have been likened to pair-bonds exhibited by mating partners in other species (Dunbar & Shultz, 2010; Shultz & Dunbar, 2007). The ‘generalisation’ of these pair-bond relationships to non-kin partners in primate species, and the formation of non-reproductive social bonds, has been referred to as “friendships” (Silk, 2002). The consequences of this generalisation is that primates tend to have more cohesive and intensely bonded, and larger social groups than most other mammals and birds (Broad, Curley, & Keverne, 2006; Curley & Keverne, 2005). More cohesive and tightly-bonded groups are well coordinated, and group-level selection predicts that members of these groups are more likely to survive than those acting alone or in less bonded groups (West, El Mouden, & Gardner, 2011). Furthermore, experimentally manipulated social support influences a range of physiological measures such as blood pressure, cortisol levels and heart rate in humans (for a review see: Thorsteinsson & James, 1999) and there are various health benefits associated with social contact, such as increased life expectancy (as social isolation is

correlated with risk of morbidity and mortality: Cacioppo & Patrick, 2008; Holt-Lunstad, Smith, & Layton, 2010).

1.3.1 The Social Brain Hypothesis

The cognitive demands of maintaining these large, complex and cohesive social groups is thought to have played a significant role in the expansion and reorganisation of primate brains. This forms the basis of the Social Brain Hypothesis (Dunbar & Shultz, 2007; Dunbar, 1998; Kappeler & Silk, 2010; Silk, 2007). Comparative evidence across primate species reveals a correlation between various brain measures (such as the ratio of neocortex to the remaining volume of the brain), and a variety of social complexity indices including group size (Dunbar, 1995), grooming clique size (Kudo & Dunbar, 2001), number of females in the group (Lindenfors, 2005), prevalence of social play (Lewis, 2000), frequency of tactical deception (Byrne & Corp, 2004), frequency of coalitions (Dunbar & Shultz, 2007), and frequency of social learning (Reader & Laland, 2002). Specifically, covariance between mean group size and neocortical volume predicts a species-specific upper limit to group size, as determined by the cognitive constraints associated with sociality (Dunbar, 1993). According to this relationship between neocortex size and group size, it is predicted that, in terms of cognition, the maximum number of individuals with whom a human would be able to maintain a social relationship by personal contact is approximately 150 (Dunbar, 1993). This number is three times as large as the group size for some of our closest living relatives (e.g. chimpanzees), whose social bonds are underpinned by EOS activation during grooming, as discussed in the following sections.

1.3.2 Mechanisms of social bonding: The EOS

Investigation into the neuropeptide underpinnings of bonding have implicated neurohormonal cascades involving oxytocin and vasopressin (e.g. Carter, 1998), dopamine and serotonin (e.g. Depue & Morrone-Strupinsky, 2005), and endorphins released by the Endogenous Opioid System (Curley & Keverne, 2005; Dunbar, 2010). Recently, oxytocin has been promoted as *the* social neurohormone (Bartz, Simeon, et al., 2011; Meyer-Lindenberg, Domes, Kirsch, & Heinrichs, 2011), largely due to evidence from pair-bonding and mother-infant bonding (e.g. Atzil, Hendler, & Feldman, 2011; Feldman, 2012). However, despite apparent interactions between opioids (specifically endorphins) in the bonding activity of oxytocin (e.g. Depue & Morrone-Strupinsky, 2005), and evidence of the EOS's role in bonding for non-sexual, non-kin related conspecifics in primates (Keverne et al., 1989; Machin & Dunbar, 2011; Martel, Nevison, Simpson, & Keverne, 1995; Ragen, Maninger, Mendoza, Jarcho, & Bales, 2013; Schino et al., 1992); see this section, pg. 21), the role of the EOS in social bonding remains relatively underexplored, possibly due to the difficulties in measuring endorphin titres directly (Dearman & Francis, 1983).

Endorphins play a role in the social bonding in many non-human species such as rhesus macaques (Graves, Wallen, & Maestripieri, 2002; Schino et al., 1992), other monkeys (Keverne et al., 1989; Martel et al., 1995; Ragen et al., 2013), voles (Resendez et al., 2013), puppies, rats and chicks (Panksepp, Herman, Vilberg, Bishop, & DeEskinazi, 1980) and mammals generally (Broad et al., 2006). Given the role of endorphins in bonding in other species, it is plausible that the EOS may also underpin human social bonds (Depue & Morrone-Strupinsky, 2005; Dunbar, 2010; Matthes et al., 1996; Moles, Kieffer, & D'Amato, 2004), perhaps including those that arise during music and dance activities.

What is the EOS?

The EOS consists of opioid receptors and associated peptides distributed throughout the central nervous system and peripheral tissues, such as the NAcc (Fields, 2007; Trigo, Martín-García, Berrendero, Robledo, & Maldonado, 2010). There are three main types of endorphin peptides: β -endorphins, enkephalins and dynorphins, all of which display variable affinities for δ , μ , and κ opioid receptors (Boecker et al., 2008). These receptors play a role in mood, for example, deactivation of μ -opioid receptor sites is associated with negative affect (Zubieta et al., 2003), while Koepp et al. (2009) report activation of general opioid receptors in the hippocampus and amygdala in response to positive affect. Opioid receptors are also activated during subjective feelings of euphoria (Bodnar, 2008), interpersonal warmth, well-being, and bliss (Comings et al., 1999; Depue & Morrone-Strupinsky, 2005; Ferrante, 1996; Koob, 1992), and during opioid-mediated reward (Olmstead & Franklin, 1997), social motivation (Chelnokova et al., 2014), and pleasure and pain perception (Janal et al., 1984; Leknes & Tracey, 2008). In particular, the role of β -endorphins in the pain management system is thought to explain the association between grooming and the EOS.

Primate grooming triggers the EOS, establishes and maintains social bonds

Observations of various primate species indicate that other primates create and maintain their social bonds predominantly via allo-grooming (the grooming of others), which is a prominent behaviour in primate social life (Dunbar & Dunbar, 1988; Fedurek & Dunbar, 2009; Keverne et al., 1989).

Grooming and social bonding

Whilst many species engage in social grooming (e.g. allo-preening amongst social birds: Brooke, 1985; Radford & Plessis, 2006), primate allo-grooming is distinguishable on the basis of

various functional differences. Firstly, primates spend significantly more time grooming each other than do other species (up to 10-20% of the waking day for anthropoid primates), and in some cases are noted to maintain this temporal investment, even in the face of other survival demands (e.g. lactating female geladas prefer to rest less in order to satisfy their increased feeding needs, rather than to decrease their social time; Dunbar & Dunbar, 1988). Furthermore, much of primate grooming is directed at body regions which the receiver can reach themselves, implying that hygiene is not the only function for this time investment, and that social bonding may be a significant driver for this behaviour (Dunbar, 2010).

Behavioural evidence supporting the link between primate grooming and social bonding is based on two main observations. Firstly, there is a significant correlation between the amount of time allocated to grooming, and group size (Lehmann, Korstjens, & Dunbar, 2007). Specifically, grooming occurs between individuals within established ‘cliques’, which appear to be fairly stable and determined matrilineally (Dunbar, 2010). For some species (e.g. gelada baboons; *Theropithecus gelada*), these grooming cliques appear to form the basis for alliances (Dunbar, 1980).

Secondly, there is a correlation between the number and intensity of relationships serviced by grooming, and offspring survival (e.g. wild female savannah baboons - *Papio hamadryas cynocephalus*; Silk, Alberts, & Altmann, 2003). This may be linked to the fact that alliances established within grooming cliques could conceivably translate into mutual protective support (Datta, 1983, c.f. Dunbar, 2010). However, the low frequency of disputes, relative to time spent grooming, indicates that there might be additional mechanisms re-enforcing selection for widespread investment in allo-grooming. It is thought that grooming provides the physiological basis for mutual trust underlying an individual’s willingness to offer coalition support (Dunbar, 2010). This is likely to involve various cognitive and neuropeptide components, primarily activation

of the EOS, which may help establish and maintain social bonds yielding associated survival benefits.

Grooming and the EOS

Grooming has a number of physiological effects, including facilitating relaxation via a reduction in heart rate, and immediate lowering of stress (e.g Schino, Scucchi, & Maestripieri, 1988). Grooming involves pinching and pulling of the skin, which is believed to cause micro-pain stimuli (comparable to that experienced in humans during acupuncture: Clement-Jones et al., 1980). Given the role of the EOS in mediating pain, it was theorised that grooming may directly trigger the release of endorphins, which would result in the range of effects reviewed above, including social closeness and pleasurable reward. Tactile stimulated neuropeptide cascades act on the reward system in the brain and can thus facilitate bonding (Carter, 1998).

The association between grooming and elevated endorphins have been empirically confirmed in talapoin monkeys (Keverne et al., 1989), and rhesus macaques (Graves et al., 2002; Martel et al., 1995). Intervention studies (where animals are treated with opioid-blockers which prevent endorphins from attaching to receptors) demonstrate that grooming behaviour, and associated social bonds, are affected by endorphins (Fabre-Nys, Meller, & Keverne, 1982; Martel, Nevison, Rayment, A, & Keverne, 1993; Martel et al., 1995; Meller, Keverne, & Herbert, 1980). For example, Fabre-Nys et al. (1982) found that talapoin monkeys treated with opiate blockers experienced significant changes in social grooming behaviours, but there were no changes in self-grooming or scratching behaviours, suggesting that the EOS is associated specifically with socially contextualised tactile grooming. The relationship between the EOS and bonding is formalised in the Brain Opioid Theory of Social Attachment (BOTSA).

Brain Opioid Theory of Social Attachment: opioids and bonding

BOTSA is based on evidence of behavioural and emotional similarities between those in intense relationships, and those addicted to narcotics and exogenous opiates (Insel, 2003; Panksepp, 1999). Addiction to relationships and dependence on opiates (such as morphine) involve a euphoric stage, where feelings of pleasure, liking, and gratification drive continued seeking of the stimulus (Machin & Dunbar, 2011). In this stage of addiction, rats and non-human primates display elevated self-administration of a stimulant (e.g. Koob, 1992), which is comparable to addiction behaviour in humans (e.g. Comings et al., 1999). Furthermore, attachment in intense relationships and opioid addiction can result in tolerance-habituation, and withdrawal if the source of dependence is removed (Liebowitz, 1983 c.f Machin & Dunbar, 2011). In summary, BOTSA highlights that both social attachment and exogenous opiates have similar neurophysiological effects, due to elevated levels of opioids in the brain (Nelson & Panksepp, 1998).

Accordingly, BOTSA predicts that social isolation will decrease levels of endogenous opioids, thereby inducing the animal to seek opioid stimulation (i.e. social interaction or exogenous opioid stimulant; Machin & Dunbar, 2011). Once achieved, the social interaction (or opiate fix) will result in a pleasant sense of gratification that acts as a reward (and thus motivation to sustain the activity: Depue & Morrone-Strupinsky, 2005). Beta-endorphins, which are implicated specifically in social contact and reward (Keverne et al., 1989) degrade quickly in vivo and therefore require the individual to continually engage socially in order to maintain levels of opioids. Opioid interventions have been used to experimentally test the predictions of BOTSA.

Opioid interventions and social behaviour

There are a multitude of (non-human) studies that report increased social activity and affiliative behaviours after administration of opioid antagonists (Fabre-Nys et al., 1982; Herman &

Panksepp, 1978; Kalin, Shelton, & Barksdale, 1988; Keverne et al., 1989; Martel et al., 1995; Warnick, McCurdy, & Sufka, 2005). These studies show that blocking opioid receptors causes individuals to seek more stimulation of positive affect (as the antagonist dampens their experience), thereby increasing engagement in social activities such as grooming (in non-human primates), which release endorphins. These results are supported by the fact that administration of an exogenous agonist causes individuals to reduce their demand for and engagement with opioid producing activities (e.g. monkeys: Keverne et al., 1989), limit the amount of time individuals spend in close vicinity to others (Herman & Panksepp, 1978; Panksepp, Najam, & Soares, 1979), and reduce separation stress behaviours, such as isolation calls (e.g. non-human animals: Panksepp, 1999). Overall it seems likely that exogenous opioids substitute the rewarding experience associated with social interactions such as grooming (Eisenberger, 2012).

However, it is important to highlight that opioid antagonists have also been recorded to have the same effect as agonists, i.e. to reduce rather than enhance affiliative behaviours. Martel et al. (1993), demonstrated that monkeys treated with beta-endorphin antagonists such as naloxone engage in *less* not more grooming, and in rats the same antagonist reduces social interaction (Dokla, 1992). It is likely that the incongruity in findings is due a combination of differences in the levels of endogenous opioids in the animal at the time, the pre-treatment social status and context, the dose of antagonist used, and the regularity of administration (Martel et al., 1995). For example, repeated doses of opioid antagonists can lead to an aversion to the administered drug (Martel et al., 1993; Meller et al., 1980), and the effect on social behaviour is likely to depend on whether the individual has existing social interactions with conspecifics and care-givers (Panksepp et al., 1980).

Despite some paradoxical evidence regarding the direction of effect associated with administration of an antagonist or agonist, these studies demonstrate that EOS activity is

associated with social behaviour. Although these studies are focussed on non-human animals, further evidence for BOTSA lies in similarities in the manner that social and physical pain are neurochemically processed in humans (Eisenberger, Lieberman, & Williams, 2003; Eisenberger & Lieberman, 2005; Macdonald & Leary, 2005; Panksepp, 1999). In order to explore this link, it is necessary to first review evidence regarding the role of the EOS in pain management.

The EOS and (physical) pain

The well-established role of the EOS in pain management is based on three main categories of evidence. Firstly, exogenous opioid agonists (such as morphine or opium) have strong analgesic effects (e.g. van Ree et al., 2000). Secondly, endogenous opioids (i.e. those which are produced by the brain, e.g. when exercising) are similarly associated with, among other things, analgesia and the attenuation of pain (Belluzzi & Stein, 1977; D'Amato & Pavone, 1993; Nelson & Panksepp, 1998; Stefano et al., 2000). Both endogenous and exogenous agonists activate a pain modulatory pathway, which acts at the spinal-cord level to inhibit pain transmission (Fields, 2007). Physiologically, pain tolerance is a function of opioid receptor availability. When opioids bind to receptors (mostly located in the insula and orbitofrontal cortex), this causes an analgesic effect (Mueller et al., 2010). The specific role of beta-endorphins in causing this analgesia was first established in mice (Loh, Tseng, Wei, & Li, 1976; Tseng, Loh, & Li, 1976), and subsequently in humans (e.g. Janal et al., 1984). Finally, opioid antagonists (such as naloxone and naltrexone) cause hyperalgesia (i.e. increased sensitivity to pain: e.g. D'Amato & Pavone, 1993; Janal et al., 1984), and can reverse the effects of placebo induced analgesia (Benedetti, 1996; Levine, Gordon, & Fields, 1979). These studies demonstrate the clear link between pain tolerance and opioids (Leknes & Tracey, 2008), and due to this link, pain threshold is an established operational definition of (and recognised proxy test for) endogenous opioids.

Endogenous opioids do not pass through the blood-brain barrier, and consequently direct measurement of endorphins requires either sampling spinal fluid via lumbar puncture (e.g. Dearman & Francis, 1983) or brain scans (e.g. Positron Emission Tomography (PET): Mueller et al., 2010), which are invasive and costly. Consequently, many studies interested in the EOS use pain tolerance as a proxy for opioid activity (Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Cogan, Cogan, Waltz, & McCue, 1987; Dunbar, Kaskatis, et al., 2012; Dunbar, Baron, et al., 2012; Jamner & Leigh, 1999; Machin & Dunbar, 2011; Zillmann, Rockwell, Schweitzer, & Sundar, 1993).

Similarities between social and physical pain

It has been suggested that the neurological correlates underpinning social attachment may be co-opted elements of the EOS's pain-management pathways (Eisenberger et al., 2003; Eisenberger & Lieberman, 2005; Macdonald & Leary, 2005; Panksepp, 1999), whereby separation elicits distress (or 'social pain'), and closeness provides pleasurable reward and comfort due to heightened opioid activity (Eisenberger, 2012; Panksepp, 1999). Social pain refers to the negative experience associated with one's perception of or actual loss of social connection and social value, and arises during situations of social rejection, loss, experience of exclusion or negative social evaluation (Eisenberger, 2012). Social pain reportedly results in somatic symptoms (e.g. Gudmundsdottir, 2009) and some experiments which manipulate the experience of social exclusion report activation in areas of the brain associated with sensory components of pain (posterior insular: e.g. Bolling et al., 2011; Bolling, Pelfrey, & Vander Wyk, 2012; Onoda et al., 2009). Based on this evidence, it can be argued that there is significant overlap between the neurological substrates of physical and social pain, providing further support for BOTSA.

Human social bonds: “grooming at a distance”

Whilst physical grooming offers a strong mechanism for establishing and maintaining primate social bonds (as discussed in ‘Primate grooming triggers the EOS, establishes and maintains social bonds’, pg. 21), it poses two limitations - grooming is generally a dyadic activity (i.e. involving two individuals at once), and the number of individuals one can groom in a day is limited by the amount of time that can be spared from other activities, such as foraging and sleeping (Dunbar, 1993). For humans to establish and maintain larger social groups, individuals would need to invest an excess of 40% of their day grooming (Dunbar, 1996). Evidently this time investment is unfeasible, and as a result, additional means for social bonding, and for “grooming at a distance” aid the establishment and maintenance of social bonds with a large number of individuals.

A number of different behaviours are likely to have helped humans establish social bonds with multiple individuals simultaneously, and to maintain those bonds with relatively little time investment. One hypothesis, which is the topic of the present thesis, is that bodily movement and synchronisation may have played (and continue to play) an important role in contributing to group cohesion and social bonding (Dunbar, 2009; Björn Merker et al., 2009; Reddish et al., 2013; Reddish, 2012; Wiltermuth & Heath, 2009). If these activities increase social bonds between more than two participants simultaneously, they would allow for participants to ‘groom at a distance’ and circumvent the need to rely predominantly on dyadic grooming in the formation and maintenance of social bonds.

I.4 Links between dance and social bonding

The antiquity and ubiquity of dance and music (as reviewed in ‘The scope of the thesis’, pg. 6) has led to the consideration that there are likely to be a range of explanations regarding how and why these behaviours originated and persisted in human culture. One such explanation is the social bonding hypothesis of music and dance, which postulates that these activities are effective tools in establishing and maintaining social bonds by increasing cooperation and prosocial behaviours between group members (Anshel & Kipper, 1988; Chanda & Levitin, 2013; Freeman, 2000; Huron, 2001; Kirschner & Tomasello, 2010; Kokal et al., 2011; McNeill, 1995; Reddish et al., 2013; Roederer, 1984). However, before reviewing the wealth of evidence in support of this hypothesis, it is important to acknowledge that the evolutionary history of music and dance remains contested, with on-going investigation into whether these abilities may have been shaped by selection, or if they simply reflect alternative uses of other, directly adaptive cognitive skills.

I.4.1 Theoretical explanations of the functions of dance

As a null model, it is hypothesised that music, dance and other arts are examples of non-adaptive pleasure seeking behaviours (Carroll, 1998; Pinker, 1997), and therefore are merely side effects of traits that evolved for other functions. This hypothesis is based on assumptions that 1) musicality and dance currently offer no directly selected survival benefits to humans; and 2) the traits involved in the performance and appreciation of these activities exploit one or more existing pleasure channels that are linked to other adaptive traits. Consequently, the null model postulates that any ubiquity of music and dance is based on this above mentioned exploitation or, alternatively, non-evolutionary processes of enculturation. These assumptions conflate ‘non-

adaptive’ with ‘non-evolutionary’², as well as present-day adaptive benefits with those that may have existed at the origin of musicality and dance. In addition, while it is likely that musicality and dance did, and/or still do, exploit adaptively-selected pleasure channels, this does not preclude the possibility of viable evolutionary functions at the time of their origin.

Adaptationist hypotheses regarding our aptitude for music and dance draw on the fact that these activities involve expending large amounts of energy, and that their persistence through time and presence cross-culturally are likely due to some associated benefit (Huron, 2001). Possible explanations range from sexual selection benefits (e.g. Miller 2000, Merker 2000) to the fitness benefits afforded by group musical and dance activities, such as fostering the ability to better improvise, communicate, signal coalitions (e.g. Hagen & Bryant, 2003) and bond socially (e.g. Huron 2001).

Dance ability as a sexually selected trait

The role of music and dance activities in sexual selection and courtship was first proposed by Darwin (1871), who suggested that musical and synchronous abilities may have evolved as a mechanism to attract mates. A variety of species use synchronised display in order to attract females, for example fireflies, fiddler crabs, katydid, frogs (for a review see: Greenfield, 1994; Murai & Backwell, 2006). The synchronisation of movement in time and space is believed to be central in successfully attracting mates in these circumstances (Backwell, Jennions, & Passmore, 1998; Moiseff & Copeland, 2010). Evidence from humans suggests that females prefer males who are good dancers (Neave et al., 2011), and, particularly in men, dance ability appears to act as an ‘honest’ signal of a good quality genotype (e.g. as measured by finger-length ratio, which is

² A confusion which is based on the inappropriate assumption that valid evolutionary explanations are exclusively identifiable by current and direct adaptive traits.

influenced by testosterone levels and considered a signal of masculinity and attractiveness: Fink, Seydel, Manning, & Kappeler, 2007) and phenotype (e.g. physical strength: Hugill, Fink, Neave, & Seydel, 2009). Furthermore, if a female is attracted to a male, this is associated with nonverbal patterns of body synchronisation (Grammer et al., 1998). Whilst these results suggest clear potential for music and dance to act as methods to display mate quality, musical and dance synchrony are evidently not limited to only males of reproductive age (see Brown, 2000 for a critique), nor does the sexual selection hypothesis help to explain the widespread performance of synchronised music and dance performance in groups (e.g. Hagen & Bryant, 2003). Furthermore, it is possible for sexual selection to act as a secondary pressure for the development of expertise in any skilled behaviour. The selection of good dancers as preferred mates can only occur once the behaviour already exists. Consequently, musicality and the ability to dance may have first emerged for some other reason, but subsequently these abilities became relevant in mate choice. An additional explanation regarding the widespread nature of music and dance is that it acted as a coalition signalling system.

Dance/music as a mechanism for signalling coalition

Merker (2000) suggested that music had evolved as a display signal, whereby synchronous chorusing/dance could act as a signal of coalition strength or internal stability. Hagen and Bryant (2003) furthered this theory by highlighting that the group's ability to organise itself to act collectively would serve as an indicator of internal stability, which would help to defend territories and signal group cohesion to other groups. Whilst the group display theory is compatible with the sexual selection hypothesis (as reviewed, synchronous displays may well have also served to attract migrating females: Merker, 2000), it is unclear how such a signalling system may have originated in the first place. For example, as pointed out by Kirschner and Tomasello (2010), participation in

group displays does not necessarily require an honest signal of coalition (and free-riders would be difficult to police). Consequently, it is more likely that any coalition signalling system may have acted as a secondary, proximate or partial explanation for the widespread nature of music and dance.

1.4.2 Evidence linking dance and social bonding

An alternative hypothesis suggests that dance and music may have been selected for by the fact that these activities foster cooperation, build and maintain social bonds (Anshel & Kipper, 1988; Chanda & Levitin, 2013; Dunbar, 2012b; Freeman, 2000; Huron, 2001; Kirschner & Tomasello, 2010; Kokal et al., 2011; McNeill, 1995; Reddish et al., 2013; Roederer, 1984). It is argued that ritualised group music and dance activities may serve several social functions all falling under the broad umbrella of the social bonding hypothesis, including the fostering of social contact, social cognition, homogenous emotions, communication, coordination, cooperation, and group cohesion (Koelsch, 2014).

Firstly, many music-based activities are generally social (Nettl, 1983), and engaging with music involves making some form of contact with others. Koelsch (2014) further argues that engaging with music itself and, for example, attempting to imagine the composer's intentions, fosters social cognition (broadly inferred as being the ability to ascribe mental states to others: Frith & Frith, 2007). The link between music and social cognition is an important feature of some Autism Spectrum Disorder (ASD) therapies (e.g. Allen & Heaton, 2010), as people with ASD appear better at perceiving music-based emotions and social cues despite limited non-musical social cognition skills (e.g. Caria, Venuti, & de Falco, 2011). Furthermore, it is argued that engaging in musical activities with others can homogenise participants' emotional states (Brown & Volgsten,

2006; Koelsch, 2014), which may decrease social conflict and increase cohesion (Cross & Morley, 2008; Huron, 2001).

Finally, Koelsch (2014) highlights that music-based group activities demand some degree of coordination of actions and cooperation in terms of establishing a shared goal and shared intention (with experimental evidence provided by: Reddish et al., 2013). Whilst these activities are themselves a signal of affiliation to some extent, engaging in coordinated, specifically synchronised, activities increases, *inter alia*, inter-personal trust (Launay et al., 2013), feelings of affiliation (Hove & Risen, 2009), connectedness (Wiltermuth & Heath, 2009), rapport (Miles et al., 2009) and cooperative behaviour (Reddish et al., 2013; Wiltermuth & Heath, 2009). Synchronisation has been linked to two (thus far independently investigated) mechanisms which may contribute to the social bonding effects of dance: action-perception networks facilitating a merged sense of ‘self’ and ‘other’, and activation of the EOS (which releases endorphins) during exertive synchronous movement. Evidence in support of these mechanisms are reviewed in the following sections.

1.4.3 Mechanisms by which dance might foster social bonds

In order to review the evidence supporting social bonding hypothesis of music and dance, I will first explore the link between synchrony and bonding, and subsequently the evidence that physical exertion and activation of the EOS also fosters social bonding. For the former mechanism, I begin with a review of the theoretical links from synchronisation to affiliative feelings and behaviours and the mechanism of ‘self-other merging’, which is thought to underpin the bonding that arises when individuals perceive the similar actions of others. Following this, I review experimental evidence that demonstrates a causal link between synchrony and bonding. The majority of these studies were conducted on dyads, with an isochronous metronome beat to establish synchrony, and only a small number of studies have tested the bonding effects of

synchrony in larger groups (>2 participants), and where music has been used rather than a metronome. Finally, I will review the evidence for EOS activation in music-based activities, as an additional explanation for how prosocial tendencies might arise in situations of synchrony.

Literature relating to synchrony and social bonding

Synchronisation is often cited as an important mechanism by which bonding can occur (Hove & Risen, 2009; Launay et al., 2013; Valdesolo & Desteno, 2011; Wiltermuth & Heath, 2009). The expectation that synchrony is a mechanism of inducing bonding builds in part on an identified association between mimicry and affiliative behaviour (e.g. LaFrance & Broadbent, 1976; LaFrance, 1979). For an extensive review on mimicry refer to Chartrand & Van Baaren (2009), but in summary, mimicry improves rapport between people (Chartrand & Bargh, 1999; Lakin & Chartrand, 2003), which in turn influences the amount of mimicry that people perform (Stel et al., 2010; van Baaren, Holland, Kawakami, & van Knippenberg, 2004), thereby causing a positive feedback loop. Given that synchronisation is similar to mimicry, but involves temporally matched movements and the prediction of the movements of co-actors, it is likely to have similar, if not more pronounced effects on bonding.

Unintentional synchrony can be used (unconsciously) as a tool to establish inter-personal rapport and affiliation (Kendon, 1970). For example, there is a strong correlation between rapport and degree of synchrony in natural conversations (Bernieri, 1988), and those with prosocial tendencies exhibit more spontaneous synchronisation than those with proself (i.e. self directed) tendencies (Lumsden, Miles, Richardson, Smith, & Macrae, 2012). Furthermore, the desirability of a partner can influence whether synchrony occurs, with participants synchronising less with a partner who arrived late to the experiment (Miles et al., 2010). Individuals are also more likely to spontaneously synchronise with another participant if they perceive them as belonging to the same

(arbitrarily defined) group as themselves (Miles, Lumsden, Richardson, & Neil Macrae, 2011).

These studies suggest that synchronising is a social behaviour, rather than an automatic motor process. Perception of synchrony is also interpreted as a signal of rapport for both basic sounds (e.g. sound of people walking together: Lakens & Stel, 2011; Miles et al., 2009) and more complex musical stimuli (Hagen & Bryant, 2003). Miles et al. (2009) demonstrated that participants perceive stable forms of walking synchrony (in-phase and anti-phase) as indicative of higher degree of interpersonal closeness. As such, synchrony is both a signal of, and tool for establishing, social bonds.

Agent-driven sounds, and the associated perception of movement of another person, engage motor regions in the listener's brain (Launay, in press.), potentially resulting in 'self-other merging', which has been argued to arise when individuals experience their movement simultaneously with another's. In cases of both mimicry and interpersonal synchrony, shared action-perception circuits are thought to underlie this self-other merging effect (Chartrand & van Baaren, 2009; Hove, 2008), resulting in an inclination to act prosocially towards others.

Self-other merging: a mechanism for synchrony-induced social bonding

When we move at the same time as others we experience a degree of co-activation of motor networks related to the act of performing the movement, and networks related to perceiving the actions of another (e.g. Overy and Molnar-Szakacs, 2009). The link between these action and perception networks is well researched (Aziz-Zadeh et al., 2002; Buccino et al., 2001, 2004; Caetano et al., 2007; Fadiga et al., 2002, 1995; Rizzolatti, 2005; Watkins et al., 2003), and in macaques has culminated in the identification of 'mirror neurons' (Gallese et al., 1996; Rizzolatti et al., 1996). These mirror-neurons selectively respond to the macaque's own movement as well as perception of similar, goal-directed movements of others (e.g. reaching for and grasping an object:

Rizzolatti et al., 1988). Although presence of such a system in humans has been a subject of widespread debate (Gallese, Gernsbacher, Heyes, Hickok, & Iacoboni, 2011), essentially there is no evidence that we have neurons with the equivalent degree of selectivity (Hickok, 2009).

Nevertheless, this research does highlight how perception of another individual's goal-directed movement can engage regions of the brain related to making similar movements (Rizzolatti, 2005).

It is well recognised that perceiving the actions of another person can lead to activation of the same neural motor networks required to perform those actions oneself (e.g. Fadiga et al., 1995).

When performing matched movements with another, the difference between perceived movement of another person and enacted movements of self becomes less clear. In this event, it is possible that the intrinsic (self) and extrinsic (other) engagement of neural action-perception networks make it difficult to distinguish between self and perceived other, thereby creating an ephemeral bond between the two actors (Decety and Sommerville, 2003; Knoblich and Sebanz, 2008; Marsh et al., 2009; Overy and Molnar-Szakacs, 2009; Sebanz et al., 2006; Sommerville and Decety, 2006).

This transient 'merging' between a sense of self and other is demonstrated by the well-known rubber hand illusion (Botvinick and Cohen, 1998). In this experiment, a participant's arm is hidden from sight and a replacement rubber arm is visible where his or her own arm is expected. While they view the rubber hand being touched with a paintbrush, their own (hidden) hand is simultaneously touched with a paintbrush, with synchronised strokes. This matching of visual and tactile input leads to an increased subjective sensation that the rubber hand is in fact part of the participants' body. The effect disappears when the two inputs are not synchronised. This provides evidence that self-other blurring can occur even with an inanimate object (although granted the object mimics a human hand in form). Some aspects of this effect are likely to apply to

interpersonal synchronised interaction, particularly when both actors are performing identical movements matched in time. Indeed, behavioural synchrony has been demonstrated to cause shared neural signatures between interacting actors (Dumas et al., 2010; Oullier et al., 2005; Tognoli et al., 2007; Lindenberger et al., 2009), although this evidence should be interpreted conservatively as it can only indicate that similar neurological networks are involved in making the same movements for different individuals.

Experimental evidence linking synchrony and social bonding

Evidence that synchronisation between people can influence their subsequent positive social feelings towards one another has been established in a number of experimental studies. For example, Hove and Risen (2009), demonstrated that synchronous tapping (frequency-locked in-phase synchrony specifically) between a participant and experimenter increased how much the participant liked the experimenter, compared to an asynchronous (where participant and experimenter tapped at different frequencies) and alone condition. Tapping in synchrony not only increases positive feelings towards another individual, but also prosocial behaviour. Valdesolo & Desteno (2011) demonstrated that synchronised tapping was associated with more willingness to help (and invest more time in helping) a fellow participant, as well as rating that participant as more likable and similar to themselves following synchronisation. This demonstrates the capacity for synchrony to influence both feelings of closeness, and behaviours.

Even synchronising with virtual partners (i.e. visible only on a computer) can have a positive affect on interpersonal bonding. Launay et al. (2013) used a virtual inter-personal tapping paradigm to test the effect of synchrony on trust. In this study, participants tapped on a drum whilst listening to rhythmic woodblock beats over headphones, matched with visual feedback provided on a computer screen. Participants were either told to synchronise their tapping with the

audio-visual stimuli, or to produce their own rhythmic tapping that was not synchronised. Launay et al. (2013) reported that perception of synchrony and self-reported success measures predicted how much participants trusted their virtual partner.

Whilst the studies by Launay et al. (2013), Valdesolo and Desteno (2011) and Hove and Risen (2009), demonstrate a link between synchronised tapping between dyads, and elements of social bonding, the social bonding hypothesis of dance demands evidence relating to audio-visual feedback in groups of more than two participants, and with musical stimuli rather than metronome/ single drumbeats.

Audio-visual feedback during synchrony

Importantly, it has been demonstrated that the effects of interpersonal synchrony observed in these experiments are likely due to the actual act of synchronising with others, rather than the sensation of being in synchrony (with an auditory beat: Hove & Risen, 2009). However, the relative role of visual and auditory cues in establishing synchronisation (and thereby affecting interpersonal bonding effects) is debated. Some experiments have demonstrated that visual cues are key (e.g. Demos et al., 2012; Richardson & Marsh, 2005), whereas others indicate that auditory feedback is more likely to induce unintended synchrony (e.g. Kokal et al., 2011; Launay, Dean, & Bailes, 2014; Zivotofsky & Hausdorff, 2007). Contradictions in the literature are likely due to the manner with which the experiments were executed. For example, in Demos et al. (2012), unintentional synchronisation was measured using the stimuli of visible movement of another participant versus music (the auditory-only stimuli). In this scenario, it is likely that the results were confounded by varying degrees of agency associated with the different stimuli (i.e. the visual condition was evidently more clearly agency driven). Indeed, the source, context and agency associated with the rhythms to which individuals are synchronising are paramount.

The importance of source, context and agency

Various social cues determined by the context of the experiment affect whether synchronisation occurs. Miles et al. (2010), demonstrated that social representation influences unintentional synchronisation in the previously mentioned study where confederates arrived late. Furthermore, in an experiment using different coloured stickers to represent ‘social group’ status (where groups were delineated according to artistic tastes), participants synchronised more with (videos of) those in a different social group, than those with the same coloured sticker (i.e. same “social group”: Miles et al., 2011). This result was interpreted as indicating that synchrony appears to reflect a desire to affiliate and reduce intergroup differences (Miles et al., 2011).

In terms of agency, Kirschner and Tomasello (2009) demonstrated that children’s synchronisation with a beat is improved in the presence of a person compared to when interacting solely with an isochronously beating drum. This suggests that from a young age, the awareness of agency related to perceived sound (and belief that the sound is produced by the intentional movements of another person) encourages synchronisation with that sound thereby likely influencing the social bonding effects of musical activities.

Researchers who argue that self-other merging is an important part of the bonding effects of synchronisation have primarily undertaken dyadic experiments in which participants’ actions are perceived to occur at the same time as one another. Theoretically, dyads are capable of achieving synchrony with relative ease simply because there is only one other person to keep track of. As such, synchrony is reasonably attainable, and associated self-other merging (and bonding effects) are likely to be achieved fairly easily.

Musical activities, on the other hand, are not limited to one-on-one interactions, and have historically involved groups (Nettl, 2000, 1983). With large numbers of people, it is difficult to

simultaneously observe the movements of all the other participants, making self-other merging a less likely prospect. Rhythm provides an external, predictable scaffolding that can facilitate synchrony with both music, and by extension, aids synchrony with the surrounding individuals engaging in the same musical experience.

Whilst these studies highlight that social context is important in determining the effects of synchrony, only a handful of studies have investigated these effects in groups of more than two people.

Group synchrony and social bonding

Wiltermuth and Heath (2009) demonstrated that walking in synchrony in a group is associated with both increased liking (and other self-report measures of prosociality), as well as strategy in the weak link coordination game, a behavioural prosociality measure. Participants (in groups of three) were told to either walk in synchrony around a campus, or just to walk normally without any synchrony. Participants then played a game that tested their cooperation over six rounds in a weak-link coordination game, a variation of a public goods or stag hunt game in which participants choose whether to cooperate or defect on some collective goal (for a general review see: Camerer, 2003). According to their results, participants who walked in synchrony on average chose higher numbers to contribute to the public good, compared to those that had not walked in synchrony. In addition to this willingness to cooperate, those primed by synchrony also scored higher on self-report ratings of connectedness and trust towards other testing group members.

In a recent set of experiments, Reddish et al. (2013) investigated the effects of shared intentionality in promoting cooperation following group synchrony. Participants (in groups of four) performed three simple movements in time to a metronome beat relayed through

headphones. In the synchrony condition, all participants heard the same metronome beat, whereas in the asynchrony condition each participant's metronome beat differed by 5bpm from the other participants. The synchrony and shared goal condition involved participants being instructed to work together to keep in time, and no metronome beat was provided. The results indicated that synchrony in combination with explicit shared intentionality (i.e. instructions to synchronise) resulted in the greatest level of cooperation, compared to conditions where synchrony was a by-product of hearing the same rhythmic beats (through headphones), or an asynchrony condition. This result was confirmed in a follow up experiment where participants who worked together to create synchrony were significantly more cooperative towards each other compared to those who worked together to create asynchrony (Reddish et al., 2013).

These experiments demonstrate that the bonding effects of synchrony evident in dyads is also present in small groups of participants moving in time to a metronome. However, as described in 'Dance to music, rather than a metronome' (pg. 12), differences between a metronome beat and music suggest that an investigation into the social bonding effect of dance should involve movement to music, rather than a metronome. The importance of bonding following interpersonal synchrony to music (and not just synchrony itself) was highlighted in a study by Demos et al. (2012). In this experiment, pairs of participants rocked on rocking chairs, either with music playing in the room, or no music. They found that self-reported rapport between co-actors correlated with synchronisation achieved with the *music*, but rapport did not correlate with synchronisation that occurred between co-actors. This implies that externalising the target of synchrony (e.g. to music) allows bonding with a partner, in the absence of explicit synchrony between those people. This finding has important implications given that group musical activities often involve non-identical movements between people, but furthermore it highlights how there is something about music, not just rhythmic movement, that is likely to be important in interpersonal bonding during dance.

Synchronising to music

Experimentally, there is some evidence that music-based activities induce social bonding (e.g. the effect of group singing (versus passive music listening, watching a movie or reading poetry) on trust and cooperation: Anshel & Kipper, 1988), but only a handful of studies have specifically investigated the role of synchrony (Kirschner & Tomasello, 2009, 2010; Wiltermuth & Heath, 2009).

In addition to their walking experiment, Wiltermuth and Heath (2009), manipulated singing, movement, and synchrony (through the use of headphones). In the singing condition, participants (in groups of three) sang an ‘out-group’ national anthem (the participants were American, but sang the Canadian anthem to a recording). In the movement and singing condition, participants sang the same song, and simultaneously held a cup and waved it rhythmically to the song. Synchrony between participants was manipulated using headphones which provided cues for the singing and movement. In the synchronous condition, all participants heard the same version of the song through their headphones, and in the asynchronous condition each participant heard (and therefore sang and moved to) different versions of the song, each of which had a different tempo. A no singing and no movement condition was included as a control. Here participants held their cup stationary and mentally read the anthems lyrics while listening to the song through their headphones. Wiltermuth & Heath (2009) found that synchrony (with or without movement) led to more cooperative behaviour, compared to those in the asynchrony or the control condition. In this experiment, cooperation was determined using various self-report questions (of trust, connectedness, how much they felt on a team with the other participants), as well as behavioural measure in the form of a weak link coordination game, and public goods game.

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However, the use of a national anthem in the study by Wiltermuth and Heath (2009), may have influenced the social bonding experienced by participants. National anthems are emotionally arousing due to the fact that they evoke semantic association (i.e. activate meaningful concepts that prime an emotional response: Juslin & Västfjäll, 2008). The lyrics of the anthem used in Wiltermuth and Heath (2009) include words like “we” and “our”, which can induce priming of collective identity (Greitemeyer, 2009; Oyserman & Lee, 2008). Kirschner and Tomasello (2010) avoided this possible confound, by investigating synchrony-induced bonding during music-based activities using a song that was not a national anthem.

Kirschner & Tomasello (2010) investigated whether children cooperated more with each other following a shared musical task or a non-musical task. In the musical condition, two children sang, danced and played musical instruments in time with background music (and were guided by an experimenter, resulting in a group of three people). The non-musical tasks involved no background music, walking (rather than dancing) and spoken lyrics rather than sung. Furthermore, the children held the same instruments as used in the musical condition, but moved them in a non-rhythmical fashion and did not use the instruments to create sound. Prosocial effects were determined using a measure of spontaneous cooperation (on a task that could be solved individually or jointly), and helpfulness (in coming to the aid of another child who accidentally spilled marbles). On both measures, children in the musical condition acted more prosocially.

The various experimental studies reviewed above indicate that interpersonal synchrony (including in the context of music-based activities, and in groups) fosters prosocial tendencies between participants. The study by Kirschner & Tomasello (2010) provides the most ecologically valid (i.e. most similar to what dance is really like) exploration into these effects, among children. The present thesis aims to contribute further evidence regarding the link between dance and social

bonding, with older children and adults as the focus, and groups of three or four moving to music, as explored in greater detail in ‘Contribution of this thesis’ (pg. 52). In addition, given the role of the EOS in social bonding in other species (as reviewed in ‘Mechanisms of social bonding: The EOS’, pg. 20), this thesis aims to investigate whether dance may encourage social bonding amongst co-actors by stimulating the production of endorphins.

Literature relating the EOS to social bonding in humans

In order to review the reasons why it is plausible to hypothesise that endorphins might be involved in the social bonding that arises during dance, I begin by reviewing the various other activities that activate the EOS in humans, and the evidence that the EOS is activated during music-based activities (both passive listening and active performance).

What activates the EOS in humans?

In humans, EOS activation (as measured by pain threshold) occurs in response to low levels of muscular and psychological stress (Howlett et al., 1984), for example during exercise (Harbach et al., 2000). PET scans have confirmed the euphoric state that follows exercise (termed ‘runner’s high’) is due to endogenous opioids (Boecker et al., 2008). Exercise is associated with an enhanced sense of well-being and analgesia (Belluzzi & Stein, 1977; Janal et al., 1984; Nelson & Panksepp, 1998; Stefano et al., 2000), stress reduction (Boecker et al., 2008), anxiolysis (Morgan, 1985), and elevated mood (Janal et al., 1984; Wildmann, Krüger, Schmole, Niemann, & Matthaei, 1986). Although there is evidence that the positive affective, analgesic and euphoric high associated with exercise is not due to endorphins alone (e.g. Dietrich & McDaniel, 2004; Sparling, Giuffrida, Piomelli, Roszkopf, & Dietrich, 2003), the attribution of these effects to endorphins is well substantiated (Boecker et al., 2008; Daniel, Martin, & Carter, 1992; Dishman & O’Connor, 2009;

Goldfarb, Hatfield, Sforzo, & Flynn, 1987; Harbach et al., 2000; Howlett et al., 1984; Janal et al., 1984; Markoff, Ryan, & Young, 1982; Radosevich et al., 1989; Thoren, Floras, Hoffmann, & Seals, 1990; Wildmann et al., 1986).

In addition to the effect of exercise on EOS activation, various other exertive human social bonding activities are also associated with elevated endorphin levels (as measured by pain threshold). For example, laughter (Dezecache & Dunbar, 2012; Dunbar, Baron, et al., 2012), group exercise (Sullivan, Rickers, Gagnon, Gammage, & Peters, 2011), synchronised sport (Cohen et al., 2010; Sullivan et al., 2014; Sullivan & Rickers, 2013), singing and dance (Dunbar, Kaskatis, et al., 2012), all appear to trigger endorphin release.

In a study comparing pain threshold increases for individual treadmill runners versus those running simultaneously with two other people, Sullivan et al. (2011) demonstrated that the social condition (i.e. running with others) was associated with higher levels of endorphin release. These results suggest that whilst exercising activates the EOS, exercising in the presence of others has a more profound effect on endorphin release. Interestingly, group *synchronised* exertive activity (such as rowing) elevates pain thresholds significantly more than alone, non-synchronised exertion (Cohen et al., 2010; Sullivan & Rickers, 2013), suggesting that in addition to the role of exertion in activating the EOS, and the presence of other individuals, synchrony itself might also be a significant factor in elevating pain threshold.

In their study on rowers, Cohen et al. (2010) used a within-subject design to compare the pain threshold of team-mates when rowing alone (unsynchronised condition) versus when rowing in synchrony (in-phase) with five other team-mates (synchronised condition). Power output (i.e. exertion) did not differ between conditions, but when rowing in the group synchrony condition, participants had significantly elevated pain threshold (measured through ischaemic pain induced by

inflating a blood pressure cuff on the upper arm). Given the strong relationship between endorphins and pain (as reviewed in ‘The EOS and (physical) pain’, pg. 26), it was concluded that those rowing in synchrony experienced elevated endorphins, independent of exertion (Cohen et al., 2010). Considering that coordinated physical exercise is associated with a heightened sense of social bonding (Durkheim, 1915; McNeill, 1995; Mueller, Agamanolis, & Picard, 2003), the rowing study indicates that the bonding that arises during synchronised exercise (such as rowing) is likely to be due to elevated endorphin release (Cohen et al., 2010).

However, the findings reported by Cohen et al. (2010) may have been confounded by the effect of familiarity between participants, as teammates are likely to already be socially close by virtue of knowing each other for some time. As reviewed in ‘Literature relating to synchrony and social bonding’ (pg. 34), individuals with an already existing degree of rapport are more inclined to synchronise with each other. In order to determine if the effect of synchrony on elevated pain thresholds was specific to intra-teammate effects, Sullivan & Rickers (2013) replicated the rowing study and contrasted the effects of stranger versus teammates rowing in synchrony. They reported that there was no significant difference between the two conditions, indicating that the effect of synchrony on elevated endorphin release is not limited to groups of people with pre-existing social bonds, but rather the act of synchronising specifically (Sullivan & Rickers, 2013).

However, these studies did not directly compare synchrony to a social unsynchronised condition, merely an alone condition where there was neither a social nor synchronised element. In order to determine if synchrony or the social presence of others was key in the findings reported by Cohen et al. (2010) and Sullivan & Rickers (2013), a follow-up study contrasted pairs of participants rowing in different phases of synchrony (Sullivan et al., 2014). In this within-subject study, participants rowed alone, in phase-locked synchrony with another participant (replicating the

synchrony condition of the earlier rowing studies) and in an anti-phase synchrony condition. The latter involved participants maintaining the same rowing rhythm, but participants were at opposite points of the movement cycle at any one time (for a comprehensive description of anti-phase synchrony see: Miles et al., 2011). They found that pain threshold increase was significantly higher when participants rowed in synchrony compared to either the alone or anti-phase synchronised conditions (Sullivan et al., 2014).

Key in these studies is the fact that synchrony is based on rhythmic, sustained movement. If rhythmic synchrony has a significant effect on endorphin release, a logical hypothesis is that activities involving music may be particularly well suited to activating the EOS, and by extension influencing social bonding. In the following section, I review the evidence linking music (passive listening and active engagement) and EOS activation.

Evidence that the EOS is important in music-based activities

The majority of evidence regarding the activation of the EOS through music is based on investigation into the effects of passive listening (for a summary of the relevant literature see Table 1.1). Listening to music reportedly helps to manage pre-operative hypertension and psychological stress (Allen et al., 2001), reduces sedative requirements during spinal anaesthesia (Lepage, Drolet, Girard, Grenier, & De Gagné, 2001) and other surgical procedures (Koch, Kain, Ayoub, & Rosenbaum, 1998), decreases perception of pain (Good et al., 2001; U Nilsson, Rawal, Enqvist, & Unosson, 2003) thereby diminishing the need for opioid agonists following operative care (Bernatzky, Presch, Anderson, & Panksepp, 2011; Cepeda, Carr, Lau, & Alvarez, 2006), and improving post-operative recovery (U Nilsson, Rawal, Uneståhl, Zetterberg, & Unosson, 2001). Many of the experiments in this area directly attribute these results to the EOS, and given the strong role of opioid receptor activation in analgesia (Leknes & Tracey, 2008), the body of work

linking music and pain may generally be considered convincing evidence of the role of opioid activation.

Table 1.1 Summary of studies providing evidence for the role of EOS in music related activities.

	Passive listening	Active performance
Pain threshold, pain management	Post-operative pain: (K. Allen et al., 2001; Bernatzky et al., 2011; Good et al., 2001; Koch et al., 1998; Lepage et al., 2001; U Nilsson et al., 2003, 2001; Ulrica Nilsson, 2008)(for a review see Cepeda et al., 2006)	Singing, drumming, dance: (Dunbar, Kaskatis, et al., 2012)
Brain activation regions	EOS, pleasure and reward circuits: (Blood & Zatorre, 2001; Menon & Levitin, 2005; Stefano, Zhu, Cadet, Salamon, & Mantione, 2004) NAcc and pleasure states: (Koelsch, 2014)	
Emotions and mood	Techno-music: (Gerra et al., 1998) Emotional effects of music: (Koelsch, 2010) Positive affect: (Huron, 2006)	Increased positive affect: (Dunbar, Kaskatis, et al., 2012) Enhanced mood: (Fritz, Halfpaap, Grahl, Kirkland, & Villringer, 2013)
Health	Lower blood pressure and relaxation: (Chiu & Kumar, 2003; Stefano et al., 2004) Anxiolytic music: (McKinney, Tims, Kumar, & Kumar, 1997)	
Other	Musical ‘trills’: (Goldstein, 1980; Menon & Levitin, 2005; Panksepp, 1995) Opiate receptor expression in response to relaxed music: (Stefano et al., 2004)	Perception of exertion and desire to exert oneself: (Fritz, Hardikar, et al., 2013)

PET and functional Magnetic Resonance Imaging (fMRI) data also provide evidence that passive listening to music activates the EOS, and areas linked with pleasure and reward (e.g. Blood

& Zatorre, 2001). For example, recent evidence that music listening is associated with activation in areas such as the NAcc (Brown, Martinez, & Parsons, 2004; Koelsch, 2014; Menon & Levitin, 2005), the high number of opioid receptors in this region (Fields, 2007; Trigo et al., 2010) and the role of opioids in mood and pleasure states (Berridge & Kringelbach, 2008) support the action of the EOS in music listening.

The importance of the EOS in regulating affective experiences in response to music (Zubieta et al., 2003) is further supported by evidence linking music induced ‘thrills’ to endorphin activation (Goldstein, 1980), and the EOS’s association with reward circuits (Menon & Levitin, 2005). In addition, the sense of elation that arises when engaging in musical activities has been attributed to endorphin release (Chiu & Kumar, 2003; Dunbar, 2009; Huron, 2006). Calming music is thought to act via the EOS by buffering the effect of stressful events (see McKinney, Tims, et al., 1997 for a review), and relaxation following music-listening is also linked to the EOS (Stefano et al., 2004). Gerra et al. (1998) report that listening to techno-music significantly changes emotional states (and increases beta-endorphin levels), due to its strong rhythmic beat and engagement of motor regions of the brain. Activation of the EOS, and its role in various affective, calming and analgesic effects, is therefore evident in cases of passive music listening, although a systematic investigation of this effect is still lacking.

It is important to note that there is also some evidence indicating that neurohormones other than endorphins are involved during music-based activities (e.g. Bachner-Melman et al., 2005; Chanda & Levitin, 2013; Grape, Sandgren, Hansson, Ericson, & Theorell, 2003). In a recent review, Chanda and Levitin (2013) highlight evidence suggesting that stress and arousal effects associated with music-based activities can be linked to cortisol, corticotrophin-releasing hormone and adrenocorticotrophic hormone (e.g. Gerra et al., 1998; McKinney, Antoni, Kumar, Rims, &

McCabe, 1997). Various immunity benefits of music have been attributed to, among other things, cortisol (e.g. Beck, Cesario, Yousefi, & Enamoto, 2000; Kuhn, 2002), cytokinin (e.g. Stefano et al., 2004), and growth hormones (e.g. Gerra et al., 1998). Finally, dopamine is key in reward and motivation circuits during musical activities (e.g. Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011), which are likely to interact synergistically with the EOS in mediating the pleasure states associated with music (Chanda & Levitin, 2013).

Based on the association between exertion and endorphin release (as reviewed in ‘What activates the EOS in humans?’, pg. 44), a handful of studies have investigated the effect of active engagement in musical activities on the EOS (see Table 1.1 for a summary). For example, in a recent set of studies, exercise machines were linked to musical output software such that individuals ‘created’ music as they exerted themselves (Fritz, Halfpaap, et al., 2013; Fritz, Hardikar, et al., 2013). These experiments demonstrated that when movement (during group exercise) results in musical feedback, participants perceived exertion to be lower (Fritz, Hardikar, et al., 2013), reported enhanced mood, and felt a greater desire to exert themselves further (Fritz, Halfpaap, et al., 2013), in comparison to when they were exercising whilst listening (passively) to independently provided music. In these studies, improved mood and effects on perception of exertion were interpreted as evidence for activation of the EOS (substantiated by the evidence of mood effects associated with ‘runner’s high’, pg. 44). According to these results, musical agency (i.e. perception of a relationship between purposeful movement and sounds that are being produced) is associated with greater endorphin activation, and therefore greater effects in terms of mood and ability to withstand strenuous exercise.

Considering that the ability to record and store music separate from its source (to be played back later and at a different location) is a very recent technology, it is not surprising that we are

well attuned to scenarios where movement is directly linked to musical feedback, as demonstrated in the studies by Fritz et al. (2013). Furthermore, the results from these studies are in accordance with the well established link between music and movement (as reviewed in ‘Coupled concepts: music and dance’, pg. 13). The authors speculate that exercising in the presence of music may have some (though limited) effects on EOS activation due to the fact that people spontaneously synchronise to music (e.g. Large, Fink, & Kelso, 2002; Snyder & Krumhansl, 2001), and that synchronising may create an ‘illusion of agency’ (Fritz, Halfpaap, et al., 2013; Fritz, Hardikar, et al., 2013). However, these studies did not specifically manipulate synchrony. Furthermore the absence of a no-music control condition, or an actual measure of endorphins (such as pain threshold), was lacking from the studies by Fritz et al., but were included in a series of studies conducted by Dunbar, Kaskatis et al. (2012).

Dunbar, Kaskatis et al. (2012) contrasted the pain threshold increase experienced by those in active music conditions to no-music and passive (listening) music conditions. Participation in a charismatic Christian meeting (which involved communal singing, accompanied by clapping and upper body movement) resulted in significantly higher pain threshold increases compared to participation in an Anglican prayer group (in which there was no music or singing: Dunbar, Kaskatis, et al., 2012). In a follow-up experiment, they demonstrated that actively taking part in a samba drumming circle similarly had a significant positive effect on pain threshold (compared to people passively listening to music or watching a speech-only video of a lecture). Active dancing (in street and pop dance classes, and Capoeira classes) resulted in an almost significantly larger increase in pain threshold compared to the control condition of an orchestra-participation (and the lack of significance was attributed to the less reliable method of measuring pain - an ice test). In a final study, listening to music of different tempos were compared, but neither high nor low tempo music listening resulted in the elevated pain thresholds recorded for the active conditions. Their

experiments also highlighted that the active music conditions were associated with a significantly higher increase in positive affect and mood, compared to the control activities, although there was no such effect on negative affect scores (Dunbar, Kaskatis, et al., 2012).

In conclusion, these studies provide prima facie evidence suggesting that active engagement in music-based activities is key when it comes to endorphin release. However, missing from these experiments are actual measures of social bonding. The effect of synchronisation on social bonding (as reviewed in ‘Literature relating to synchrony and social bonding’, pg. 34), and the effect of synchronisation on activation of the EOS (as reviewed in this ‘Evidence that the EOS is important in music-based activities’, pg. 47) thus far remain independently investigated.

1.5 Contribution of this thesis

The literature reviewed in the preceding sections illustrates that there is a strong link between synchrony and interpersonal social bonding, and that two mechanisms: self-other matching, and EOS activation, may both contribute to this social bonding effect. This thesis aims to contribute to the growing evidence for the social bonding hypothesis of dance via two main novel contributions: 1) including both social bonding and a proxy measure of EOS activity (pain threshold) as dependent variables in an empirical investigation into the effects of synchrony, and the use of a direct manipulation (administration endorphin antagonist, naltrexone) of the EOS to determine whether this system plays a causal and critical role in the social bonding that arises during synchronised dance.; 2) investigating synchrony in an ecologically valid paradigm of dance.

Contribution 1: Linking the topics of synchrony, bonding and endorphin release

Despite the wealth of literature linking synchrony and bonding which illustrates the positive feedback loop of synchrony and prosociality, these studies have not included any tests of the

psychopharmacological underpinnings of these trends. It is unknown whether tapping, walking, drum beating, rocking, singing while cup waving, or moving to a metronome are also associated with activation of the EOS, as none of these studies included a measure of this. Conversely, the few studies which have demonstrated that synchronous exertive activity is associated with elevated pain threshold have not included any measures of bonding. The studies on rowers and dance cite that synchrony is associated with bonding, but there is no direct evidence in these studies that group exertive rhythmic movement does indeed contribute towards interpersonal bonding, and that this effect is associated with the EOS. This is a large gap in the literature.

As such, the two mechanisms of self-other matching and the role of endorphins remain independently investigated. This is of particular relevance when considering the relative roles of synchrony and exertion on the bonding and EOS effects. Although the experiments conducted by Dunbar, Kaskatis et al. (2012) provide preliminary evidence that sufficiently vigorous singing, drumming and dancing triggers the EOS (as reviewed in ‘Evidence that the EOS is important in music-based activities’, pg. 47), the present thesis offers a number of improvements on their experimental design. While the results in Dunbar, Kaskatis et al. (2012) indicate that physical effort in combination with a musical element is important in elevating pain threshold, they did not include a physically exertive non-musical activity. This is the starting point for the exploratory study presented in Chapter 2 of the present thesis. Furthermore it is not clear from Dunbar et al. (2012) whether exertion and synchrony have independent or interacting effects on the pain threshold results. Unravelling this relationship is the main aim of Chapter 3 in the present thesis. In addition, the effect of specific elements of synchrony (e.g. behavioural synchrony or temporal synchrony) was not determined in their studies, which are addressed in Chapter 4. A final contribution by this thesis is the use of an endorphin blocker, naltrexone, to better investigate the causal link between endorphins and the social bonding experienced during synchronised dance

(Chapter 5). This intervention based method has to date not been used in any prior studies investigating endorphin release and synchrony (Cohen et al., 2010; Dunbar, Kaskatis, et al., 2012; Sullivan et al., 2011, 2014; Sullivan & Rickers, 2013). In summary, this thesis provides a novel empirical investigation into both the bonding effects *and* EOS activation during synchrony in dance.

Contribution 2: An ecologically valid testing paradigm of dance

As reviewed in ‘Experimental evidence linking synchrony and social bonding’ (pg. 37), the range of studies investigating synchrony and bonding can inform a hypothesis regarding the social bonding effects of dance, but in an attempt to measure these effects in an unbiased and robust manner, the deviation from an ecologically valid form of dance may be critical. This deviation is evident in terms of the musical stimulus used, the types of movements included, and the group sizes tested. Consequently the results from these studies may only have partial relevance for dance in ritual, social settings.

Sloboda (2008) describes how the varying elements which combine to constitute music (reviewed in ‘Elements of music’, pg. 10) provide a collective impact which is diminished when it is altered or a single element is extracted. Accordingly, the effects of a metronome versus rhythmic music may be important. The relative effects of music versus metronome rhythms has been investigated in a number of studies on the affective and motivational role of music in sports (for a review see: Karageorghis & Priest, 2012). Indeed, endurance during exercise is improved in the presence of motivational music (with lyrics and melody, timbre and pitch elements) rather than a mere drum beat (Crust & Clough, 2006), and positive affect is similarly affected by the lyrical content of music (Crust, 2008; Priest & Karageorghis, 2008).

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Further to the effects on mood and exertion, synchronising to music and synchronising with others may be of particular relevance when building social closeness. Some studies have demonstrated that key in increasing social closeness is synchronisation with another individual (in the presence of a metronome beat), not synchronisation with the external beat (e.g. Hove & Risen, 2009). However, in one of the only studies using music as a stimulus for interpersonal synchrony, Demos et al. (2012) found that participants who performed a chair rocking task to music reported feeling more connected to each other. However, the connections participants reported were predicted by synchrony with the music, and not by synchrony with one another. Accordingly this study suggests that synchrony to music is sufficient to cause bonding effects, and synchrony *between* people is irrelevant when they are engaging with a shared external source of rhythm (music). Consequently they conclude that music is key in providing the ‘social glue’ during group synchrony (Demos et al., 2012), but as they did not manipulate synchrony specifically it is not known to what extent the social synchrony and musical synchrony inter-relate.

Furthermore, dance is a complex sensorimotor activity. The movements used in the range of studies reviewed in this chapter (such as rocking, tapping, walking and cup waving) are not necessarily comparable to dance movements. Given that the simple movements used in previous studies are easy to achieve and perceive, it is possible that synchronisation of more complex movements (as occur in dance) may not have the same social bonding effects. In dance, participants often synchronise temporally to the music but perform different movements, which may be of relevance for self-other matching and EOS activation, and warrants investigation.

Differences between simple and more complex dance movements may also be of importance when interested in the effects of group dance, where more than just two people are taking part in the synchronisation. As discussed in ‘The importance of source, context and agency’

(pg. 39), there are likely to be different action-perception challenges when people are synchronising with multiple people as compared to just dyads. Given that dance frequently involves synchronisation between large numbers of people, an ecologically valid investigation should test groups of more than two individuals. It is possible that the social bonding effects of synchrony previously reported are dependent on only small number of people performing easily monitored movements. Whether these effects scale up in real life situations of group dance to music is yet to be determined.

Consequently, in the present thesis, experiments consisted of groups of three or more participants, and stimulus music and dance moves were chosen to reflect the cultural context (either in the UK (Chapters 2, 4 and 5) or Northern Brazil (Chapter 3)). Brazil was chosen as an additional location for one of the studies in order to provide some data not from a UK participant pool. The present thesis therefore provides an important contribution through the use of a naturalistic and ecologically valid definition of dance, which includes movements more like those one might actually find in a real dance setting, popular music rather than a metronome, and in group rather than dyadic settings.

1.6 Overview of data chapters

To begin, the exploratory first data chapter (Chapter 2, pg. 58) establishes whether dance in a naturalistic setting makes people feel more socially bonded. This study provides an initial, and non-laboratory investigation into participants' self-reported closeness and generosity in an economic game before and after either a real-world dance class (exertive and synchronised) or gym session (exertive and non-synchronised).

Chapter 1 – Introduction

Chapter 3 (pg. 94) improves on the design of the first study to determine the relative and potential interactive effects of synchrony and exertion on endorphin release and social bonding. Conducted in Northern Brazil, this study had non-strangers perform either high- or low-exertive dance movements to music in either a synchronous condition (same movements made at the same time) or partially synchronised condition (different movements made at the same time).

Chapter 4 (pg. 129) moves into a laboratory context to determine what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with endorphin release and social bonding. This experiment utilised silent disco technology to better manipulate the audio-visual experience of synchrony between strangers, and Actiwatches to measure exertion.

Chapter 5 (pg.174) uses the same experimental set-up as the experiment in Chapter 4, but focuses on establishing whether endogenous opioid (specifically endorphin) uptake mediates the social bonding effects in dance. This experiment involved the double-blind administration to participants of either a placebo, naltrexone (endorphin blocker) or no pill in order to manipulate the EOS and better test the causal link between endorphin release, pain threshold and social bonding during synchronised dance.

Chapter 2 – Synchronised dance versus unsynchronised gym circuit training

2.1 Chapter Abstract

A relationship between synchronisation and social bonding has been widely demonstrated for dyads (e.g. tapping, walking and rocking: discussed in ‘Literature relating to synchrony and social bonding’ pg. 34), and small groups synchronising to a metronome beat (e.g. Reddish et al., 2013). In this exploratory study, I look at whether dance (to music, not a metronome) in a naturalistic (i.e. non-laboratory) context, makes people feel socially bonded compared to another real-world, social, exertive activity: gym circuit training sessions. Both dance classes and gym circuit sessions are popular, exertive group activities, but the former involves individuals synchronising their movements (usually to music), whereas the gym sessions investigated here did not involve music, nor movement in unison. This allows for a comparison between an exertive synchronous activity (dance) to an exertive unsynchronised activity (gym), where the former is expected to lead to greater social bonding than the latter. In a between-subject non-laboratory design, participants from both activities took part in a dictator game (measure of generosity/altruism) and answered various questions relating to their feelings of closeness towards a (randomly assigned) fellow dancer/gym goer. For convenience different participants were sampled at the start and end of each activity session. Comparing the results for before versus after each activity provided an indication of the effects of spending time together, and comparison between gym and dance provided an indication of the effects of activity condition. Contrary to expectations, the type of activity did not affect the measures of social bonding, suggesting that dance did not lead to more social bonding than the gym sessions. However, regardless of activity, participants scored higher on some prosociality questions

after the activity session compared with before, indicating that time spent together performing these activities does affect social bonding. Similarly, on average, participants had a higher positive affect, and lower negative affect score, after the activity session. However, the lack of a significant difference between the dance classes and gym sessions may be due to a range of confounding factors such as how much synchrony occurred in the dance classes, the fact that some dance classes involved physical contact, and differential levels of exertion in the two activities. The results indicate that synchrony and exertion may each have a significant effect on social bonding, which should be further investigated through direct manipulation of these factors.

2.2 Introduction

As reviewed in Chapter 1, the link between synchronisation and feelings of social closeness and prosocial behaviour between co-actors is well established (see ‘Literature relating to synchrony and social bonding’ pg. 34). Studies have mainly included an assessment of these bonding effects between dyads (e.g. Miles et al., 2009), and when larger groups have been tested, synchrony was induced using metronome beats (e.g. Reddish et al., 2013), or music which was likely to induce social closeness for reasons other than synchronising (e.g. national anthems: Wiltermuth & Heath, 2009). In order to investigate the social bonding hypothesis of dance, it is useful to do so in a group context (i.e. more than 2 individuals), with the use of music rather than a metronome beat, and in a natural rather than experimental setting.

Dance in a natural context

In naturalistic settings, dance often involves groups of individuals performing complex movements to music (‘What is dance?’, pg. 10). This means that previous studies on dyads performing simple movements to non-musical rhythmic stimuli are limited by the lack of ecological

validity, and it is not known to what degree the social bonding effects scale-up in a real world dance scenario. The present study begins in an exploratory capacity, by sampling dance classes of various styles, each consisting of at least 8 participants. These classes occurred as part of a dance festival, and were organised independently from the present research project. Each class involved music and synchronised exertive movement to some extent. Given that synchronisation increases feelings of social closeness (‘Self-other merging: a mechanism for synchrony-induced social bonding, pg. 35), it is predicted that people will feel more socially close to each other after engaging in a dance class.

Non-synchronous bonding: sport

In addition to the social bonding that can arise during synchrony, non-synchronised activities may lead to increased social closeness based on activation of the EOS and release of endorphins. As reviewed in Chapter 1 (‘Human social bonds: “grooming at a distance”, pg. 28) physical exertion activates the EOS (e.g. Boecker et al., 2008), a system which is hypothesised to play a role in underpinning social closeness between people. There is evidence that individuals feel closer to those with whom they perform physical (i.e. exertive) exercise and that social context and peer-support play a significant role in motivating participation in sports training, even in a virtual setting (Mueller et al., 2003). The particular mechanisms by which this social closeness may arise is a still underdeveloped area of research, and studies which have investigated EOS activation during sport have not tested social closeness (e.g. Cohen et al., 2010; Sullivan et al., 2014). Nevertheless, based on the link between endorphins and social bonding in other primates, it is hypothesised that activities which trigger EOS activation (such as sport) will result in increased social closeness.

However, whilst exertion evidently has a role in endorphin release and likely the interpersonal social bonding that subsequently arises, *synchronised* exertion is associated with significantly higher release in endorphins. As reviewed in Chapter 1 (‘What activates the EOS in

humans?', pg. 44), rowers experience a greater increase in pain threshold when rowing in synchrony with others compared with rowing out of synchrony (Sullivan et al., 2014) or alone (Cohen et al., 2010; Sullivan & Rickers, 2013). In these studies, exertion was standardised across conditions, indicating that synchrony itself was responsible for the elevated pain thresholds. Based on these studies, it is plausible that synchronised exertive activities are also associated with increased social bonds between people, compared to non-synchronised exertive activities. The present chapter tests this by comparing the social bonding effects between individuals taking part in dance classes (a physically exertive and synchronised activity) to a generic, non-synchronised physical activity (gym circuit sessions).

Gym session as a control condition

Gym sessions, which did not involve any background music or personal music systems, were chosen as the relevant control activity for the present study. People spontaneously and subconsciously synchronise to music whilst exercising (Schneider, Askew, Abel, & Strüder, 2010; Waterhouse, Hudson, & Edwards, 2010), which improves mood and the ability to withstand strenuous exercise (Fritz, Halfpaap, et al., 2013; Fritz, Hardikar, et al., 2013; Terry & Karageorghis, 2006). Furthermore, exercise output and team bonding during sporting activities appear to be enhanced in the presence of music (e.g. 'SoundSoccer' research: Gerd Schmitz, pers. com). It is plausible that the inclusion of music in an unsynchronised activity condition may confound an effort to measure the effect of synchrony on bonding. As a result, in the present study participants took part in a group gym session without any music.

Furthermore, the type of gym session included in this study involved a group of people sharing the same space, but rotating through a series of physical exercise stations every 3 minutes, which inadvertently helps to limit spontaneous synchronisation between participants. Given that

there is evidence that exercising in the presence of others rather than alone makes a significant difference in terms of pain threshold (e.g. Sullivan et al., 2011), group circuit training sessions were chosen. For these reasons, the gym sessions were considered sufficiently similar to dance classes to act as a control condition, whilst differing in the features pertinent to the current study.

Comparing gym and dance: This study

The two activities were chosen because both are a) physically exertive (and therefore expected to activate the EOS), and b) social, in that they involve spending time with other individuals.

The two activities were organised independently from the research, which provided a ‘real-world’ context, and when arriving at the venue participants were not intending to take part in research per se. Consequently, there was a tight schedule within which to recruit participants for the study, take consent and conduct the questionnaire, without disrupting the normal functioning of the activity sessions. I decided to focus solely on paper-based questionnaires, with different participants taking part before and after each activity session. The social bonding effects associated with synchronous dance and non-synchronous gym sessions were determined using an economic game (e.g. Guala & Mittone, 2010), and a range of self-report prosociality questions sourced from studies on social closeness (e.g. Aron, Aron, & Smollan, 1992; Wiltermuth & Heath, 2009).

Economic games as a measure of prosociality: the dictator game

A common means of investigating cooperation are economic games (e.g. Haley & Fessler, 2005; Meier, 2006; Shariff & Norenzayan, 2007), which involve contrived situations in which participants make decisions regarding the allocation of money. When participants choose to share money (i.e. not keep the money for themselves) this is interpreted as cooperation and an indication

of how socially bonded participants feel (e.g. Launay et al., 2013; Wiltermuth & Heath, 2009). This interpretation is based on the fact that a generous monetary decision is not predicted by economic theory, and monetary decisions are taken to reflect social preferences (Von Neumann & Morgenstern, 1944).

The dictator game is one of the simplest forms of economic games, in which two players divide a sum of money (e.g. £5), but only one player (the ‘dictator’) can decide the size of the shares (Guala & Mittone, 2010). Based on standard economic theory, a rational dictator dealing with another anonymous individual should act out of self-interest (i.e. keep all the money; Nettle et al., 2013). Consequently, non-zero contributions by the dictator are interpreted as a signal of generosity, a sense of fairness or ‘altruism’ (Guala & Mittone, 2010). The amount of money donated in this and other economic games is directly related to a number of factors including level of communication, anonymity, and social closeness (Bohnet & Frey, 1999). Furthermore, contributions are known to be significantly affected by pre-game interactions, which provide a platform for social norms (and associated expectations) to become relevant (Roth, 1995). Accordingly, it is expected that the presence or absence of a social activity prior to the dictator game will influence participants’ generosity. It is expected that people will donate more in the dictator game after spending time together (regardless of activity), but that given the strong link between synchrony and bonding (as reviewed in Chapter 1), a logical prediction is that those in the dance classes will be comparatively more generous than those in the gym condition, as a consequence of the synchronisation that occurred during the session. Performance in the dictator game is likely to be influenced by individual variation in altruistic tendencies and familiarity with fellow participants. As a result, the present study included a shortened version of a commonly used Altruism Scale (adapted from Eckel & Grossman, 2000), and a quantification of the number of friends or acquaintances in the activity

session. In addition to the dictator game, various self-report measures of prosociality were included to provide an additional indication of social bonding.

Self-report prosociality questions

A number of self-report, Likert-scale questions were included in the present study in order to complement the behavioural economic game measure. These ‘prosociality questions’ as they will be referred to in this Chapter included the pictorial Inclusion of Other in Self Scale (IOS, which was developed in order to measure interpersonal closeness in dyadic relationships (Aron et al., 1992). The IOS is a one-item scale in which participants rate their current relationship towards another target individual by choosing one of a series of seven images. Each of the seven images consists of two overlapping circles, one labelled ‘self’ and the second labelled ‘other’, and the circles overlap by increasing amounts on a scale from 1 – 7. The scale has been used in its original dyadic form (e.g. Aron et al., 1992; Bartz et al., 2010; Dibble, Levine, & Park, 2011; Vacharkulksemsuk & Fredrickson, 2011), and in various adapted versions in which the target ‘other’ is a group, rather than one particular individual (Coats, Smith, Claypool, & Banner, 2000; Hornsey, Olsen, Barlow, & Oei, 2011; Reddish et al., 2013; Schubert & Otten, 2002). In the present study, an adapted group version was used (see Appendix 7.1.2, Figure 7.1 for the image used).

Whilst the IOS is verified as an effective measure of interpersonal closeness (Aron & Fraley, 1999; Coats et al., 2000; Schubert & Otten, 2002), it is commonly used in parallel with various verbal questions relating to particular elements of social closeness. In the present study, I included Likert-scale questions of connectedness and trust: *‘how connected do you feel to X?’*, *‘how much do you trust X?’*, (taken from Wiltermuth & Heath, 2009). Furthermore, an additional question of *‘how likely are you to turn to X for advice?’* was included (taken from Dunbar & Spoor, 1995). As is predicted with the

dictator game, if the synchronised dance classes are associated with greater social bonding between participants, dancers should give higher ratings on average for these prosociality questions.

It is likely that social bonding experienced by participants in these activities will be affected both by exertion and synchronisation. Although the present study does not partition out or measure these different factors, it provides a starting point for an investigation into the social bonding hypothesis of group dance, which is a synchronous and exertive activity, compared to a non-synchronous exertive activity.

The effect of positive and negative affect

In addition to the expected effects on social bonding, non-synchronised sporting activities are known to positively affect mood (Boecker et al., 2008; Harbach et al., 2000; Thoren et al., 1990). Similarly, active engagement with music (by singing or dancing) has been shown to lead to increased positive affect, but unchanged negative affect ratings (Dunbar, Kaskatis, et al., 2012; Fritz, Halfpaap, et al., 2013). Increased positive affect is also associated with enhanced prosocial behaviours and affiliative tendencies in general (e.g. Batson & Powell, 2003), and more specifically following exercise (e.g. Batson, 1998; Mueller et al., 2003). As a result, the present study included a Positive and Negative Affect Scale (PANAS: Mackinnon et al., 1999) in order to determine whether there are differences in ratings before and after the dance and gym sessions. PANAS scales claim to provide independent measures of both positive and negative states (Crawford & Henry, 2004), and consist of a series of self-report questions regarding various moods (e.g. anxiety, anticipation, fear and excitement). It was expected that participants' ratings of positive affect would be higher after both the gym or dance classes, and possibly that this effect would be greater for those in the dance classes due to the positive influence of music.

The aim of the present study was to determine whether dance, which involves both exertive and synchronised movements (in time with the music and with other dancers), is particularly good at bonding people relative to the alternative control activity.

2.3 Hypotheses and predictions

Hypothesis 1: Social bonding (as measured by self-report prosociality questions and the dictator game) is significantly affected by exercising together (before vs. after the activity), and whether the activity is a synchronised dance or un-synchronised gym session.

Predictions:

- A) Individuals will donate more in the dictator game after the activity compared with before the activity, but the increase in donations in the dance sessions will be greater than those in the gym sessions.
- B) Individuals sampled after either activity will give higher ratings on the self-report measures of prosociality compared to before the sessions, but those in the dance sessions will give higher ratings than those in the gym sessions.

Hypothesis 2: Positive affect scores increase as a consequence of exercising together, and the extent of these changes is influenced by whether the activity is a synchronised dance or un-synchronised gym session.

Predictions:

- A) Individuals will score higher on the positive affect scale after the activity compared with before the activity, but the change in affect will be greater in the dance sessions compared

with the gym sessions. Negative affect scores may not differ between activities and time-points (before versus after).

Furthermore, it is expected that participants across conditions will not differ in terms of general altruistic tendencies, and the role of the activity in their sense of personal identity. Also, the two activities should not differ in terms of how many familiar people are in their testing group.

2.4 Methods

2.4.1 General

The study was advertised as a ‘Group exercise study’, with no mention of the hypothesis relating to social bonding, nor the comparison between different activity conditions. Dance session data were collected between February and March 2012 during the “Oxford Dancin’ Festival”, and the gym session data were collected from March – December 2012 at two local gyms (Oxford Brookes University Gym and Iffley Gym). A total of 167 participants of ages 18-67 years ($M = 27.51$, $S.D = 8.79$) took part in the study (see Table 2.1), 65 were males and 101 were females. Dance sessions included on average 13.63 (± 0.486) individuals, and the gym sessions 31.76 individuals (± 1.471).

Table 2.1 Number of participants sampled in each condition and at each time point (before and after the activity). Total $N = 167$ participants.

Condition	Before	After	Total	Number of activity sessions
Dance	28	32	60	8
Gym	42	65	107	16

2.4.2 Data structure

The dependent variables of interest are:

- 1) Prosociality measures: included self-report measures of Inclusion of Other in Self (IOS), connectedness, trust, and willingness to seek advice from a fellow participant. Each participant rated these four measures with respect to a randomly assigned fellow participant in their testing group. These self-report measures were combined to create a Prosociality Index (as explained in Section 2.5.1). The participants also played a dictator game, which provided a measure of generosity towards another (anonymous) individual taking part in the activity session, but not the testing session.
- 2) Measure of self-reported mood: 10-point Positive And Negative Affect Scale (PANAS)

The independent variables are activity condition (dance or gym), and the timing of data collection (before or after the activity).

Other variables of interest are:

- 1) Altruism score (using a scale adapted from Eckel & Grossman, 2000).
- 2) Familiarity with fellow participants (i.e. measure of how many friends or acquaintances in the activity session).
- 3) A question relating to how important the particular activity was for the participant's identity was included in order to check that the gym-goers and dancers did not differ in terms of their interest or commitment in the activity in question. Additionally, questions were asked of the gym-goers regarding their opinion of the role of music in gym sessions, and the

importance of sociality in gym sessions. These were included in order to gain extra information on how gym-goers generally engaged with their work-out sessions.

2.4.3 Participant selection and allocation of condition

Participants were recruited before and after various “Dancin’ Oxford festival” dance classes and circuit-training gym sessions. The activity sessions were organised and advertised by Oxford City Council (dance sessions) and the respective gyms (gym sessions) independently from the present research. Participants were included on the basis of their attendance at the activity sessions, their age (over 18 years), and were only permitted to take part in the study once.

2.4.4 Pre- and post-activity questionnaires

As participants arrived at either the “Dancin’ Oxford” or gym venues they were invited to add their email addresses to a class register. Permission was granted to use this list to contact participants who randomly received donations from the dictator game.

Different participants were recruited to take part in the questionnaire before and after the activity (i.e. between-subject design). After signing a consent form, participants were seated in a row in a quiet area of the venue. They were asked to sit next to someone that they did not know. Each participant received an envelope with £5, in 50p coins. They were invited to decide how much of this money to keep, and how much to donate, anonymously, to another randomly assigned individual who was due to take part/had just taken part in the activity session (for full details of the dictator game instructions, see Appendix 7.1.1).

Following the dictator game, participants answered a paper-based questionnaire including gender, age, employment status, PANAS, baseline altruism scale, and prosociality questions (for a

full description of the questions see Appendix 7.1.2.) The pre- and post-questionnaires were identical.

2.4.5 Activity session

Dance sessions

Dance classes included a range of dance genres. For a full description of each style, see Appendix 7.1.3. The sessions had different instructors, but generally involved a 5-10 minute warm up session, following which the participants learnt a series of moves (usually in unison) and performed them to music. The amount of time spent moving to music was observed for each dance class. The dance sessions were advertised as ‘taster-classes’ for individuals to try new styles of dance, were mostly aimed at a beginner level, and were available during the festival only.

Gym sessions

The gym sessions were regular classes offered by two local University gyms. Sessions consisted of circuit training where participants rotated through a series of stations, each of which involved a particular physical exercise. The exercises included push-ups, sit-ups, rope skipping, weight lifting, sprints, squats, and various other strength and endurance based activities. Participants randomly chose a station to start on, and often more than one individual started at the same station. Participants rotated stations approximately every 3 minutes. There was no music during the gym session and participants were not permitted to use personal music units (e.g. ipods). Although multiple people shared stations, the nature of the exercises did not involve participants coordinating the rate and rhythm of their exercises. On occasion, one of the stations involved a participant boxing a pad held by a fellow participant, but no other stations involved physical contact or direct coordination of any kind.

2.5 Analysis

Analyses were conducted in R64-3.03 (for the multilevel analyses) and SPSS 20 for all other analyses.

2.5.1 Prosociality index

Given that the various self-report prosociality questions were all aimed to measure a single concept – experience of social closeness – the measures were combined into a single index. However, the IOS scale was not included in this index because this was posed in relation to the whole class, whereas the other three questions (connectedness, trust and advice seeking) were asked in relation to a random person in the testing group (assigned randomly by asking participants to ensure that they were not sitting next to anyone that they knew, and having them look left to identify the person in reference to whom they should answer the prosociality questions). For these three measures, Cronbach's alpha ($\alpha = 0.639$) was sufficiently close to the recommended level (Field, 2009), to warrant combining these measures.

2.5.2 Normality testing and homogeneity of variance

Normality was tested using the Kolmogorov-Smirnov test, with a Lilliefors significance correction. Levene's test was used to compare the homogeneity of variance. All data had homogenous variance, and on occasion the distribution of the data were significantly different from normal (see Appendix 7.1.4). Log transformation did not change the distributions, and as a result, multilevel modelling was used as this method is sufficiently robust to non-normality (Maas & Hox, 2004).

2.5.3 Multilevel linear modelling

In the present study, data are arranged in a hierarchical manner. Participants took part in one of two activities (gym or dance), either before or after the activity. Each activity consisted of a number of different sessions, (see Table 2.1) and individuals rated fellow participants (within their testing group) according to the various prosociality questions. This hierarchical structure lends itself to multilevel linear modelling (MLM) analysis, which is commonly used in the social sciences as a means of taking into account non-independent data points (Gelman & Hill, 2007). Including testing group as a level in the MLM accounts for the non-independence of group membership, in which it is more likely that participants rate each other similarly compared to other individuals in other activity sessions and other testing groups with whom they did not come into contact. MLM accounts for individual variability (for example, the starting scores of different individuals), and non-independence of group and class membership by calculating ‘random effect’ coefficients.

In the present study, the various dependent measures were modelled using the fixed factors of activity session (gym or dance), and time point (measurements before or after each activity session), and included interactions between these effects. For one model, testing group was included as a Level 1 random intercept. In a second model, testing group was not included in the analysis (i.e. a standard linear model). The results from these two models were compared and in the event that the models were statistically equivocal, only the results for the model that included testing group as a level in the analysis are presented as this is the most theoretically justified. Equivalent non-parametric tests are not available (and are limited to comparisons between two conditions at a time, e.g. Friedman’s ANOVA), and as a result, only the parametric MLM results are presented in this chapter.

2.6 Results

2.6.1 Baseline differences between activities

Dancers and gym-goers did not differ significantly in terms of baseline altruism scores, and in how much the respective activities were important to their identity (see Appendix 7.1.5, Table 7.3). However, the activities did differ significantly in terms of average class size ($F(1)=80.177, p < 0.001$), with the gym sessions on average larger ($M = 31.757$) than the dance classes ($M = 13.695$). As a result, class size was included as a covariate in all subsequent analyses of the dependent variables. Activities did not differ in terms of the number of people the participants knew in their classes by name ($F(1) = 2.797, p = 0.195$). Familiarity scores were calculated as a function of class size (number of familiar people/total class size), and this measure was not significantly different between the two activity types (see Appendix 7.1.5, Table 7.3), although there was a significant main effect of timing ($F(1) = 4.421, p = 0.037$), with participants reporting a higher percentage of familiarity after ($M = 11.14\%$) compared to before the sessions ($M = 7.75\%$). It was not clear from this measure, however, whether people felt like they knew people better after the class, or if before the class started they merely did not know who might also be attending. When only the data from before the class started were analysed, there was no significant difference between activity types ($F(1) = 0.1137, p = 0.741$), and similarly, after the class there was no significant difference between activity types ($F(1) = 0.294, p = 0.594$). This indicates that the gym and dance classes did not, according to this measure, differ with regard to baseline familiarity of other participants.

2.6.2 Differences in dependent variables

Prosociality

Hypothesis 1: Social bonding (as measured by the dictator game (1A) and self-report prosociality questions (1B)) is significantly affected by exercising time together (before vs. after the activity), and whether the activity is a synchronised dance or un-synchronised gym session.

1A) Dictator game

Contrary to predictions, the amount of money contributed during the dictator game was not significantly affected by the act of spending time together (i.e. the amounts donated before and after activities were not significantly different from each other: ($F(1) = 1.633, p = 0.203$), and, contrary to expectations, the non-significant trend was indicative of participants being marginally less generous after the activity (see Figure 2.1). Furthermore, there was no significant interaction between activity and time point of the data collection (before versus after: ($F(1) = 0.082, p = 0.775$)). In addition, activity condition did not significantly affect the amount of money donated by participants ($F(1) = 0.002, p = 0.966$; see Figure 2.1).

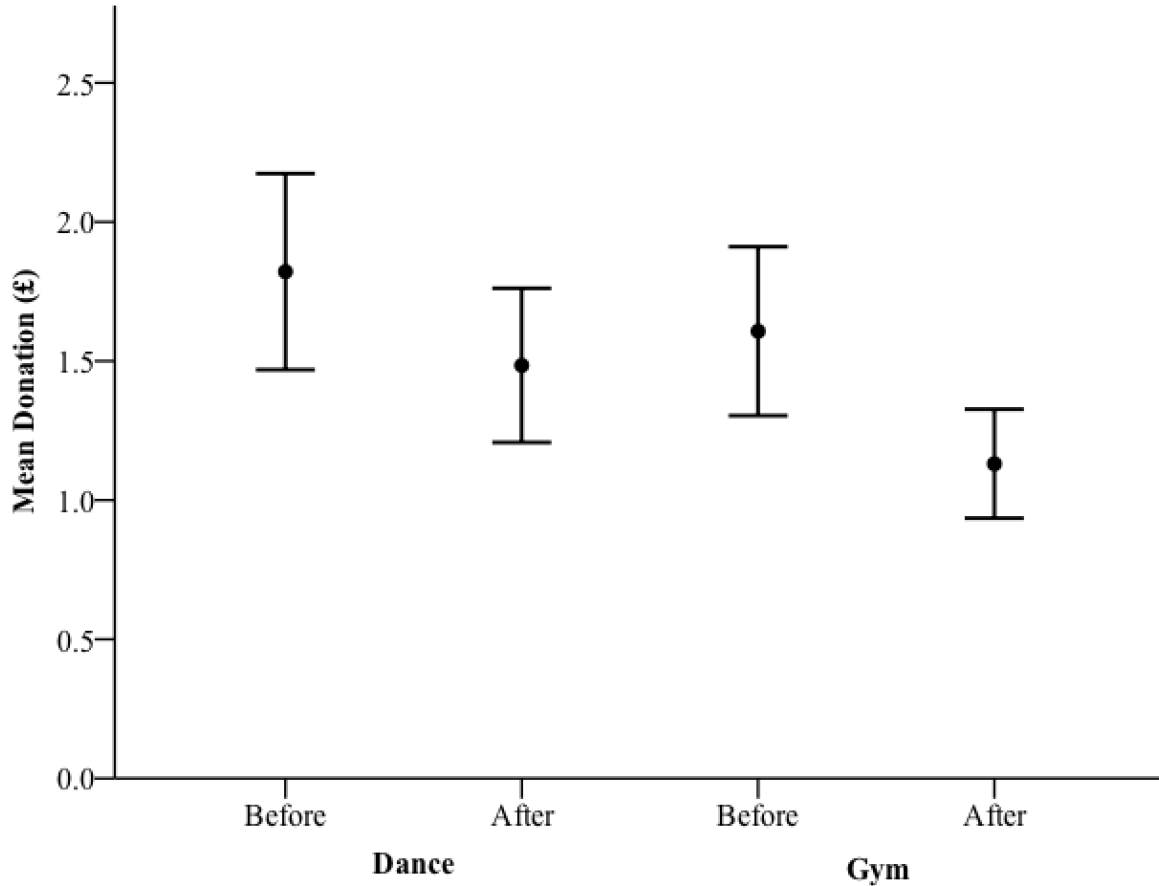


Figure 2.1 Average amount of money donated in the dictator game before and after each activity condition (± 1 SE).

1A) Self-report questions

As predicted, taking part in either activity led to a significant increase in the ratings of Inclusion of Other in Self (IOS: ($F(1) = 13.003, p < 0.001$), see Figure 2.2), with IOS scores after the sessions ($M_{\text{dance}} = 3.563; M_{\text{gym}} = 4.000$) exceeding those taken before ($M_{\text{dance}} = 2.732; M_{\text{gym}} = 3.071$). However, there was no significant main effect of activity ($F(1) = 1.182, p = 0.293$) and there was no interaction between the activity and the time point of measurement ($F(1) = 0.028, p = 0.866$).

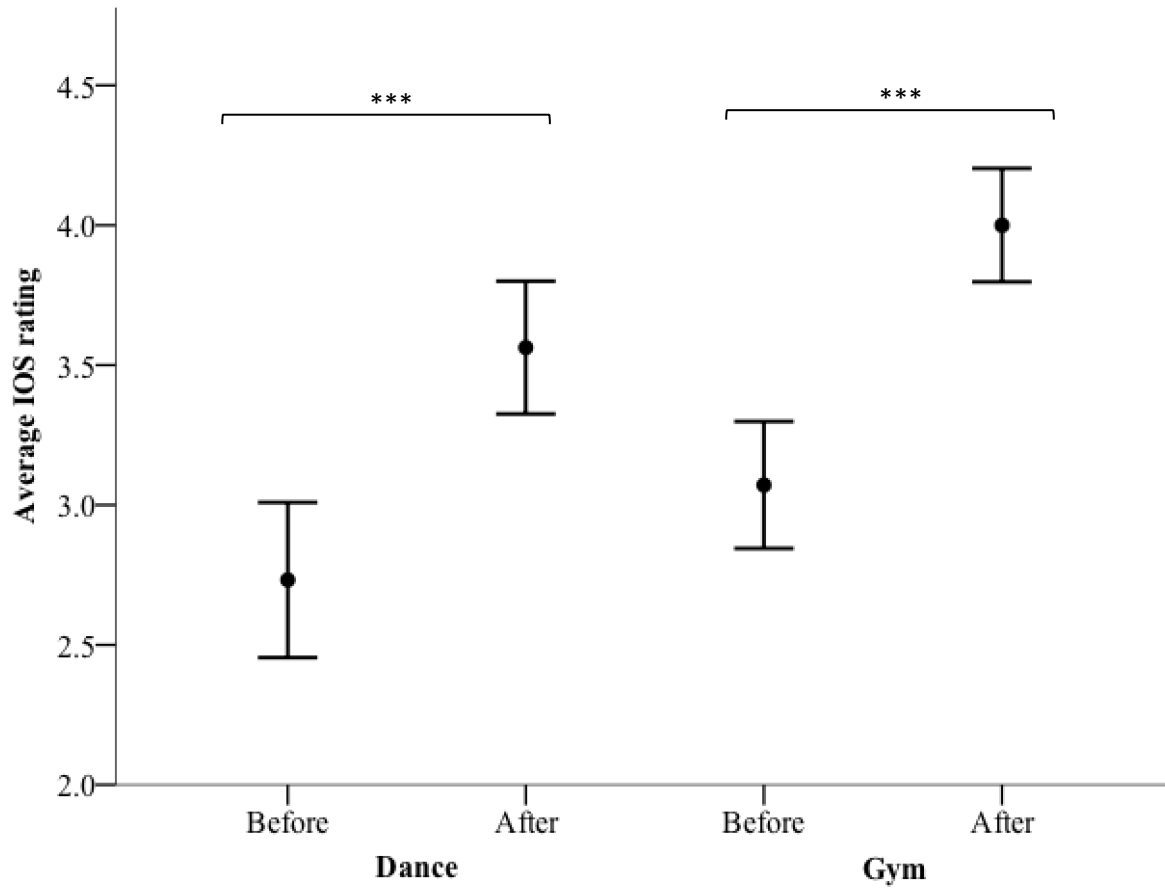


Figure 2.2 Average IOS score before and after each activity condition (\pm SE).

*** indicates significance of $p \leq 0.001$

In the prosociality index there was no significant main effect of activity ($F(1) = 0.448, p = 0.512$), or time point ($F(1) = 1.058, p = 0.305$). Furthermore, there was no significant interaction ($F(1) = 2.054, p = 0.154$); see Figure 2.3).

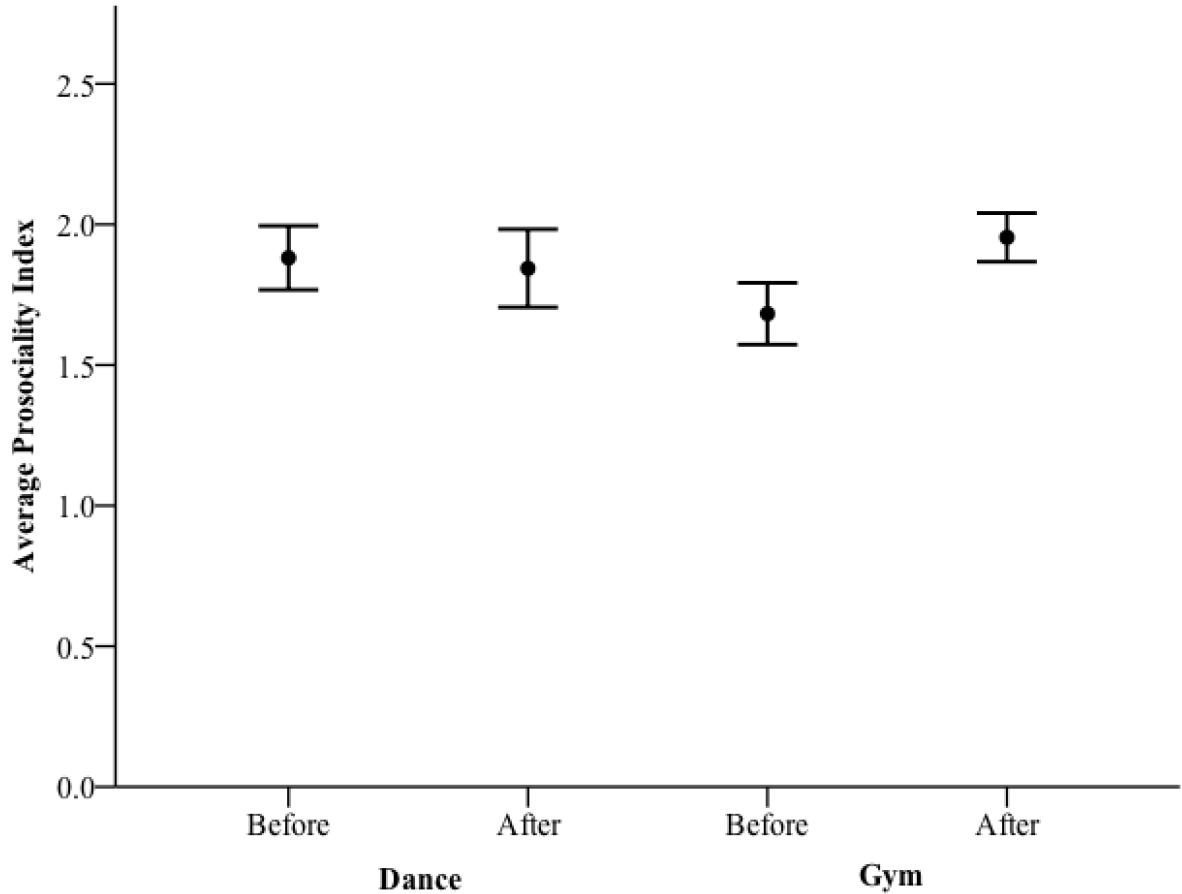


Figure 2.3 Average Prosociality Index score before and after each activity condition (± 1 SE).

Hypothesis 2: Positive affect scores increase as a consequence of exercising together, and the extent of these changes is influenced by whether the activity is a synchronised dance or unsynchronised gym session.

As predicted, there was a main effect of time point on positive affect, although this was only statistically significant when testing group was excluded as a level ($F(1) = 4.481, p = 0.036$; see Figure 2.4); with testing group this was borderline significant (see Table 2.2). The results for negative affect were identical with or without testing group as a level, and negative affect was significantly affected by time point ($F(1) = 4.680, p = 0.032$; see Figure 2.5), with the after scores on average

lower after ($M_{\text{dance}} = 1.223$; $M_{\text{gym}} = 1.209$) compared to before ($M_{\text{dance}} = 1.352$; $M_{\text{gym}} = 1.324$).

Contrary to predictions, there was no main effect of activity and no interaction effect between activity and timing for positive or negative affect (see Table 2.2).

Table 2.2 Results for positive and negative affect multilevel analyses showing the main effects of activity (gym and dance), time point (before and after), and interaction effects.

		Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Activity	Positive affect	0.070	1	0.070	0.416	0.521
	Negative affect	0.035	1	0.035	0.134	0.719
Time point	Positive affect	2.759	1	2.759	3.385	0.068
	Negative affect	0.600	1	0.600	4.680	0.032
Activity*Time point	Positive affect	0.782	1	0.782	1.271	0.261
	Negative affect	0.009	1	0.009	0.071	0.790

MLM includes testing group as a level.

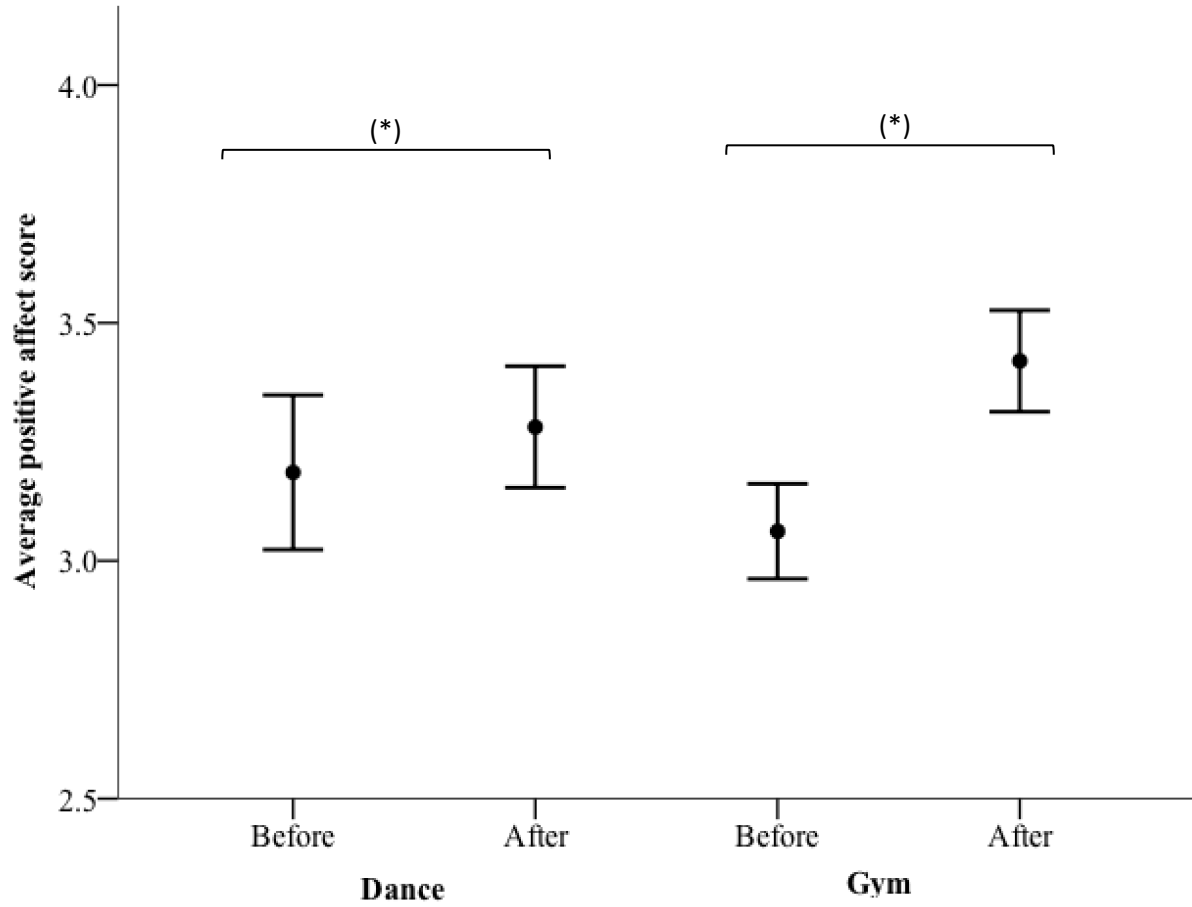


Figure 2.4 Average positive affect score before and after each activity condition (± 1 SE).

(*) indicates borderline significance of $0.06 < p > 0.05$

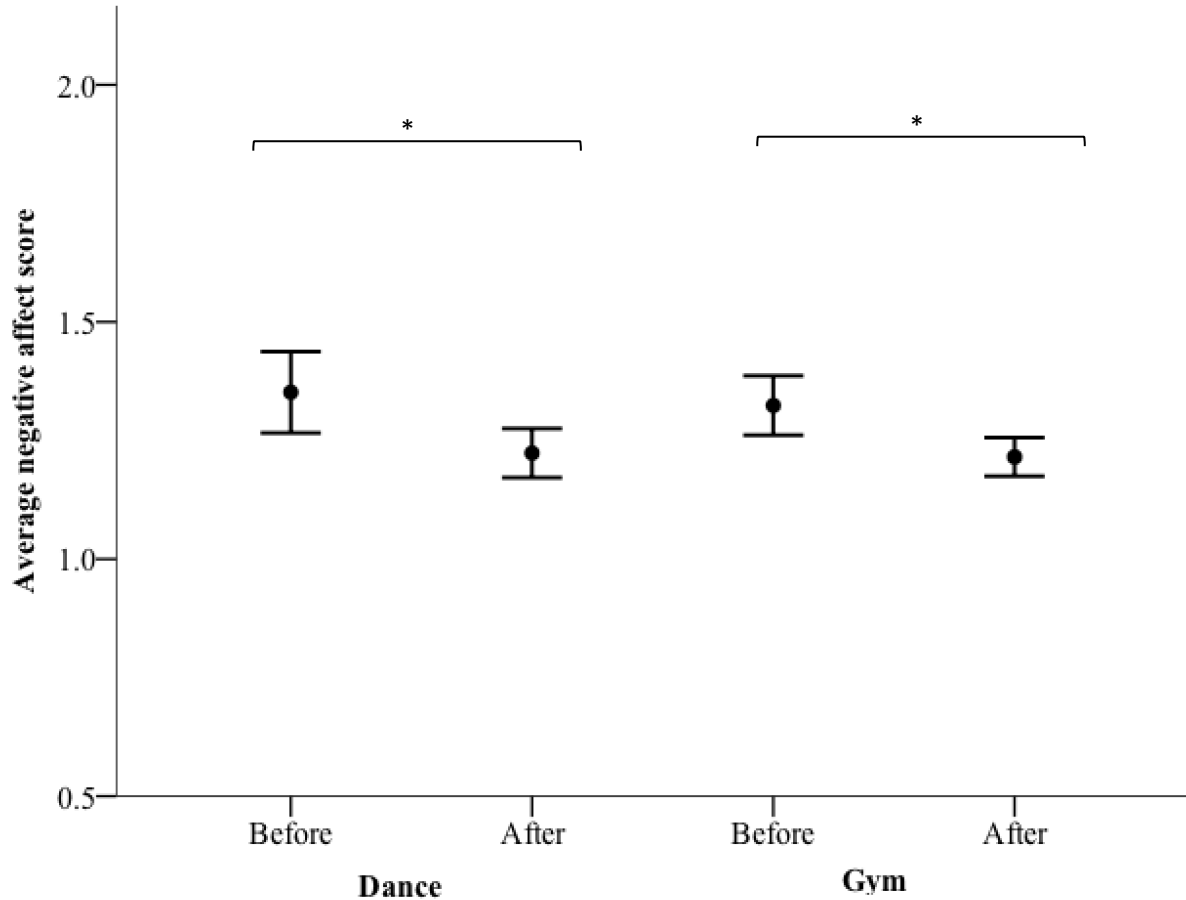


Figure 2.5 Average negative affect score before and after each activity condition (± 1 SE).

* indicates significance of $p \leq 0.05$

Additional questions

On of a scale of 1-5, gym-goers reported that listening to a personal music system improved their enjoyment of the workout session compared to no music ($M_{\text{before}} = 3.43$; $M_{\text{after}} = 3.66$), and that they enjoy a work out more if there is music playing in the room compared to no music ($M_{\text{before}} = 4.12$; $M_{\text{after}} = 4.28$). There was no significant difference in these ratings before versus after the activity session. However, participants agreed more strongly with the statement that “*circuit training is a social activity*” after the gym session ($M = 4.200$) compared to before ($M = 3.810$; $F(1) = 4.597$, $p = 0.034$), but as this statement was not included in the dance questionnaires (which were conducted earlier), a comparison between the activities was not possible for this measure.

Were the dance classes heterogeneous?

Unlike the gym sessions, the dance classes differed according to their style and structure and it is possible that these differences led to increased variability in perceived bonding that occurred during the classes. Consequently, further exploration into the dance data was conducted.

As indicated by Figure 2.6, the IOS scores before and after the dance classes were very varied across the different genres due to small sample sizes. Direct statistical comparison between class types was not possible due to the small sample sizes in each class (as described in Appendix 7.1.3, Table 7.1). For example, only two participants took part in the questionnaire prior to the Butoh class, and only one participant from the breakdancing class took part. The latter appears to be a clear outlier with regards to this particular measure, although when it was removed from the analyses it did not change overall trends in significance in other analyses.

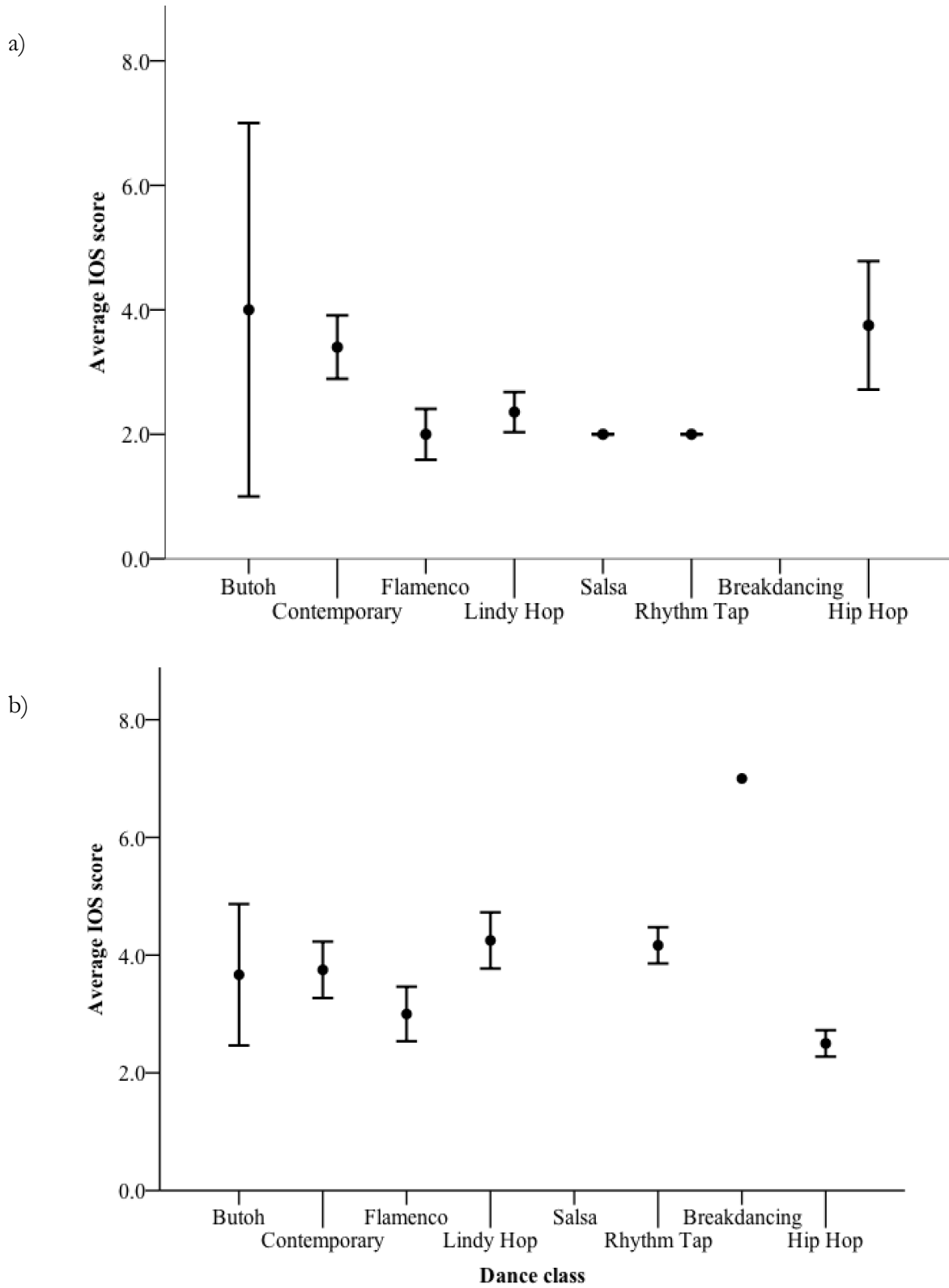


Figure 2.6 Average IOS score a) before and b) after the dance class (± 1 SE).

The variability identified in ratings between different classes is possibly because the range of styles involved different amounts of physical contact (or partner work) and synchronisation to music. Five of the eight dance classes involved physical contact (see Appendix 7.1.3, Table 7.1), either in the form of improvisation involving body contact, or partner work (for those styles which involve a leader and a follower). The dance classes also differed with regards to the amount of synchrony they involved. The degree of synchronisation between participants in the dance classes was not quantified during the classes, so instead the amount of time spent moving to music was quantified based on observations of each class. This varied greatly across the different sessions, as illustrated by Figure 2.7 (and outlined in more detail in Appendix 7.1.3, Table 7.1).

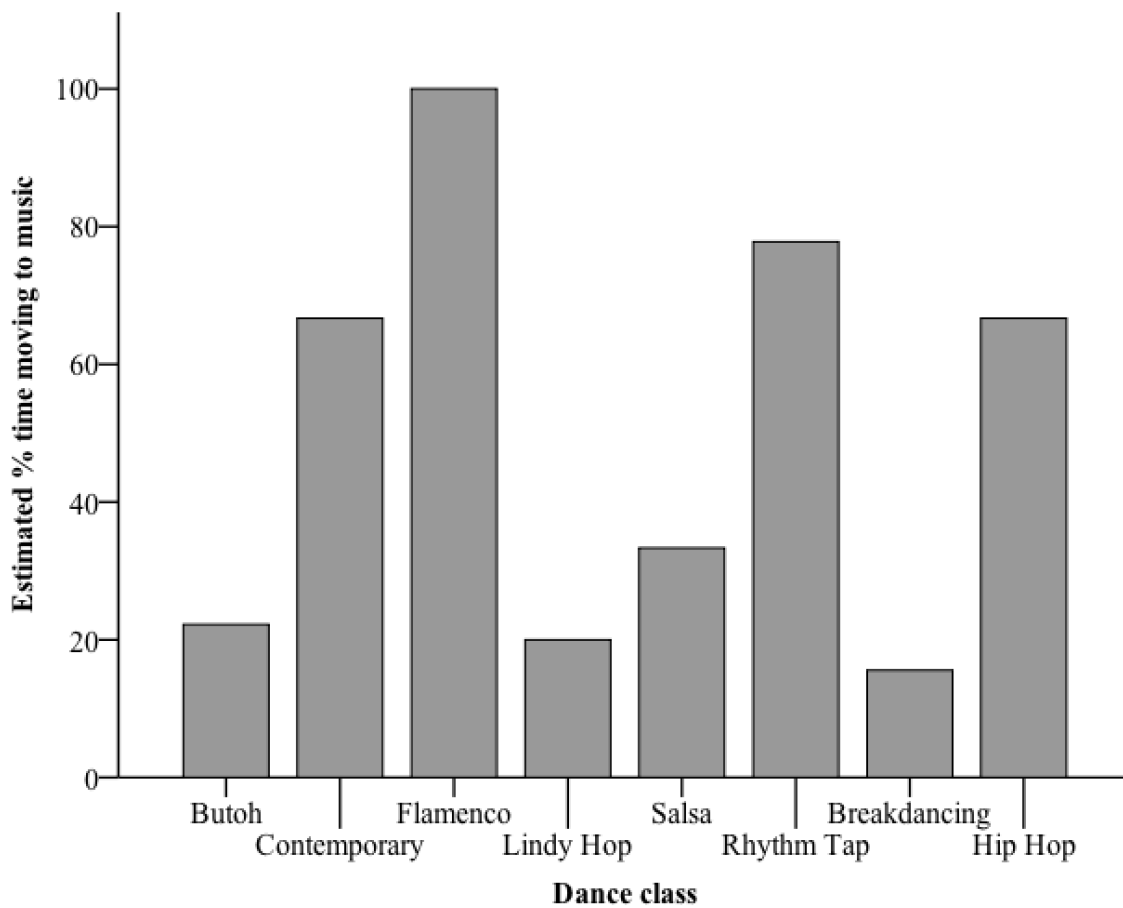


Figure 2.7 Estimated percentage of time each dance class involved moving to music.

Exploratory MLM analyses were used to determine if whether this variation in physical contact and time spent dancing to music affected the change in the social bonding measures.

Physical contact versus no contact

The monetary donations in the dictator game was significantly higher after ($M = 2.583$ compared to before ($M = 1.500$) for the classes which involved physical contact ($F(1) = 4.514, p = 0.044$; see Figure 2.8). This opposite trend was evident in the classes where no-physical contact occurred ($F(1) = 8.355, p = 0.007$), with donations after the class ($M = 0.825$) decreasing significantly from donations before the class ($M = 2.318$; Figure 2.8). In terms of IOS scores, those who had physical contact on average had higher IOS scores after ($M = 4.167$) compared to before the dance classes ($M = 2.794; F(1) = 5.396, p = 0.028$; Figure 2.8). However, for those in the no-contact classes, the increase in IOS was not significant ($F(1) = 1.435, p = 0.241$), although this increase was likely non-significant due to small sample sizes. Both contact and no-contact classes showed non-significant increases in prosociality index scores (for a summary of these results see Appendix 7.1.3, Table 7.2).

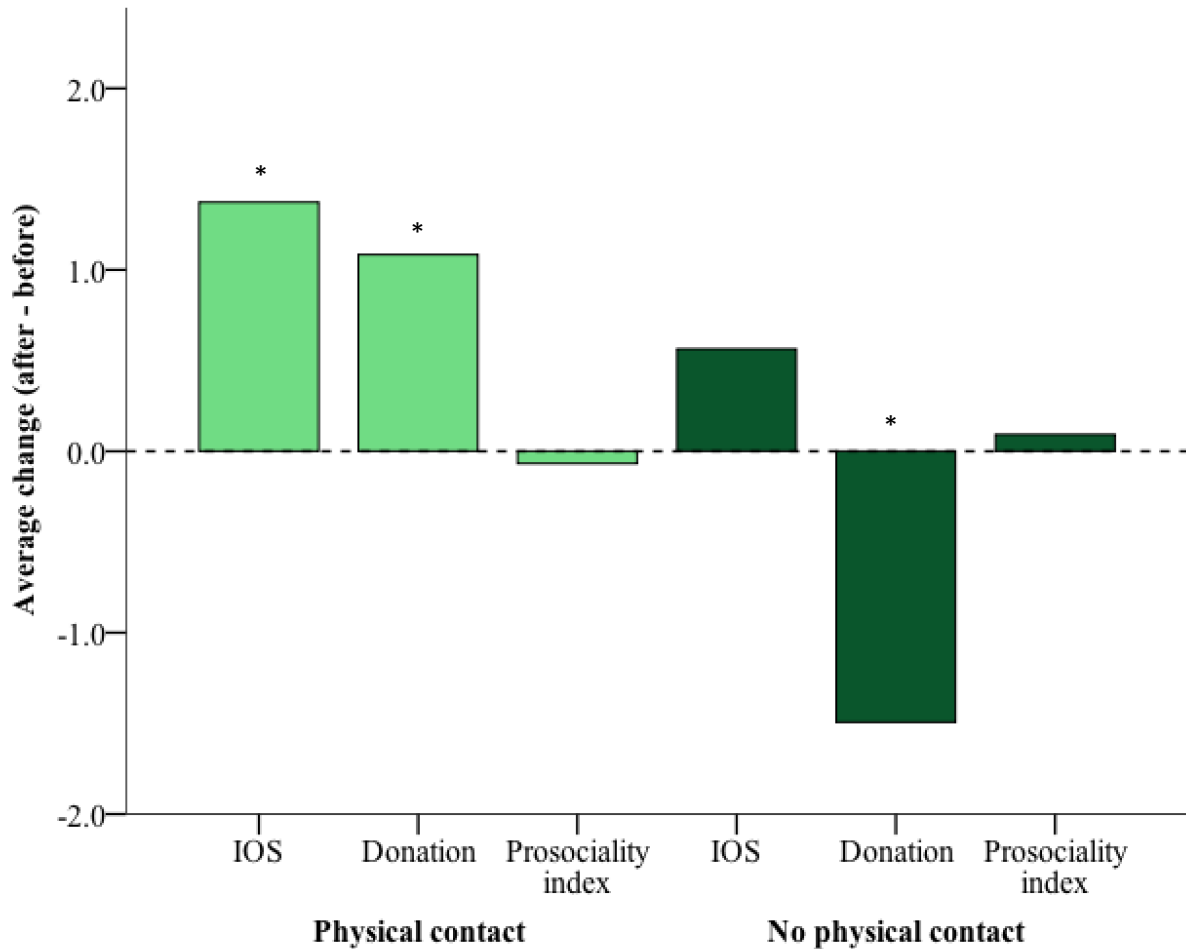


Figure 2.8 Average change in IOS, donation amount and prosociality index scores for the dance classes which involved physical contact or no contact.

*N=29 participants in classes with physical contact; N = 31 participants in classes without physical contact. * indicates $p < 0.05$.*

Less than or greater than 50% of the time spent dancing to music

For the exploratory analysis, the dance classes were split into those that involved music less or more than 50% of the time. The MLM showed that there was no significant change in monetary donations in the dictator game in the more musical classes ($F(1)=2.911, p = 0.106$), but in the classes that involved less music, donations were almost significantly lower after ($M = 1.354$) compared to before the dance classes ($M = 2.563 ; F(1)=3.686, p = 0.063$; see Figure 2.9), suggesting that the absence of music made people act less prosocially. In terms of IOS scores, those

who were in the more musical classes on average had higher IOS scores after ($M = 4.375$) compared to before the dance classes ($M = 2.542$; $F(1) = 5.044, p = 0.038$; see Figure 2.9). However, for those in the less musical classes, the increase in IOS was not significant ($F(1) = 1.412, p = 0.242$; see Figure 2.9). Both categories of class (more or less musical) showed non-significant increases in prosociality index scores (for a summary of these results see Appendix 7.1.3, Table 7.2).

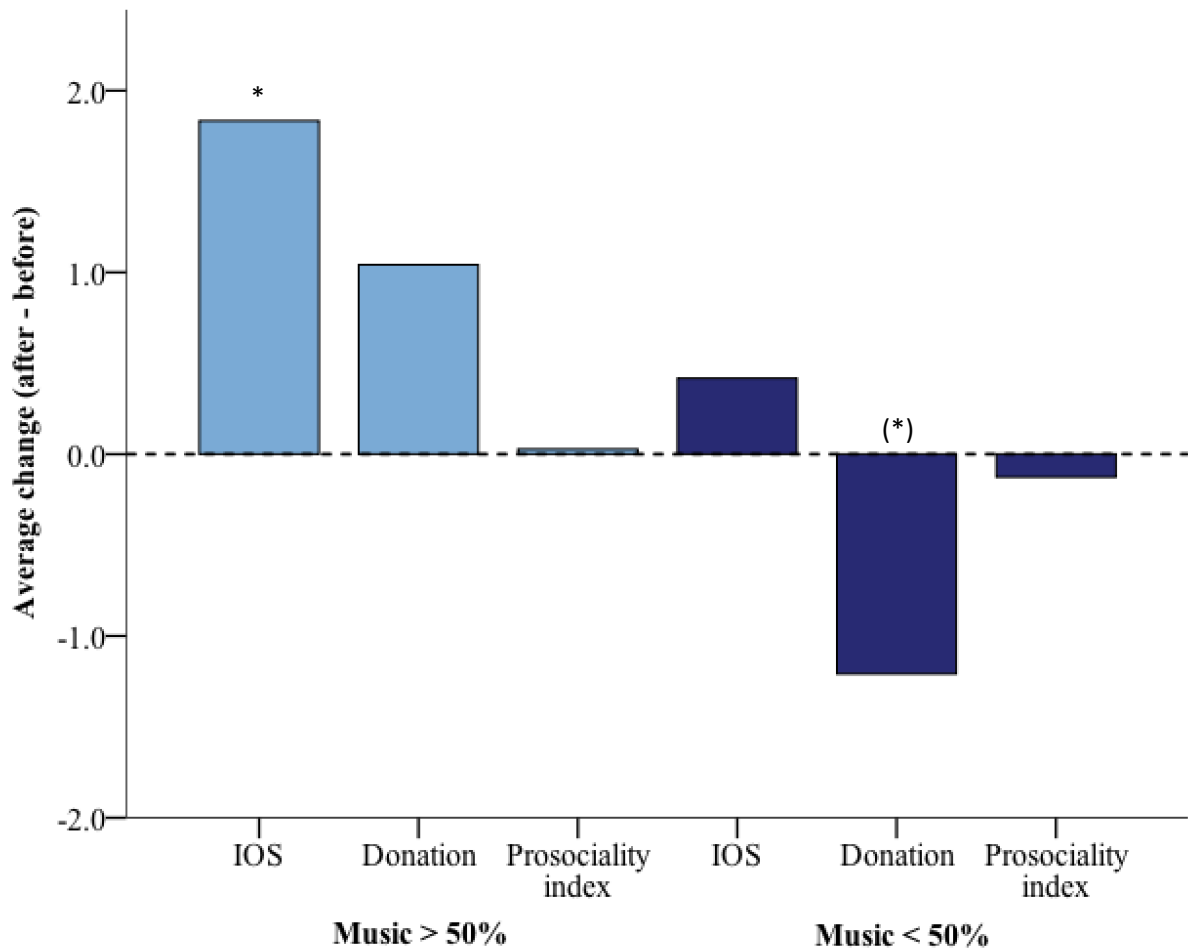


Figure 2.9 Average change in IOS, donation amount and prosociality index scores for the dance classes which involved more or less than 50% of the time dancing to music.

*N=20 participants in classes with more music; N = 40 participants in classes less music. * indicates $p < 0.05$ and (*) indicates $0.05 < p < 0.07$*

2.7 Conclusion and discussion

The aim of this exploratory study was to compare an ecologically valid synchronised exertive activity with an unsynchronised exertive activity, and the main expectation was that the synchronised activity would be associated with increased prosociality.

Spending time together doing an exertive activity (of either synchronised or unsynchronised nature) significantly affected the IOS measure, but not the contributions made in the economic game or the prosociality index. Unexpectedly, the various measures of social bonding did not differ significantly between the two activities. A similar trend was evident for the positive and negative affect scores, and although the increase in positive affect was only borderline significant after both activities the trend was in accordance with previous studies which have reported improved mood after physical exercise (e.g. Boecker et al., 2008) and music-based activity (e.g. Dunbar, Kaskatis, et al., 2012). Although a change in negative affect has not been previously reported (e.g. Dunbar, Kaskatis, et al., 2012), the present study found that negative affect scores were lower after engagement in both activities. However, affect scores did not differ according to activity condition per se.

The lack of a significant difference between activity conditions for the social bonding and affect scores may be due to potential confounding factors, which are an inherent limitation when comparing activities in a naturalistic setting. These confounds include the fact that the dance classes were themselves very variable (in terms of physical contact and the actual amount of movement to music), that there was no control for how exertive the dance and gym classes may have been, or the fact that the motivation for attending (and therefore engagement in the sessions) and group sizes varied significantly between these two activities.

Heterogeneous dance classes

Although there was very limited body contact in the gym sessions, the dance classes varied in whether they included partner work and physical contact. Social touch (i.e. tactile engagement from another person) triggers the EOS, thereby reinforcing interpersonal bonds (Nummenmaa et al., 2011). Indeed, the presence or absence of physical contact in the dance class did appear to be a significant factor in influencing some of the measures of social bonding in this study, for example donations in the dictator game (Figure 2.8). Although these statistical results should be interpreted with caution (due to low samples sizes), the results were in the expected direction; classes involving physical contact had a significant increase in monetary donations after compared to before the session, but those in the classes where there was no contact donated less afterwards. Importantly, the low donations after the no-contact dance class were below the average donations from those in the gym sessions, suggesting that whether classes had physical contact or not likely affected the dictator game data for the overall dance condition. As a result, the experiments in the subsequent Chapters controlled for this effect by ensuring that participants did not come into contact with each other, thereby allowing a better analysis of the bonding effects of synchrony independent of the potentially confounding effects of physical contact.

In addition, whilst the aim was broadly to compare the dance classes and gym sessions on the basis of synchrony versus non-synchrony, in reality the two activities differed primarily in the fact that the gym classes did not include music, and the dance classes did, though to varying degrees. It is not possible from these data to determine a precise relationship between the amount of time spent moving to music and social bonding, and the lack of standardisation regarding how much of the time participants moved in unison limits our understanding of both how dance might actually bond us and the relative role of synchronising to the music or to other participants. Based on previous studies, it is expected that synchronisation to music will increase interpersonal affiliation

(Demos et al., 2012) and the exploratory analyses of the dance classes with more or less than 50% of the time spent dancing to music was in accordance with this. Classes with more music were associated with an increase in all measures of social bonding (and a significant increase in the IOS scores), and interestingly those in classes with less music donated (almost) significantly less after the class. However, as the amount of music, and more specifically the amount of synchrony was not directly manipulated in the dance conditions, the precise relationship between percentage of time spent moving to music and the social bonding is not clear from these data. Even if one assumes that the dance classes involved on average (relatively) more synchrony compared to the gym sessions, the two activities also differed with respect to the amount of exertion involved in each.

Uncontrolled effect of physical exertion

As this study did not involve any standardisation of the types of movements, it is very likely that there was variation in the amount of exertion experienced in the gym sessions compared to the dance classes. This is problematic, given the relationship between exertion and EOS activation, (Boecker et al., 2008; Harbach et al., 2000; Thoren et al., 1990), and the likely link between this and social bonding. Consequently, if the gym sessions were more exertive than the dance classes, then the social bonding effects experienced by gym-goers may be attributed to this physical exertion, whereas those in the dance classes might have felt socially close due to synchronising with each other, to the music, and making physical contact, resulting in no overall difference between the two activity conditions. Evidently non-synchronous exertive activities, such as these circuit training sessions, may bond participants, as is suggested by the fact that gym-goers rated the circuit training as a social activity more highly after the gym session compared to before. In addition to the differences in the movements involved in the two activities, differences in the motivation behind

attending the sessions may have impacted the degree to which participants applied themselves (and exerted themselves) in the sessions.

Differences in motivation behind attending the sessions

As already mentioned, the gym classes were part of a weekly schedule at the gyms, whereas the dance classes were once-off taster sessions organised as part of a festival. Although this difference in regularity did not change how many people knew each other in the two activities (as confirmed by analysis of the familiarity measure), it is possible that the intention behind attendance by the gym-goers and the dancers may have differed. Those attending the gym did so with the explicit intention to work out intensely, and those in the dance classes were attending with the interest of trying out a new style. In this vein, it is important to note that the dance classes involved more stopping and starting, as the participants watched a demonstrator and began to learn the movements step-by-step. This is greatly contrasted by the gym sessions, where, although participants changed stations every 3 minutes, their engagement in the work-out was continuous and at no point did they stop to rest or observe others performing movements. This difference in the amount of ‘flow’ experienced in the two classes may be of significance. Dunbar, Kaskatis, et al. (2012) showed that musical activities which involve constant stopping and restarting (e.g. during a rehearsal) are associated with less of an effect on the EOS than those in which activity proceeds uninterrupted.

Group-size effects

Finally, the dance and gym sessions differed significantly in terms of group sizes. As reviewed in Chapter 1, the link between synchrony and bonding has mostly been investigated with dyads, and the few experiments on group effects have included three (Wiltermuth & Heath, 2009) or four participants (Reddish et al., 2013). Dyads are capable of achieving synchrony with relative ease

(even without music), while in larger groups it is likely that music can facilitate synchrony by the provision of rhythmic scaffolding. However, the group size limit to these effects, and the importance of synchrony and exertion is not known. In the present study, group size was included as a covariate in the analyses, but ideally future experiments should aim to standardise group size as much as possible.

An improved experimental design

Although the present study aimed to determine the bonding effects associated with dance in an ecologically valid context, this approach was confounded by a number of important factors. The subsequent experiments in this thesis are constructed in such a way as to avoid these confounds, but with the aim of involving movement to music that is still representative of ‘dance’.

The first important improvement involves the direct manipulation of both synchrony and exertion, which, according to the initial results in this chapter, might each influence the bonding experienced by those engaging in an activity. This is the primary concern of the next chapter which uses a two-by-two design to more robustly test the relative effects of exertion and synchrony on the bonding associated with group movement activities (Chapter 3, pg. 94). Furthermore, it is important to standardise the movements performed in both synchrony and non-synchrony conditions (as was done in Chapters 3 – 5), as this helps to control for differences in exertion associated with the different movements.

In addition, the present study did not allow for a control of the degree of synchrony either to the music or to other participants. In subsequent chapters, direct manipulation of synchrony enables the effects of temporal and behavioural synchrony to be compared. Also, none of the subsequent

experiments involved physical contact with other participants, removing this possible confound from experiments.

Furthermore, the present study was limited by its between-subject design, and given this experimental design, individual differences in mood and baseline social bonding were not accounted for. In order to improve on this, the next chapter samples individuals before and after each activity session (Chapter 3). Furthermore, due to the time constraints associated with operating the present study in collaboration with externally organised activity sessions, it was not possible to include a measure of endorphin release, which is time consuming and ideally involves testing all participants simultaneously (Cohen et al., 2010). The subsequent chapters (Chapters 3, 4 and 5) improve on the design of the present study by including a proxy measure of endorphins in order to better understand whether the bonding associated with synchronised group movement activities is also associated with endorphin release. Also, these chapters include 3 – 4 participants in each testing group, and as many research assistants in order to test all participants simultaneously, and immediately after the movement activity, thereby maximising the accuracy of this proxy measure of EOS.

As a final improvement on the present design, the methods of measuring prosociality were adapted and expanded in subsequent chapters. For example, with regard to the dictator game, it is possible that the payoff (£5) was too low, and too close to the amount that participants paid for the activity session (between £2-£4.50 depending on their membership to the gym or dance society). It is possible that an alternative economic game would provide a more relevant measure of prosociality. For example, two other commonly used economic games are the trustee game (Launay et al., 2013) and variations of public goods games (e.g. the weak-link coordination game: Wiltermuth & Heath, 2009). These two games are most suited to laboratory-based (and computerised) testing

sessions, and are discussed in further detail in Chapter 4 (pg. 129) where they were used as behavioural measures of prosociality. In addition, I expanded the self-report prosociality questions to include questions of likeability, and similarity in personality, discussed in more detail in the chapters which follow.

In conclusion, the present study highlights that spending time together during a group movement activity increases social bonding (according to some measures), but that this bonding does not occur more during dance classes than the control gym sessions. Whilst naturally existing social activities (such as dance classes and gym sessions) are an ecologically valid way to test hypotheses regarding the social bonding effects of group synchrony, these activities are easily confounded by a number of factors. The next chapter provides an improved design in a more controlled setting, in which the types of movements, degree of synchrony, exertion and group sizes are standardised in order to investigate the relative effects of synchrony and exertion on bonding, and also endorphin release during movement activities.

Chapter 3 – Role of synchrony and exertion in endorphin release and social bonding

3.1 Chapter Abstract

As reviewed in Chapter 1, synchronised movement leads to social bonding, although this has mostly been investigated in dyads and with low-exertive movements (e.g. finger tapping, walking, rocking). Previous studies suggest that (non-exertive) synchrony involves blurring of self and other via neural pathways that code for both action and perception. Synchronised exertive movements are also known to activate the EOS, which is associated with social bonding in other primates. The relative roles of exertion and synchrony in the social bonding that arises during dance, and the role of the EOS, is unknown. Chapter 2 confirmed that social bonding occurs during gym and dance classes, but did not include a measure of EOS activation, and the activity sessions were confounded by varied group size, and the degree of synchrony and exertion in each activity session.

In this chapter, I investigate the relative roles of synchrony and exertion in effecting pain threshold and bonding amongst people that already know each other, in Northern Brazil. Groups of 3 students (from a high school class) were randomly allocated to one of four conditions: high exertion synchrony, high exertion partial synchrony, low exertion synchrony or low exertion partial synchrony. Pain threshold (a proxy measure for endorphin release) and various in- and out-group prosocial measures (i.e. social closeness with others in the testing group, or the general school class) were obtained before and after the movement activity.

The results demonstrate that both synchrony and exertion have significant but independent effects on pain threshold, and on an index of in-group prosociality. Out-group prosociality is not significantly affected by synchrony condition, or manipulation of exertion. This study provides

incipient evidence to suggest that synchrony itself (in the absence of exertion) is associated with endorphin release. Although EOS activation and self-other mechanisms of social bonding have previously been independently investigated, both (possibly related) mechanisms are likely to be operating in cases of low and high exertive synchrony.

3.2 Introduction

The previous chapter demonstrated that assessment of the bonding effects of dance in real classes may be ecologically valid, but suffers a series of possible confounds. A more controlled experimental setting is necessary to better investigate whether social bonding can result from group dance, and the role of synchrony and the EOS in this bonding.

The present chapter provides an improved design by 1) standardising group size, 2) standardising the types of movements involved in the synchrony and non-synchrony conditions, 3) directly manipulating both synchrony and exertion, 4) including a proxy measure of endorphin release, 5) having the same participants answer these questions before and after the movement session, and 6) including an extended range of prosociality measures. Furthermore, in the interest of pursuing ecological validity, this study involves acquaintances rather than strangers, and includes an investigation into whether the social bonding effects are generalised towards a familiar group of people (class-mates) not taking part in the study, or specific to those in the testing group.

Exertion, synchrony and endorphins

As reviewed in Chapter 1, opioids are released in response to low levels of muscular and psychological stress (Howlett et al., 1984), for example during exercise (Harbach et al., 2000). PET scans have confirmed that the euphoric state that follows exercise (termed ‘runner’s high’) is due to endogenous opioids (Boecker et al., 2008), as is the post-exercise analgesic effect (Dishman &

O'Connor, 2009). Furthermore, synchronised exertive activities such as rowing (Cohen et al., 2010; Sullivan et al., 2014; Sullivan & Rickers, 2013), and active musical performances (Dunbar, Kaskatis, MacDonald, & Barra, 2011) elevate pain thresholds significantly more than alone or non-synchronised exertion, indicating that the EOS is activated during these exertive group synchronous activities. It is possible that this EOS activation during synchronisation may facilitate the subsequent interpersonal social bonding that arises.

In the rowing studies, 'power-output' (i.e. exertion) was held constant across conditions, suggesting that the elevation in endorphins was independent of exertion, and due solely to synchrony. However, the relative effects of synchrony and exertion on pain threshold were not directly investigated in these experiments, nor was social bonding measured in these studies. Other studies investigating synchrony and bonding have a) tended to involve low exertive movements and b) lacked investigation into endorphin release associated with those matched movements. As such, the effect of synchrony and exertion on endorphin release and the associated social bonding requires more extensive, direct investigation.

Bonding effects: synchrony and endorphins

Evidence that synchrony can enhance social bonds amongst co-actors draws on the mechanism of self-other merging (see Chapter 1, 'Self-other merging: a mechanism for synchrony-induced social bonding', pg. 35). Independent of the mechanism underlying the bonding, whether the bonding effect is directed (towards the other people taking part in the synchronised task), or generalised (directed towards others), is of interest, particularly given that it is hypothesised that group dance may help contribute to large scale social bonding. As mentioned in the previous chapter, it is not known what the group size limit might be in dance-related social bonding. A 'generalised prosocial model' predicts that synchronisation will increase prosociality between co-

actors as well as non-performers who did not take part in the synchronised activity (Reddish, Bulbulia, & Fischer, 2014). Research on mimicry supports this theory, demonstrating that participants cooperate more not only with someone whom they mimicked or were mimicked by, but also the experimenter (Ashton-James, van Baaren, Chartrand, Decety, & Karremans, 2007), an unrelated stranger (van Baaren et al., 2004), or faceless charity organisation seeking donations (Stel, van Baaren, & Vonk, 2008; van Baaren et al., 2004).

It is argued that this generalised prosociality is likely mediated by an increase in interdependent self-construal following activities involving mimicry (Ashton-James et al., 2007). Interdependent self-construal describes the sensation of feeling closer to others rather than separate (Markus & Kitayama, 1991), and can be measured using the Inclusion of Other in Self Scale (e.g. Ashton-James et al., 2007; Reddish et al., 2014). Reddish et al. (2014) hypothesised that given the relationship between mimicry and generalised prosociality, synchrony might have the same effect. They report evidence in support of the generalised prosociality model, where strangers in a synchronised condition were more willing to help a non-performer, or an out-group member (consisting of strangers who had not shared the synchronous task), than those in an asynchrony or no movement condition (Reddish et al., 2014). However, there was no significant effect on self-report measures of social unity or self-construal, suggesting that prosociality may have been affected independently from social perceptions.

Based on these results, the prosocial effects associated with group synchronisation appear to be generalisable, but this effect might depend on how prosociality is measured, and the ‘out-group’ in question. In this chapter, I use self-report questions (including the IOS) to determine the feelings of social closeness towards co-actors in the testing group, and towards a group of people not part of that testing session, but familiar to the participants (their school class). These are referred to as ‘in-

group prosociality’ and ‘out-group prosociality’ respectively. Although the social bonding measures used in this chapter are similar to those that did not show a generalised prosocial effect in Reddish et al. (2014), it is plausible that prosocial effects following synchronisation may extend to those not present in the room because the non-performing ‘out-group’ is familiar to the participants.

Maintenance of social bonds

Whilst the role of synchrony in establishing rapport amongst strangers has been widely investigated, it is well acknowledged that interpersonal co-ordination not only primes positive interpersonal feelings, but also signals it (e.g. Stel et al., 2010; van Baaren et al., 2004). Those with pro-social tendencies exhibit more spontaneous synchronisation than those with pro-self tendencies (Lumsden et al., 2012), and Fantino et al. (2005) report that friends are more generous towards one another in economic games than strangers (cf. Henrich et al., 2005). Much of the research on synchrony as a prime and signal of interpersonal rapport has focused on stranger dyads, demonstrating the role of synchrony in establishing rapport between pairs of people who have never previously met. According to Sullivan and Rickers (2013), synchrony enhanced endorphin release occurs regardless of whether participants are teammates or strangers. In reality much of our social synchronous activity (e.g. group dancing, music making, and singing) occurs most regularly amongst acquaintances and friends. Given that those with pro-social tendencies tend to synchronise more than those with pro-self tendencies (Lumsden et al., 2012), people who are already friends are more likely to synchronise. In order to investigate the endorphin mechanism and bonding implications of synchrony in naturally occurring groups of people, this study compares groups of friends rather than strangers, and uses multilevel modelling to account for the lack of independence between how people feel towards each other (considering that they knew each other prior to the experimental session).

Measuring social bonding

Building on the previous chapter, the present study uses the IOS scale (adapted from: Aron et al., 1992), and a series of self-report measures of prosociality. These included the same questions regarding connectedness and trust (from: Wiltermuth & Heath, 2009), but additional questions of perception of similarity (as used in: Valdesolo & Desteno, 2011; Valdesolo, Ouyang, & DeSteno, 2010) and likeability (two questions, adapted from: Hove & Risen, 2009; Valdesolo & Desteno, 2011) were added in order to expand the range of prosociality questions. Questions relating to how similar participants feel are relevant as this is likely to form part of self-other merging and inter-dependent self-construal that may arise during synchronisation. Valdesolo et al. (2010) reported that synchrony enhances perception of interpersonal similarity (e.g. in personal attributes), and it is argued that this enhances a unified identity, cooperation and compassion (Valdesolo & Desteno, 2011). Likeability was included due to the findings of Hove and Risen (2009) who report that participants liked a confederate more when they had synchronised with them, rather than when they had been tapping at different rhythmic speeds. Questions of likeability are therefore used as a measure of prosociality as people who like each other more are expected to be more ‘socially glued’ than those who score each other as unlikable (Valdesolo et al., 2010).

All questions were asked on the same scale (1-7), and in relation to i) the in-group and ii) the out-group, in order to allow for the creation of a prosociality index using all measures. The dictator game was not included in the present study, as the research was conducted in Catholic schools in Brazil, where it was not encouraged for participants to be reimbursed monetarily.

Brazil and the culture of group dance

The present research was conducted in northern Brazil, which boasts a wide range of local dance and musical practice, some of which are tightly synchronised group dancing (e.g.

<http://www.youtube.com/watch?v=uesqv--k-lk>), and free-styled or partnered social dancing (e.g. http://www.youtube.com/watch?v=jP_XcqDI_ck). In this culture, music based activities form an important social role (Cohen, Mundry, & Kirschner, 2014). Given that this thesis is concerned with general rather than culturally specific effects of synchronisation on social bonding and endorphin release, it is useful to investigate this effect in more than one cultural context, with the expectation that the effects will be present cross-culturally. The music and dance movements used in the study were sourced from the local culture, with the aim of making the experiment as ecologically valid as possible.

Manipulating synchrony

As demonstrated by Chapter 2, it is difficult to measure the effect of synchrony in comparison to a control activity that may be unsynchronised but involves different movements and may therefore be associated with different levels of exertion. In order to compare the relative effects of synchrony and exertion, it was necessary to manipulate synchrony independently of exertion, and to keep the movement conditions as similar as possible. Consequently, both movement conditions involved identical music and movements, but the synchrony condition had participants perform identical movements at the same time (i.e. behavioural synchrony, see: Miles et al., 2010), compared to the alternative, partial synchrony condition, where participants were each performing a different movement at any one time (i.e. temporal synchrony, see: Bernieri & Rosenthal, 1991). It is predicted that behavioural synchrony will lead to higher levels of social bonding and a greater change in pain threshold (compared to the partial synchrony condition) because it involves perceiving and performing movements at the same time as co-performers (i.e. complete self-other matching). The partial synchrony condition is an appropriate comparison (rather than a condition that involves no temporal synchrony) as it is known that performing movements in a temporally co-ordinated

manner is easier than moving out of time (e.g. Schmidt, Carello, & Turvey, 1990; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008). Consequently, comparison between the synchrony and partial synchrony conditions allows for an investigation into the effect of exact movement matching on increased social bonding, whilst avoiding any confound of elevated cognitive load associated with moving out of time with other people.

Predictions regarding the effect of synchrony versus partial synchrony on pain threshold draw upon the various rowing studies (Cohen et al., 2010; Sullivan et al., 2014; Sullivan & Rickers, 2013). These demonstrate that synchronising fully (i.e. matched movement and timing) results in elevated pain threshold in comparison to rowing alone (i.e. no synchrony condition: Cohen et al., 2010; Sullivan & Rickers, 2013), and that in-phase rowing has a stronger effect than anti-phase rowing (i.e. 180° oscillation: Sullivan et al., 2014). Individuals (unconsciously) prefer in-phase synchronisation (Marsh, Richardson, Reuben, Schmidt, & Baron, 2006; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007), tend to rate it as representative of more socially close co-actors (Lakens & Stel, 2011; Lakens, 2010; Miles et al., 2009), and in-phase synchrony has a stronger effect on inter-person perception and social cognition than anti-phase synchrony (Macrae, Duffy, Miles, & Lawrence, 2008). Although the rowing study by Sullivan et al. (2014) provides evidence that dyadic synchronising increases pain threshold, the use of anti-phase as a control condition may have been confounded by the fact that rowing anti-phase is not a natural occurrence in the sport. Furthermore, in a group larger than two, it is not possible to contrast in- and anti-phase synchrony, as it involves one of two binary movement states and at least two participants would end up in-phase, and therefore synchronising with each other. An alternative possible control condition would be to have participants move sequentially (e.g. Reddish et al., 2014, 2013) or to maintain rhythmic (i.e. temporal) synchrony, but have the participants perform different movements, i.e. the partial synchrony condition used in the present study. This movement condition is also more natural in real

situations of dance, where participants share an audio stimulus (music) but do not necessarily perform identical movements (e.g. partner dancers where the ‘leader’ and ‘follower’, often delineated according to gender have a different repertoire of movements). It is expected that the synchrony condition will result in a higher increase in pain threshold compared to the partial synchrony condition.

Interaction effects between synchrony and exertion

As reviewed, it is expected that synchrony (of high or low exertive movements) will have an effect on social bonding, and that exertive synchrony will have an analgesic effect (i.e. endorphin). However, from the existing literature it is not known whether low exertive synchrony will also be associated with elevated pain threshold, and whether the synchrony and exertive effects are independent or interactive when it comes to elevating pain threshold and increasing social bonding.

The present study also included a measure of participants’ experience of the experiment, in order to determine that any main effects were in fact due to the manipulation of synchrony and exertion. These questions included participants’ perception of fun, enjoyment, difficulty, embarrassment, or their musical and dance experience outside of the testing session. Furthermore, a measure of success was included as some studies have demonstrated that during synchronisation, a sense of success also predicts trust (e.g. Launay et al., 2013), suggesting that success may mediate the prosocial effects of synchrony, likely due to the role of having a shared goal.

3.3 Hypotheses and predictions

Hypothesis 1: Pain threshold is significantly affected by synchrony, and exertion.

Predictions:

- A) Individuals moving in synchrony will have a greater elevation in pain threshold than those in the partial synchrony condition.
- B) Individuals in the high exertion condition will have a greater elevation in pain threshold than those in the low exertion condition.

There may or may not also be an interaction between the effect of synchrony and exertion on pain threshold.

Hypothesis 2: Self-reported bonding (as measured by prosociality questions) is significantly affected by synchrony, and exertion, for the in- and out-group.

Predictions:

- A) Individuals moving in synchrony will experience a larger increase in bonding with i) those in the testing group (in-group), and ii) their whole class (out-group) compared to those in the partial synchrony condition.
- B) Individuals in the high exertion condition will have a larger increase in bonding with i) those in the testing group (in-group), and ii) their whole class (out-group) compared to those in the low exertion condition.

There may or may not also be an interaction between the effects of synchrony and exertion on bonding for either the i) in-group, or ii) out-group prosociality measures.

3.4 Methods

3.4.1 General

The study was advertised as “Movement and memory”, and was conducted in Soure, Ilha de Marajó, Brazil. Two local Portuguese-speaking research assistants were recruited to help execute the study during the months of August and September in 2013. All documents were translated into Portuguese by a qualified research assistant, and subsequently back translated into English by a collaborator of the project, Dr. Emma Cohen (Institute for Cognitive and Evolutionary Anthropology, University of Oxford). A total of eighty-eight sessions were conducted, with 264 school students in total (see Table 3.1), with ages ranging from 10-25 years ($M = 14.82$, $S.D = 2.289$). The sample included 99 boys and 165 girls. Twenty classes were sampled fully, i.e. a minimum of four testing groups were taken from these classes, allowing for each to be allocated one of the four movement conditions.

Table 3.1 Outline of number of participants in each experimental condition. Total $N = 264$ participants.

	Synchrony	Partial synchrony
High Exertion	$n = 72$	$n = 66$
Low Exertion	$n = 66$	$n = 60$

3.4.2 Data structure

The dependent variables of interest are:

- 1) Pain threshold test (as a proxy for endorphin release, measured at the start of the experiment and at the end, after physical activity, referred to as ‘PTT start’ and ‘PTT end’, respectively).

- 2) Prosociality measures (measured at the start and end of the experiment). These measures included IOS, connectedness, similarity in personality, trust and two measures of likeability (see Appendix 7.2.1). Each participant rated these six measures (on a scale of 1 – 7) with respect to i) their testing group (consisting of the two other people in their experiment session), and ii) for their class as a whole. This yielded a start and end measure of ‘in-group’ and ‘out-group’ prosociality respectively. These before and after prosociality data were combined to create an in- and out-group Prosociality Index for the start and end (as explained in section ‘Prosociality index’, pg. 110).

The independent variables are:

- 1) Synchrony vs. partial synchrony. Groups all learned the same dance moves, but when doing the 10 min movement task, they either performed the moves all together in the same order (synchrony), or they each performed a unique sequence of the moves (i.e. each participant was doing a different movement at any one time).
- 2) High exertion vs. low exertion. In the former condition, the movements involved standing, jumping and large arm movements. In the latter case, all movements were smaller (e.g. only hand movements) and were performed while sitting.

Other variables of interest are:

- 1) 10-point Positive And Negative Affect Scale (PANAS) determining self-reported affect before and after the activity, calculated according to Mackinnon et al. (1999).
- 2) Self-reported success measures (rating personal success and that of the group), rated after the activity. These measures were pooled on the basis of sufficient reliability ($\alpha = 0.701$, for more detail see Appendix 7.2.3, Table 7.5).

- 3) Self-reported measures of fun, enjoyment, difficulty and boredom during the movement task.
- 4) Hypothesis check: To determine if any of participants had guessed the purpose of the research.

‘Change’ variable was computed for each variable with start and end measures (PTT, PANAS and Prosociality Index). On each occasion, this was calculated simply by subtracting the end measure from the start measure.

3.4.3 Participant selection and allocation of condition

High school participants were recruited from two schools in Soure, Marajós, Brazil. Those over the age of 18 provided their own written consent, and written parental consent was obtained for the younger participants.

Each experimental session included three participants randomly selected from the same class. Wherever possible the groups were mixed in gender, in order to maintain consistency with the other experiments reported in this thesis. Each group (of three participants) was randomly allocated to one of the four treatment conditions (high exertion synchrony; high exertion partial synchrony; low exertion synchrony; low exertion partial synchrony). When possible, I tried to ensure that each class sampled had at least one group of each condition, to enable multilevel modelling.

3.4.4 Pre- and post-movement session pain threshold measure (PTT)

At the start of each session, the three participants were placed in the far corners of the testing room to ensure as much privacy as possible. The PTT measure was administered to all three participants simultaneously (one research assistant per participant) via standard procedure used in

previous studies (Cogan et al., 1987; Cohen et al., 2010; Dunbar, Kaskatis, et al., 2012; Dunbar, Baron, et al., 2012; Sullivan et al., 2014; Sullivan & Rickers, 2013). A sphygmomanometer (blood pressure cuff) was attached to the upper non-dominant arm. The research assistants told the participants “*I will inflate the cuff slowly, please indicate when it becomes very uncomfortable by saying ‘now’*”. The experimenter gently inflated the cuff at a steady rate (10mmHg/sec) until the participant indicated discomfort or a maximum pressure of 300mmHg was reached. In Portuguese, this measure was referred to as a ‘Physical Observation’. This measure was taken twice during the session: at the start of the experiment (termed ‘PTT start’), and at the end (immediately after the movement session, termed ‘PTT end’). To ensure consistency, each researcher attended to the same participant for both PTT start and end measures.

3.4.5 Pre- and post-movement session questionnaire

Following the initial pain threshold measure, each participant completed a questionnaire including age, gender, PANAS, and in – and out – group measures of prosociality. The post-movement session questionnaire included exactly the same questions as the earlier questionnaire, with additional questions regarding how much fun, enjoyment, boredom, difficulty, discomfort and embarrassment they experienced during the movement task, and how successful they felt they and the other pupils were (for questions, see Appendix 7.2.2).

3.4.6 Movement training

Following the questionnaire, the participants were seated in a straight line in the centre of the testing room facing the same way. A Brazilian (Portuguese speaking) research assistant taught the group three basic movements which were either performed standing (for the high exertion groups) or seated (for the low exertion groups). For a description of the high exertion and low

movements, refer to Appendix 7.2.3). During training, an average of two minutes was spent teaching and practicing each movement. This training time included demonstration of the movement by the research assistant, performing the movement simultaneously with the participants, and watching the participants perform the movement unaccompanied. Each movement was named ('Palmas', 'Peão', 'Cruzar'; translated as claps, cowboy, and cross respectively), and practised to music (see Appendix 7.6.1, and DVD: folder 3.1 Movement training tracks), and the students were asked to repeat the name to ensure recall. After the three movements had been taught, the research assistant checked the participants' memory and movement accuracy by randomly calling out which movement to do next.

3.4.7 Movement session

Following the training, the participants stood (for high exertion)/sat (for low exertion) in a circle, facing inwards. At the centre of the circle three chairs were placed (in front of each participant) with a card taped onto the top of each chair. Each card displayed a list of four movements ('Palmas', 'Peão', 'Cruzar' with one movement repeated twice on the list, but not consecutively). The participants were played a voice recording which described the instructions of the movement session, with brief (5 second) practice sessions embedded in the instructions (for detailed instructions, refer to Appendix 7.6.1). The students were instructed to begin with the first movement on their card, and change to the next movement immediately after hearing "3, 2, 1, *Passa!*" (translation: 3, 2, 1, Change!). The countdown was pre-recorded over the music. When they reached the last movement on their card, they were instructed to return to the top of their list. They were told to look at their cards and at the other participants, and only to change their movement when they heard the countdown.

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The circular arrangement and positioning of the cards meant that no participant could see any of the other participants' cards. In the synchrony condition all participants received identical cards, so that they performed the same movements together. In the partial synchrony condition, each participant had a different card, detailing a unique order of movements. This ensured that no two participants performed the same movement simultaneously.

The movement session consisted of ten minutes of music, with the instructions to 'change' to the next movement occurring at varied intervals (no shorter than two bars of eight, and no longer than five bars of eight apart). The intervals between instructions to change to the next movement were varied in order to prevent the participants from predicting the timing of the instructions, thereby encouraging on-going attention to the musical stimulus. The same music (average bpm of 120) was used for every session regardless of exertion and synchrony condition (see Appendix 7.6.1, and to hear the audio tracks refer to DVD: folder 3.2 Movement session tracks). The RAs were present in the room during this session, but did not directly watch the participants for more than a few seconds at a time (to ensure that they felt that they should do the task fully without becoming self-conscious from being watched constantly). The movement sessions were also filmed when possible (to see sample videos from each movement condition refer to the DVD: folder 3.3 Movement session video samples).

3.5 Analysis

Analyses were conducted in R64-3.03 (for the multilevel analyses) and SPSS 20 for all other analyses.

3.5.1 Pain threshold data exclusion

Restrictions in methodology (the sphygmomanometer only allows measurements up to 300mmHg) means that when an individual reaches 300mmHg at the start or end, this is a *minimum* measurement, which may well have been higher had the equipment and ethics allowed further measurement. To account for this bias, participants who reached 300mmHg at either the start or the end were excluded (which reduced the total sample size ($N = 264$) to 178 participants). On the occasion when this influenced the significant trend in pain threshold between conditions, I report these differences, and unless otherwise stated, the more conservative PTT results (with exclusions applied) are reported.

3.5.2 Prosociality index

The prosociality index was created by averaging all six in-group start prosociality scores, and end scores. The same was done for the out-group. All six measures were tested using a 7-point Likert scale, and the index was justified on the basis of Cronbach's reliability test.

The six measures (IOS, trust, connectedness, likeability1, likeability2 and similarity in personality) had sufficiently high reliability ($\alpha = 0.744$; see Appendix 7.2.4, Table 7.4), based on the level recommended by Field (2009). Multilevel linear modelling was used to account for the non-random variation in the repeated measures scores, and in the testing group and class membership (see section 'Multilevel linear modelling', pg. 111 for more detail).

3.5.3 Normality testing and analysis of variance

Normality was tested using the Kolmogorov-Smirnov test. Levenes' tests were used to compare the homogeneity of variance. All data had homogenous variance, and on occasion, the distributions of the data were significantly different from normal (see Appendix 7.2.5). Log transformation did not change the distributions, and as per the previous chapter, multilevel linear modelling was used throughout the analysis.

3.5.4 Multilevel linear modelling

As with Chapter 2, the experimental design and hierarchical nature of the data of the present study lends itself to multilevel linear modelling (MLM) analysis. As described in Chapter 2, MLM is appropriate when data is arranged hierarchically, and when data points are non-independent. MLM was used in the present study due to the fact that it is capable of accounting for individual variation and dealing with repeated measures. Furthermore, as the prosociality questions involved participants rating their feelings towards fellow participants (in-group prosociality) or class as a whole (out-group prosociality), MLM was used to account for non-random membership of testing group and class.

For example, individuals are more likely to be more similar to themselves than to other individuals, which is relevant when repeatedly measuring the same individual (e.g. start and end PTT and PANAS scores). MLM accounts for individual variability (for example, the starting scores of different individuals) by calculating 'random effect' coefficients. This can also be done at levels higher than the individual.

The repeatedly measured dependent variables (i.e. within-subject measures of PTT, PANAS and prosociality index) were modelled using the fixed factors of time point (i.e. before or after testing), synchrony condition (i.e. synchrony or partial synchrony), and exertion condition (i.e. high

or low exertion), including interactions between these effects. Participant ID was added as a Level 1 random intercept (effectively accounting for the repeated measure), testing group was included as a Level 2 random intercept, and school class as a Level 3 random intercept. Random effects were selected in the final models using backwards stepwise regression with log-likelihood tests to compare each model (via a χ^2 analysis). Results are presented for the model of best fit, and in the event that the models were statistically equivocal, only the results for the model that included both individual and testing group as levels in the analysis are presented, as this is consistent with the MLM approach in the previous chapter and chapters to come. Equivalent non-parametric tests are not available (and are limited to comparisons between two conditions at a time, e.g. Friedman's ANOVA), and as a result, only the MLM results are presented in this chapter.

3.6 Results

3.6.1 Baseline differences between movement conditions

The conditions did not differ according to the self-rated musicality ($F(3) = 1.492, p = 0.223$), ability to dance ($F(3) = 0.995, p = 0.396$), nor the degree to which music ($F(3) = 1.232, p = 0.303$) or dance ($F(3) = 0.928, p = 0.428$) were part of the participants weekly lives (see Appendix 7.2.6, Table 7.6 for the means and standard deviations for each variable).

3.6.2 Differences in dependent variables

Pain Threshold

Hypothesis 1: Pain threshold will be significantly affected by synchrony (1A), and exertion (1B), and there may be interactive effects between these.

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According to a maximum likelihood comparison, the model fit did not significantly improve when either testing group or both group and class were included in the analysis. Exclusion of participants who reached 300mmHg resulted in the same overall trends as analyses conducted with all data, but more conservative results. According to the more conservative analysis, there was a borderline significant increase in pain threshold after activity, regardless of condition ($F(1) = 3.304$, $p = 0.071$), and this effect was strongly significant with the larger sample size ($F(1) = 9.273$, $p = 0.003$, see Appendix 7.2.7, Table 7.9).

As expected, there was a significant main effect of exertion ($F(1) = 10.727$, $p = 0.001$) and synchrony ($F(1) = 7.8852$, $p = 0.005$) on the change in pain threshold, and there was no interaction between these effects ($F(1) = 0.095$, $p = 0.758$). The lack of interaction between synchrony and exertion indicate that both have independent significant main effects on pain threshold. In the high exertion synchrony condition this results in a cumulatively (though statistically non-significant) higher change in pain threshold than the other three conditions (see Figure 3.1).

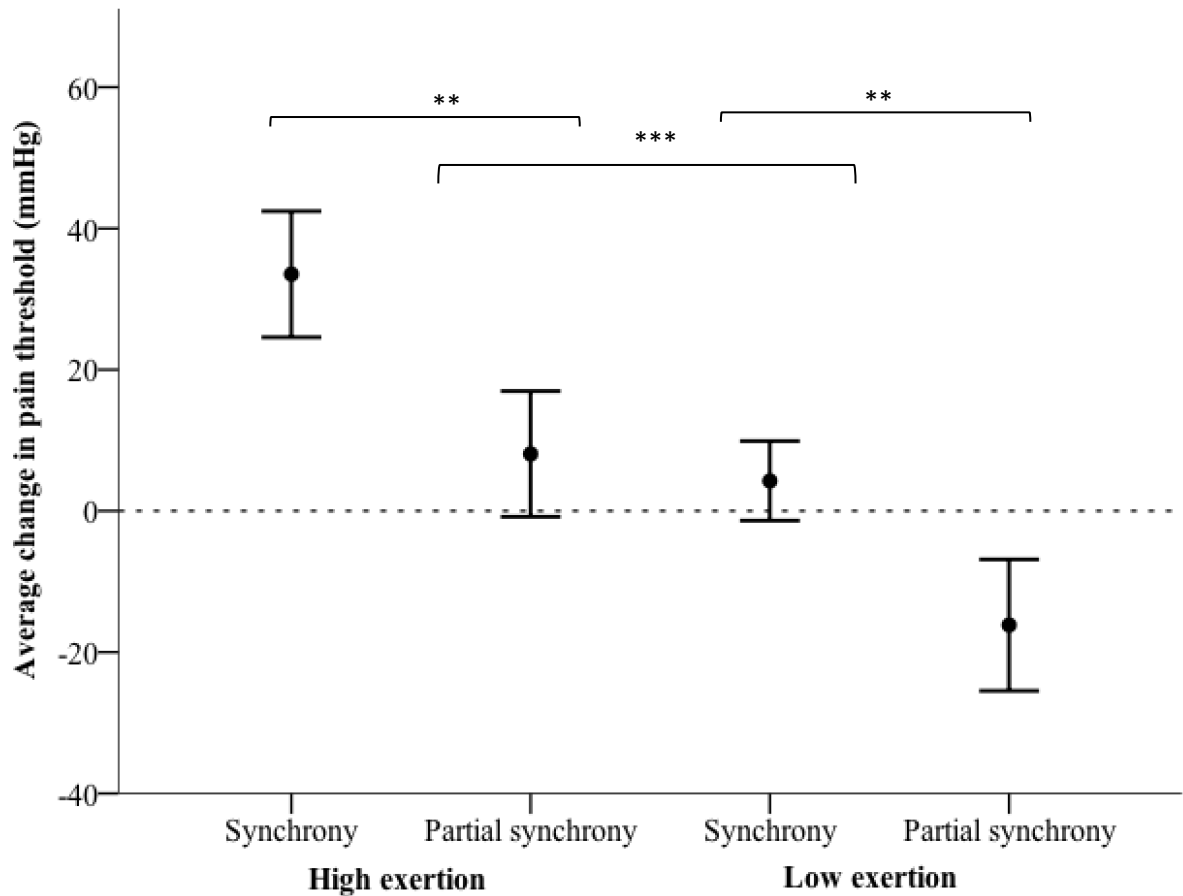


Figure 3.1 Average change in PTT (end - start) for each condition (± 1 SE).

Excluding participants who reached 300mmHg ($N = 178$); ** indicates significance of $p \leq 0.01$ and *** indicates $p \leq 0.001$ in MLM analysis with testing group included as a level.

Prosociality index

Hypothesis 2: Self-reported bonding (as measured by prosociality questions) will be significantly affected by synchrony (2A), and exertion (2B), for both the i) in-group and ii) out-group, with a possible interaction effect between synchrony and exertion.

Analysis of in-group prosociality index was significantly improved by including group ($\chi^2 = 6.669$, $d.f = 1$, $p = 0.010$), and both group and class as levels ($\chi^2 = 19.525$, $d.f = 2$, $p < 0.001$). For the out-group, the model was not improved when including group ($\chi^2 = 0$, $d.f = 1$, $p = 1.000$), nor group

and class ($\chi^2 = 0.766$, $df = 2$, $p = 0.682$), but for the sake of consistency and ease of comparison between in-and out-group results, Table 3.2 includes a summary of statistics for the most complex model.

Table 3.2 Results for prosociality index (in- and out-group) multi-level repeated measures analysis.

		Sum of Squares	<i>df</i>	Mean Square	<i>F</i>	<i>P</i>
Time point	In-group	15.903	1	15.903	35.439	< 0.001
	Out-Group	3.774	1	3.774	11.506	< 0.001
Time point *Synchrony	In-group	2.272	1	2.272	5.984	0.015
	Out-Group	0.115	1	0.115	0.361	0.548
Time point *Exertion	In-group	2.258	1	2.259	5.855	0.016
	Out-Group	0.486	1	0.486	1.398	0.238
3-way Interaction	In-group	0.951	1	0.951	2.330	0.128
	Out-Group	0.291	1	0.291	0.913	0.340

All data: N = 264; MLM includes group and class levels.

As predicted, the change in ratings of in-group prosociality is significantly affected by both synchrony ($F(1) = 5.984$, $p = 0.015$), and exertion ($F(1) = 5.855$, $p = 0.016$; see Figure 3.2). There is no significant interaction between synchrony, exertion and the change in in-group prosociality index. However, synchrony and exertion did not have significant main effects on the change in out-group prosociality index (see Table 3.2;), although the out-group prosociality index was significantly higher after the activity, independent of condition ($F(1) = 11.506$, $p < 0.001$; see Figure 3.3).

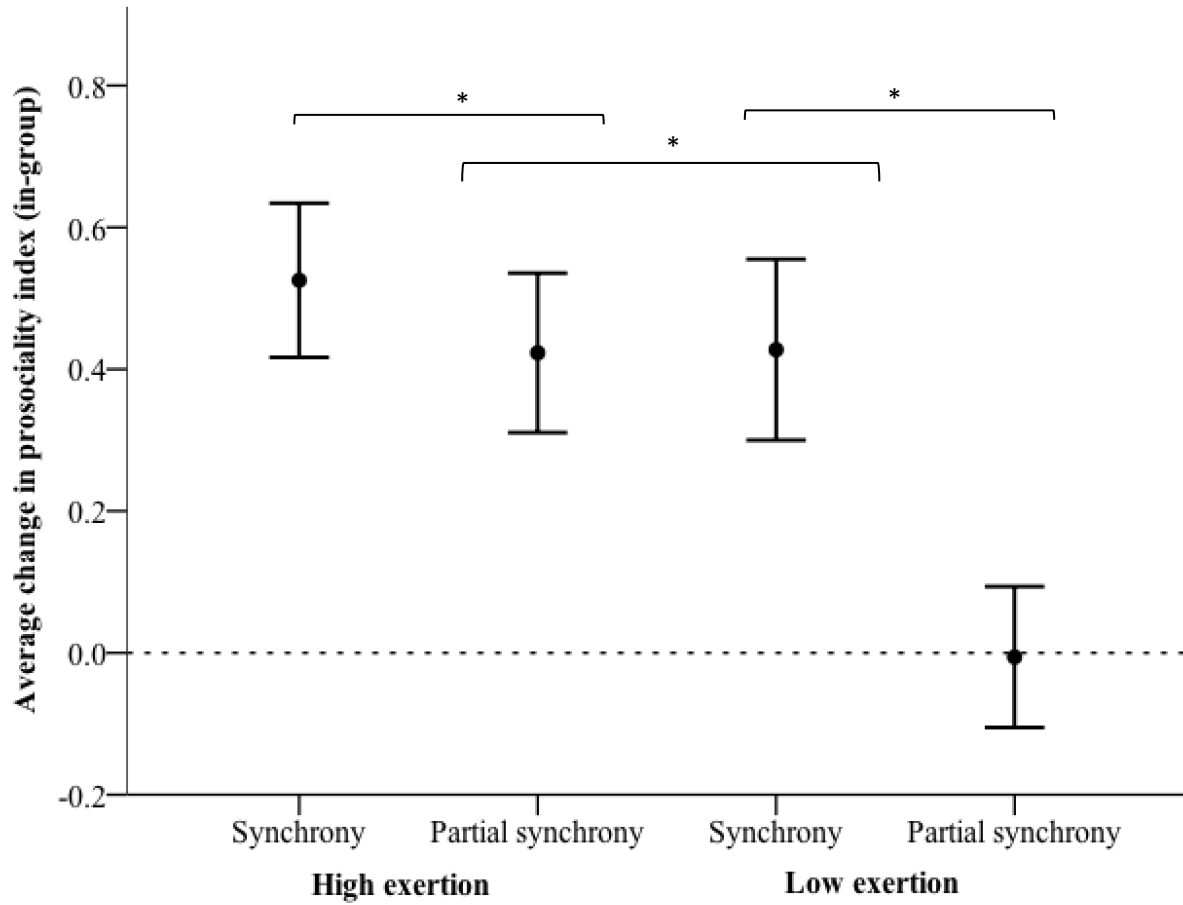


Figure 3.2 Average change (end – start scores) of in-group prosociality (\pm 1 SE).

* indicates significance of $p \leq 0.05$.

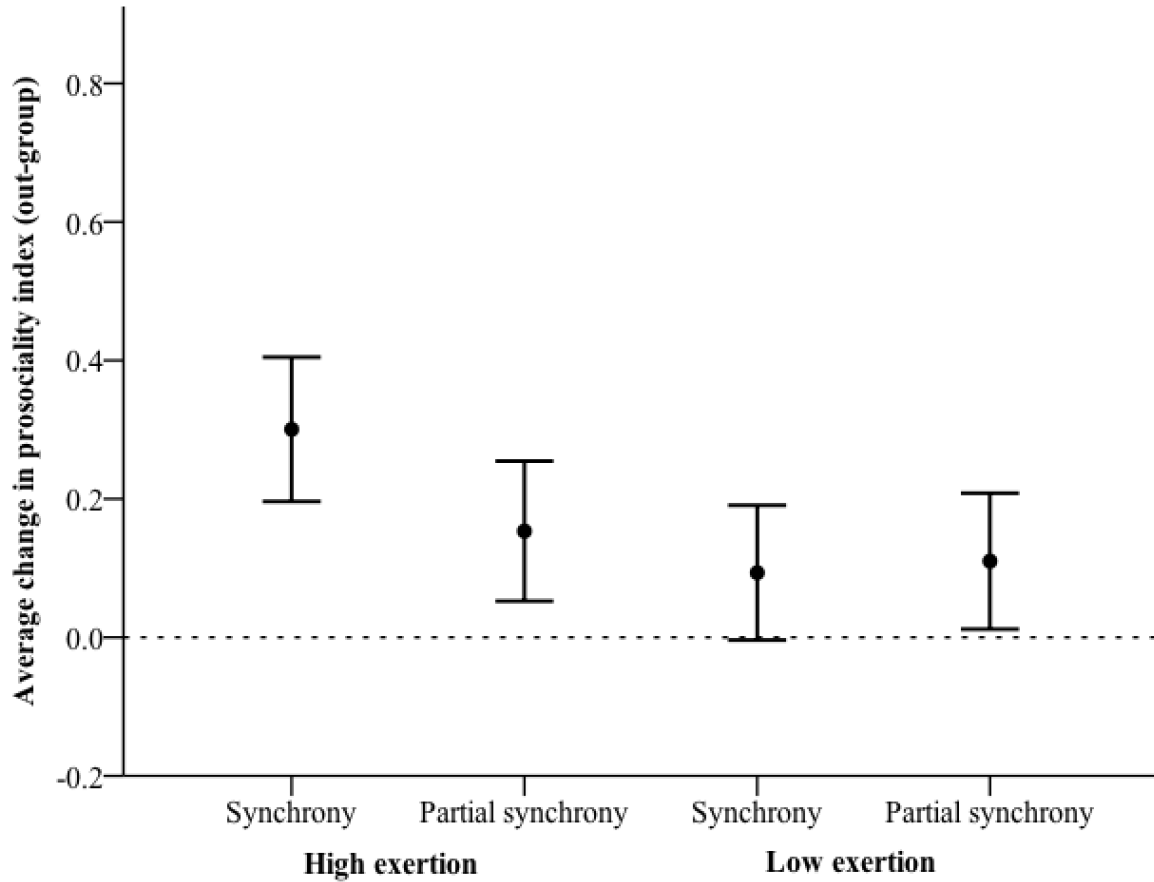


Figure 3.3 Average change (end – start scores) of out-group prosociality (± 1 SE).

Correlation between prosociality index and pain threshold

A Pearson's r correlation was used to assess the relationship between the change in pain threshold and in-group prosociality index. Despite the fact that both variables displayed similar statistical trends (with both significantly effected by synchrony and exertion), overall, these two variables were not correlated ($r = 0.084$, $N = 172$, $p = 0.275$; with $R^2_{\text{High exertion sync}} = 0.002$, $R^2_{\text{High exertion partial sync}} = 0.031$, $R^2_{\text{Low exertion rync}} = 0.013$, $R^2_{\text{Low exertion partial rync}} = 0.002$).

Participants' experience of the experiment

Analysis of the positive and negative affect data did not differ depending on the inclusion of testing group and class ($\chi^2 = 0$, $df = 1$, $p = 1.00$ for both versions of the model). For all conditions,

positive affect increased following the movement activity (Figure 3.4) and negative affect decreased on average (Figure 3.5) but these changes were not significant between conditions, and there were no significant main effects of synchrony and exertion (see Table 3.3).

Table 3.3 Results for positive and negative affect multilevel repeated measures analysis

		Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Time point	Positive affect	6.519	1	6.519	26.221	< 0.001
	Negative affect	8.090	1	8.090	36.276	<0.001
Time point *Synchrony	Positive affect	0.048	1	0.048	0.112	0.739
	Negative affect	0.000	1	0.000	0.002	0.964
Time point *Exertion	Positive affect	0.000	1	0.000	0.007	0.932
	Negative affect	0.572	1	0.572	2.540	0.112
3-way Interaction	Positive affect	0.771	1	0.771	3.064	0.081
	Negative affect	0.146	1	0.146	0.670	0.414

MLM includes testing group and class as levels.

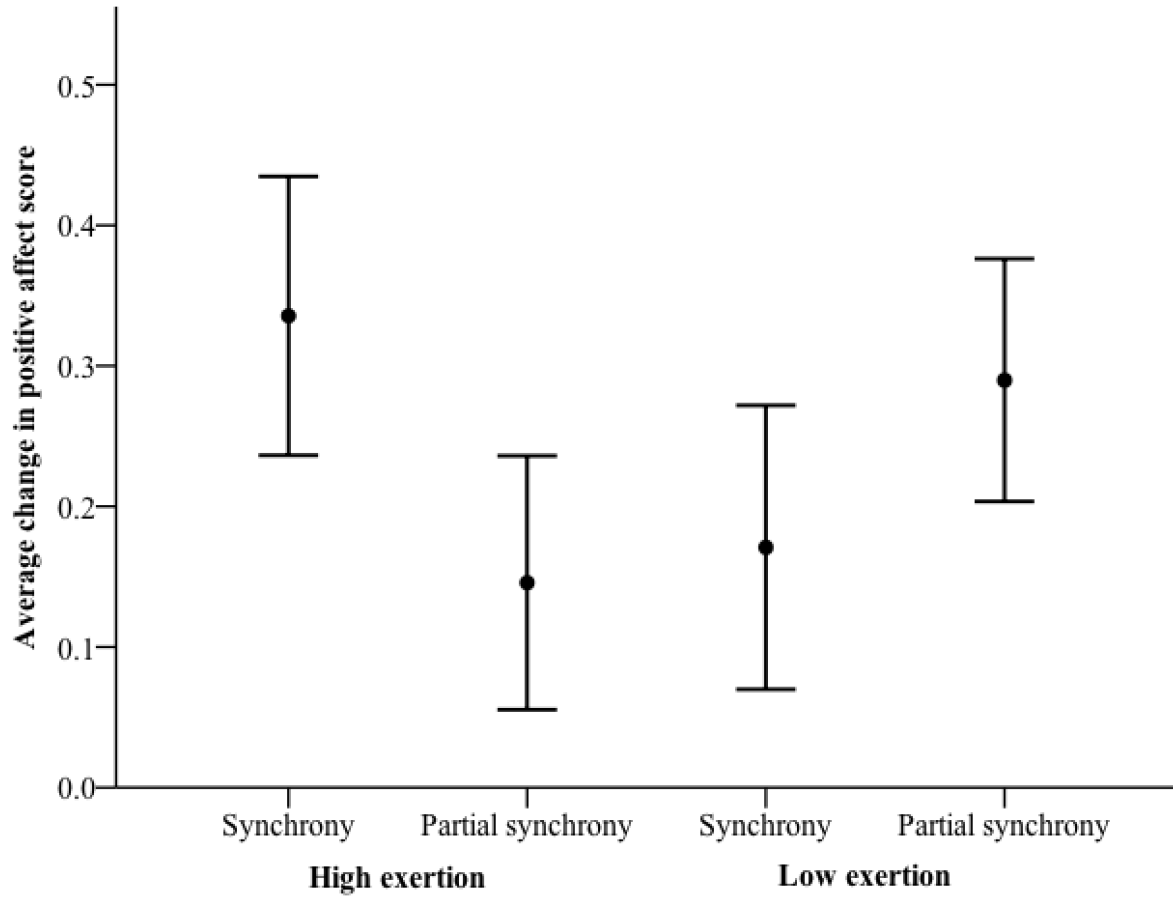


Figure 3.4 Average change (end – start) in positive affect scores for each condition (± 1 SE).

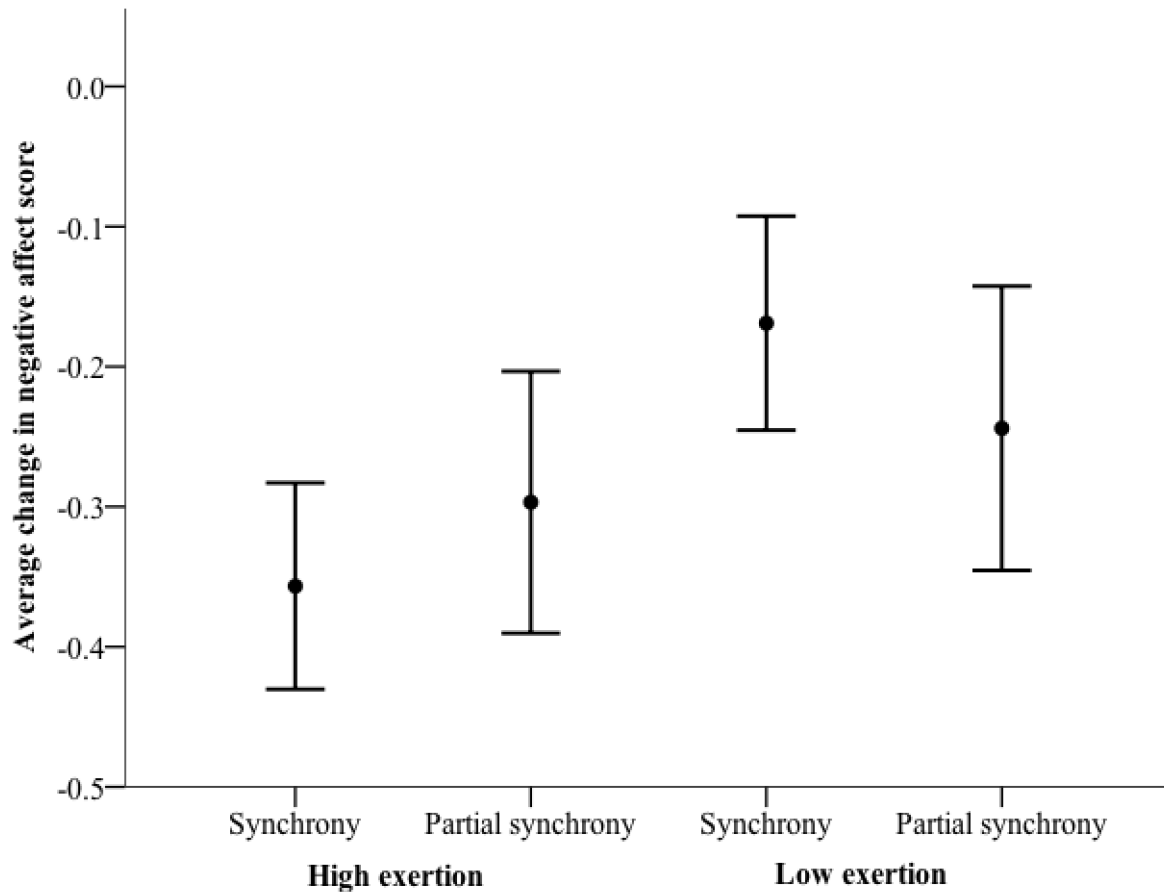


Figure 3.5 Average change (end – start) in negative affect scores for each condition (± 1 SE).

As predicted, there was no significant main effect of synchrony nor exertion on participants report of how much fun, embarrassment, enjoyment, difficulty and boredom they experienced during the experiment (see Appendix 7.2.6, Table 7.6 and Table 7.8). Notably however, there was almost a significant main effect of synchrony on how difficult participants found the movement task ($F(1) = 3.504, p = 0.065$), although inclusion of this score as a covariate did not change any of the results reported in the previous sections. Furthermore, there was no significant main effect of synchrony or exertion on the success index scores (see Appendix 7.2.6, Table 7.8).

3.7 Conclusion and discussion

Pain threshold and the role of endorphins in synchronous and exertive activities

Hypothesis 1: Pain threshold will be significantly affected by synchrony (1A), and exertion (1B), and there may be interactive effects between these.

In accordance with evidence from the rowing studies (Cohen et al., 2010; Sullivan et al., 2014; Sullivan & Rickers, 2013), the present study indicates that there is a link between exertive synchronous group movement and elevated pain threshold. Furthermore, these results indicate that low exertion synchronous tasks also result in elevated pain threshold, and that both synchrony and exertion have significant independent effects on this measure of endorphin release. Given that pain threshold is a widely used reliable proxy of endorphin release, these findings suggest that the EOS is likely to play a role in synchronous activities, independent of the level of exertion.

Although both high exertion synchrony and partial synchrony conditions included identical movements (in an attempt to control for exertive demand during the movement tasks), it is still possible that individuals exerted themselves to varying degrees. Listening to music whilst moving is known to decrease perception of exertion, enabling individuals to withstand more strenuous (i.e. painful) exercise (Karageorghis & Priest, 2012; Karageorghis & Terry, 2009). Furthermore, certain types of music enhance arousal and endorphin release more than other genres (e.g. techno music Gerra et al., 1998), and speed and volume of music can directly mediate physical output and perceived exertion (Edworthy & Waring, 2006). Although all conditions in the present study involved exactly the same music, research in the field of exercise and music highlight that individual musical preferences can moderate the degree to which high arousal music influences exertion (Terry & Karageorghis, 2006). Although music preference was not accounted for in the present study, the

conditions did not differ significantly in terms of affective arousal (based on the PANAS scores), nor according to the participant's self-reported musicality, dance abilities or how much music and dance activities featured in their weekly lives. This suggests that there were no differences in personal enjoyment across the conditions.

As a result, this study supports the finding that synchronisation can elevate pain thresholds independently from any effects of exertion (Cohen et al., 2010), and furthermore that both synchrony and exertion can have independent effects on pain threshold, i.e. release of endorphins. Given that endorphins are an important bonding hormone in other primates, this increase in pain thresholds during synchronous and exertive activities should also be associated with interpersonal bonding.

In-group but not out-group bonding

Hypothesis 2: Self-reported bonding (as measured by prosociality questions) will be significantly affected by synchrony (2A), and exertion (2B), for both the i) in-group and ii) out-group, with possible interaction effects between synchrony and exertion.

The results from this study suggest that the bonding associated with both synchronous and exertive group movement is directed towards fellow participants, rather than others who did not share the movement activity. Although ratings of out-group prosocial index were higher after the movement activity, this was not dependent on condition (see Figure 3.3).

The results from the in-group data confirms widespread evidence that synchrony can induce feelings of social closeness between participants, independent of exertion (as reviewed in Chapter 1). Importantly, these data contribute to our understanding of the effect of synchrony when there are more than two participants taking part. However, the fact that there was no such effect for the out-

group prosociality measure contrasts with some studies which demonstrated that similar movements can induce ‘generalised’ prosocial tendencies (e.g. Ashton-James et al., 2007; Reddish et al., 2014; Stel et al., 2008; van Baaren et al., 2004). The findings from the present study are better aligned with the alternative ‘parochial prosociality model’, which predicts that increases in prosociality following synchrony are biased towards co-actors taking part in the synchronisation (Reddish et al., 2014).

Wiltermuth and Heath (2009) reported that cooperation was mediated by feelings of sharing a team identity, for which active participation in a synchronised task would be key. Similarly, Hewstone, Rubin and Willis (2002) describe how group membership (signalled by subtle cues such as, *inter alia*, differential group sizes, identity) can lead to individuals being biased towards preferential treatment of others from their in-group, as opposed to non-group members. In the present study, the in-group consisted only of three individuals, whereas the out-group was far larger (approximately 25 individuals). The lack of a generalised effect in the present study may have been confounded by differential group sizes, as predicted by the fact that those in smaller (even experimentally constructed) groups feel a stronger in-group bias than those in larger groups (Hewstone et al., 2002). Furthermore, if synchronising provided a signal of group identity, then this might explain why the feelings of prosociality were directed towards fellow actors.

Although the categorisation of ‘out-group’ in the present study is different from that used in other studies (e.g. other participants in the same testing session but doing a different task: (Reddish et al., 2014), or a faceless charity: (Stel et al., 2008; van Baaren et al., 2004)), in the present experiment, synchrony did not have a generalised prosocial effect. It should also be considered that evidence relating to the neurohormonal mechanisms of bonding suggest that prosocial tendencies are generally directed towards specific individuals (e.g. mother-infant or pair bonding) and are context dependent (for, e.g. oxytocin: Bartz, Zaki, Bolger, & Ochsner, 2011). In experimental

settings, externally enhanced hormone levels (e.g. oxytocin nasal spray) can influence general affiliative tendencies (e.g. trust towards strangers: Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005), but some experiments highlight the fact that this generalised prosocial effect diminishes (and can even reverse) when dealing with an unknown individual (e.g. Declerck, Boone, & Kiyonari, 2010), or an out-group (e.g. De Dreu et al., 2010). Although the present study had an out-group that was familiar, it is important to also emphasize that in naturally occurring interactions, the activities which trigger neurohormonal release generally involve the individuals to whom the bonding is subsequently directed (e.g. child-birth, orgasm). In the case of endorphins, social bonding associated with the EOS in primate species is based primarily on dyadic experiences during which the activity, associated endorphin release, and observed bonding occur between specific grooming partners (e.g. Fedurek & Dunbar, 2009). It is plausible that synchrony induced social bonding via EOS activation may be similarly directed towards co-actors.

However, as illustrated by Figure 3.3, the out-group prosociality data have the same trend as the in-group data, but the results are non-significant. This suggests that potentially the effects of synchrony on out-group social bonding are present, but not as strong as the social bonding that occurs between co-actors.

The role of joint attention in in-group bonding

Importantly, in the present study, the change in social bonding (from the start to after the movement activity) was similar in the high exertion synchrony, partial synchrony and low exertion synchrony conditions (see Figure 3.2). The low exertion partial synchrony condition was the only condition for which there was no change in ratings of in-group prosociality index. This movement condition featured neither synchronous nor exertive elements, but the participants still spent time together and shared joint attention on the task.

Although joint attention can influence the degree of social bonding (e.g. Kirschner & Tomasello, 2010), this was not directly measured in the present study, nor other studies in this thesis. As a result it is discussed in more detail in the final discussion chapter ('The effect of joint attention', pg. 235). In the present experiment, it should be noted that in all conditions, successful execution of the activity required participants to pay attention to their own instruction card, and all groups received the instructions to also make eye contact with the other participants throughout the activity. Participants checked and corrected each other in both synchronised and partially synchronised conditions, which was facilitated by the fact that there were only three participants in each group, and only three available moves to be performed at any one time. In the partially synchronised conditions participants were immediately aware when someone made a mistake as it resulted in multiple people performing the same movement simultaneously. Similarly, in the synchrony condition if a participant forgot to move to the next movement, or miss-read their card, they could quickly self-correct based on visual feedback from the other participants. As a result, the differences between synchronous and partially synchronised conditions in this study are unlikely to be due to differences in joint attention, although direct measures (such as eye-tracking) would enable us to better rule out this possibility.

The lack of in-group bonding between individuals in the low exertion partial synchrony condition suggests that merely spending time together does not in itself encourage interpersonal bonding. Instead, in situations where no exertion nor synchrony are involved, alternative bonding elements may be necessary (e.g. laughter, talking etc.) to establish prosocial tendencies (Dunbar, 2004, 2012a, 2012b).

Synchrony versus partial synchrony

The use of a partially synchronised condition as the control movement condition in the present study has ecological validity as dance often involves individuals listening to the same music (i.e. temporal synchrony is possible), but performing unique movements. According to these results, the social bonding effects between acquaintances are greatest when individuals engage in behavioural rather than temporal synchrony, suggesting, as predicted, that self-other matching is occurring in this instance rather than when people perform mismatched movements. Well researched are the effects of synchronisation on social bonding in an (in-phase) synchrony condition in comparison to a non-movement condition (e.g. Wiltermuth & Heath, 2009), or situations where participants perform the same movement, but temporally out-of phase (e.g. Richardson et al., 2007), or sequentially (e.g. Reddish et al., 2013). It is well established that performing phase-locked movements is easier than temporally different movements (e.g. Schmidt et al., 1990; van Ulzen et al., 2008), and in the present study, those in the synchrony condition reported finding the movement task (almost significantly) easier than those in the partial synchrony condition, likely due to the fact that behavioural synchrony is the easiest situation to perceive and perform. The use of a control condition that has the same timing, but different movements, is a relevant addition to the range of possible control movement conditions. The next chapter goes one step further by including an asynchrony condition where there is both mismatched movements and timing (Chapter 4, pg. 129).

Conclusions

The findings of this study support evidence that unsynchronised (i.e. non behaviourally synchronised) exertive activities (e.g. team sports) can bond individuals (e.g. Mueller et al., 2003), as can low exertive synchronous activities (e.g. finger tapping; Hove & Risen, 2009).

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Furthermore, the data presented in this chapter illustrate that pain threshold increases during synchronous exertive activities, in accordance with evidence from the studies on rowing. The fact that partially synchronised exertive movement also elevates pain threshold, likely due to endorphins, is in accordance with studies on exercise and sports where participants do not perform identical movements simultaneously, but still experience an endorphin rush (e.g. Boecker et al., 2008; Dishman & O'Connor, 2009). The present study contributes to the field by providing evidence that pain thresholds increase during low exertive synchronous tasks.

The trends presented in this chapter indicate that a combination of exertion and synchrony result in a cumulative effect for both dependent variables (see Figure 3.1 and Figure 3.2), but that this interaction is non-significant. According to this, group dance, which is both highly exertive and synchronous, is an activity that 1) induces social bonds between individuals, specifically with others engaging in the task simultaneously (in-group), and 2) increases pain threshold (i.e. elevates endorphin release). The fact that there are no interactive effects between synchrony and exertion on either the social bonding nor pain threshold measures, and the lack of correlation between these two dependent variables suggests that the underlying mechanisms may not be directly related, or perhaps that they are mediated by a third factor not measured here. It should be considered that the non-correlative relationship between the social bonding and pain threshold measures may be a product of the fact that indirect measures were used to assess both dependent variables. Regardless, both synchrony and exertion have significant and non-interacting main effects for both variables, suggesting that an endorphin and self-other matching mechanisms are involved in social bonding during synchronous tasks that are non-exertive.

The present study provides novel data regarding the possible role of the EOS in the social bonding effects of synchronisation in dance. The next chapter builds on this by more carefully

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manipulating the audio-visual cues of synchrony by utilising a technique that allows for an additional ‘asynchronous’ movement condition to be included in the comparison, thereby investigating what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with endorphin release and social bonding during dance.

Chapter 4 – Silent disco experiment

4.1 Chapter abstract

This chapter introduces a laboratory-based synchrony paradigm to determine which aspects of synchrony are associated with endorphin release and social bonding between strangers. This experiment used the same movement conditions as in Chapter 3, but also included an asynchrony condition in which participants heard different music and performed different movements. This was achieved using a four-way headphone splitter ('Silent disco' technology). Four strangers learnt a series of dance moves in a private cubicle via video, and then danced in a group, each following their own audio instructions relayed through headphones. The instructions and music were identical for those in the synchrony condition, but unique for those in the non-synchronised conditions. Pain threshold (before and after) and prosociality (measured after) were determined using self-report questions and two behavioural games (weak link coordination game and trustee game). Participants wore 'Actiwatches' (accelerometer technology) in order to determine the intensity of their movement, which was included in analyses in order to control for the effect of exertion on social bonding and endorphin release.

The results support the findings reported in Chapter 3: those synchronising experienced elevated pain thresholds, whereas those in the partial and asynchrony conditions experienced decreased pain threshold and no change respectively. Similarly, those in the synchrony condition were more socially bonded (according to self-report measures, but not economic games). This study demonstrates that the positive effects associated with movement synchrony between strangers are not due to the act of synchronising to the music alone (as occurred in the partial and asynchrony conditions), nor do they rely on participants knowing what co-actors can hear: visual feedback

regarding their movements relative to others is sufficient. Overall, this experiment provides results consistent with the hypothesis that dance encourages social bonding amongst co-actors by stimulating the production of endorphins in the EOS, but a means of directly measuring or manipulating the EOS is necessary to better determine if it plays a causal and critical role.

4.2 Introduction

The link between synchrony and bonding has been reviewed in Chapter 1, and the subsequent two chapters (Chapter 2 and 3) provided initial evidence to support the hypothesis that dance can encourage social bonding amongst co-actors by stimulating the production of endorphins in the Endogenous Opioid System. Chapter 2 demonstrated that tighter controls (not afforded in real-world examples of group exertive activities) are desirable in order to determine what aspects of synchronising (to music and others) are associated with social bonding effects. Chapter 3 introduced the use of pain threshold as a proxy measure of endorphin release, and also highlighted the importance of controlling for exertion when measuring the effects of synchrony on social bonding and pain thresholds.

The present study builds on the two preceding data chapters in four main ways. Firstly, the manipulation of synchrony was refined via the use of sophisticated ‘silent disco technology’, in which a headphone splitter allowed for control over each participant’s audio experience. Due to this technology it was possible to include an additional asynchrony condition (described in more detail below). A second improvement was the use of actigraphy accelerometers, which quantified intensity of movement thereby allowing for some control of exertion in the analysis of pain threshold and prosociality. Thirdly, the self-report prosociality questions used in Chapter 3 (IOS, trust, connectedness, likeability and similarity) were supplemented with behavioural measures of cooperation obtained by two economic games (and the trustee game: Launay et al., 2013; the weak

link coordination game: Wiltermuth & Heath, 2009). Finally, unlike the previous chapter, the present experiment explicitly targeted strangers in order to determine the effects of movement synchrony on establishment (rather than maintenance) of social connections.

Manipulating interpersonal synchrony

Manipulations of interpersonal synchrony most commonly involve the provision of audio, visual, or audio-visual stimuli that allow participants to synchronise their movements with one another and to an isochronous beat (for a review see Chapter 1: ‘Experimental evidence linking synchrony and social bonding’, pg. 37). The relative importance of the audio-visual feedback, and the social context is debated (see Chapter 1: ‘Audio-visual feedback during synchrony’, pg.38). According to Demos et al. (2012), visual feedback of synchrony with another person is key in spontaneous interpersonal coordination, and when synchronising in the presence of shared music, participants reported feeling closer to one another. These findings suggest that synchrony (in the presence of others) to a (shared) externalised beat (as provided by music) can make people feel more socially bonded. Under these circumstances, synchrony *between* people is argued to be a by-product of synchrony with the music, rather than a direct driver of social closeness.

Empirical investigation of the effects of synchrony requires comparison to a carefully matched non-synchronised condition. As discussed in the conclusion of the Chapter 3 (‘Synchrony versus partial synchrony’, pg. 126), there are limitations associated with control conditions used in previous studies, such as non-movement conditions, phase-manipulated synchrony or sequential movement conditions. Although the previous chapter introduced a partial synchrony condition which will also be used in the present experiment, the shared music set-up of Chapter 3 is not conducive for the creation of a suitable asynchronous condition in which participants move at different tempos or to different music. A relevant asynchronous condition for the present

experiment requires participants to perform different movements of similar exertion level and in the presence of music. This is difficult to achieve with the shared-music paradigm used in Chapter 3 because people subconsciously and spontaneously synchronise their movements (Demos et al., 2012; Richardson et al., 2007), even when they are told explicitly not to do so (Issartel, Marin, & Cadopi, 2007). In order to avoid this potential confound, it is necessary to manipulate the auditory experience of each participant individually. To achieve this, the current experiment used ‘silent disco’ technology, with different individuals listening to music on headphones that provide personal stimulus material that can either be identical or unique compared to that of others.

Silent-disco technology

‘Silent discos’ are dance parties at which the music is relayed through wireless headphones rather than conventional speakers. A central music source (controlled by a DJ) uses radio waves to transmit music to the headphones, and most systems can support two or three channels simultaneously, allowing multiple tracks to be played at the same time. Silent-disco technology is popular in the modern entertainment industry because it results in limited sound pollution (all music is relayed through the headphones alone), and patrons are able to choose between alternative channels, each of which plays an independent music track. At silent-disco parties, the tracks played on different channels often differ significantly in genre, mood, and tempo, resulting in individuals mismatching their dance movements with others alongside them (for a description of this, see Cummins, 2009). This multiple-channel system is thus perfectly suited for manipulating audio-visual experiences and movement synchrony amongst groups of individuals in an experimental setting.

The silent-disco paradigm has been used to test the link between music-induced motor coordination and person-perception (Woolhouse & Tidhar, 2010). Woolhouse & Tidhar (2010), had groups of 10 strangers dancing freestyle (i.e. making up their own movements to music) whilst

wearing sashes of various colours and labelled with different symbols. The participants were covertly assigned to one of two music channels, thereby splitting the group into two sub-groups based on which music channel their headphones were tuned to. They found individuals who danced to the same music remembered more details about one another (termed ‘social memory’ in their study, and measured by recollection of sash colour and symbols worn by each of the other participants; *ibid*). It was proposed that differential attention paid towards those in- or out- of synchrony might underpin the fact that social memory was enhanced by movement in time to the same music.

A follow-up study measured gaze-time and memory of clothing details by stationary participants who were presented simultaneously with a audio-visually synchronised and non-synchronised videos of a dancer (Hadley, Tidhar, & Woolhouse, 2012). The results confirmed that participants spend more time looking at the dancer if they were synchronised with simultaneously presented auditory stimuli compared to mismatched audio-visual stimuli, although this did not lead to better memory for details about the dancer (*ibid*). Furthermore, in the original silent disco experiment, it was not clear whether people were entraining to each other or the music, merely that they were either listening to the same stimulus or not (Woolhouse & Tidhar, 2010). Nevertheless, this study does demonstrate the practical possibilities afforded by silent disco technology when it comes to testing the effects of audio-visually manipulated experiences of synchrony.

Reddish et al. (2013) used a similar set up (termed a four-way headphone splitter in their experiment) to manipulate synchrony (reviewed in more detail in Chapter 1: ‘Group synchrony and social bonding’, pg. 40). In contrast to Woolhouse & Todhar (2010), Reddish et al. (2013) directly manipulated synchrony by having participants perform a pre-learnt movement sequence in time to the metronome stimuli relayed through the headphones. The study presented in this chapter used a similarly adapted silent-disco paradigm to manipulate the experience of movement synchrony during

dance in testing groups consisting of four participants. Participants were either all listening to the same music channel (synchrony condition), or each allocated a unique channel (i.e. non-synchrony conditions).

Identical to the design of Chapter 3's experiment, the present study included a non-synchrony condition where individuals heard the same musical stimuli, but performed different movements from one another. However, using the silent-disco technology described above it was possible to add an additional condition, referred to as 'asynchrony'. In the asynchrony condition, participants each heard a *different* music track (of a different genre, and with a different tempo). In addition, as the present study was based in an experimental laboratory, it was possible for each participant to learn the dance movements in private, via an instruction video. This allowed each participant to learn a unique repertoire of movements, such that during the silent disco, participants not only heard a different music track at any one time, but also performed different movements from the others in their testing group. Given that this involves both different movements and different timing, which is notably different from other non-synchrony conditions used in previous studies (e.g. Launay et al., 2013; Reddish et al., 2013; Wiltermuth & Heath, 2009) it is not known how it will compare to the partial synchrony condition. However, based on the findings in the previous chapter it is expected that the synchrony condition will be the most conducive for elevating pain threshold and measures of social bonding.

The results from the previous chapters indicated that exertion can have an independent and significant effect on pain threshold and measures of bonding. Previous studies investigating the role of synchrony on endorphin release (as measured by pain threshold) have focused on exercise (rather than dance) activities where exertion was fairly easily monitored by controlling physical output. For example, in their study on synchrony in rowers, Cohen et al. (2010) had participants replicate the

same power output (speed and length of time rowing) during the synchronised and individual (non-synchronised) trials (reviewed in more detail in Chapter 1: ‘What activates the EOS in humans?’, pg. 44). In this way, participant’s exertion was standardised across each condition. However it was not possible to standardise exertion in the present study because participants in different conditions were performing different moves, which might involve differing levels of exertion. Given that exertion was not directly manipulated, it was instead measured using Actiwatches.

Actigraphy: measuring activity and exertion

Accelerometer actigraphy technology is a cost effective, objective and robust means of measuring physical activity in which small body-mounted devices capture moment-by-moment activity data (Gironda, Lloyd, Clark, & Walker, 2007). Actigraph accelerometers are typically worn at the waist or another body part (such as the wrist or foot), and provide an output (‘activity count’) per unit of time. ‘Activity count’ is the generic term used to describe the intensity of a movement, i.e. the “amplitude of the signal produced by the accelerometer in the Actiwatch” (CambridgeNeurotechnology, 2008, p. 60). This is calculated using the amplitude of positive or negative displacement from the vertical axis of the accelerometer per unit time (Gironda et al., 2007). The watch samples the amplitude 32 times every second and saves the highest amplitude per second. These second-by-second amplitudes are summed to create the final activity count per time epoch (e.g. 15 second epoch is the sum of 15 amplitudes: CambridgeNeurotechnology, 2008). By calculating the net acceleration during the displacement caused by a body movement (e.g. a hand wave), the actigraph provides a measure of the intensity of physical activity that is less subjective than observer ratings and self-report measures of activity.

Actigraphs have been confirmed as a valid and reliable method of measuring physical exertion in laboratory settings (e.g. Gironda et al., 2007; Leenders, Nelson, & Sherman, 2003;

Sandroff, Motl, & Suh, 2012), and have been validated in studies on sleep (Ayas, Pittman, MacDonald, & White, 2003; Wulff, Dijk, Middleton, Foster, & Joyce, 2012), chronic pain-intervention therapies (e.g. Liszka-Hackzell & Martin, 2005), and physical rehabilitation (e.g. Sandroff et al., 2012). A commonly used actigraph is a small unobtrusive ‘Actiwatch’ which is fitted to the participant’s wrist (CambridgeNeurotechnology, 2006).

In the present study, participants wore an Actiwatch during the training period (when learning their dance repertoire) and during the silent disco. The resulting measures of exertion were included as a covariate in analyses on pain threshold and social bonding in order to remove effects that occurred as a consequence of exertion. Based on the findings presented in Chapter 3 it is expected that after controlling for exertion, those in the synchrony condition will experience elevated pain threshold and be more socially bonding compared to those in the non-synchronised conditions.

Economic games as a behavioural measure of social bonding

As a final improvement on the experiments reported in the previous two data chapters, the present experiment included two economic games as measures of how much social bonding had occurred between participants. As discussed briefly in Chapter 1 (‘An experimental approach: operationalising the constructs’, pg. 7) and Chapter 2 (Introduction: ‘Economic games as a measure of prosociality: the dictator game’, pg. 62), economic games are a commonly used behavioural measure in which monetary decisions are taken to reflect the degree of generosity or cooperation (e.g. Launay et al., 2013; Wiltermuth & Heath, 2009). Behavioural measures are a useful compliment to self-report measures of prosociality which can suffer from demand characteristics (Eisenberg & Fabes, 1990).

The dictator game (used in Chapter 2) is the easiest game to implement as it does not require multiple rounds or stages, merely a once off donation. In the present experiment, which was conducted in a laboratory with computer access, it was possible to perform more complex behavioural measures more commonly used in other studies researching synchrony and social bonding: the ‘weak link coordination game’ (e.g. Wiltermuth & Heath, 2009), and the ‘trustee game’ (e.g. Launay et al., 2013).

Weak link coordination game

The weak link coordination game is an adapted version of a ‘public goods’ game. Public goods games involve participants deciding how much money to contribute to a public good, and the amount in the public good depends on the total of all participants’ contributions. This total amount is then increased by some factor (e.g. doubled) by the experimenter, and re-distributed equally among all players. The weak link coordination game, first studied by Van Huyck et al. (1990), differs from other public goods games in that the value of public good generated each round is determined by the *minimum* contribution by any one player in that round (i.e. the “weakest link”; Weber, Camerer, & Knez, 2004), rather than a gross total of contributions made by all players (Croson, Fatas, & Neugebauer, 2005). Players make contribution decisions over a number of rounds, and in each round, an individual’s profit (in money) is an increasing function of the lowest amount contributed (by anyone), and a decreasing function of the difference between this lowest amount and individual’s donation for that round (Weber et al., 2004). The game requires coordination as each player should attempt to contribute no higher than the minimum, while a larger minimum contribution results in a higher average pay-out for all players in each round. As a result, the weak link game gives rise to multiple equilibria (rewarding groups who converge on the minimum amount contributed). The most profitable strategy for all players is for all to coordinate their contributions,

and to contribute the maximum amount in every round (Croson et al., 2005). Given that the weak link coordination game has a continuum of Nash equilibria (i.e. there is a continuum of most rational strategies: Camerer, 2003), this game was used in a keystone study by Wiltermuth & Heath (2009), who investigated the effect of movement synchrony on cooperation, and found that synchrony fosters cooperation, likely due to strengthened social bonds (for a more detailed review of the findings of this experiment see Chapter 1: Group synchrony and social bonding', pg. 40).

Trustee game

The trustee game has been used extensively to determine the degree of trust between individuals, as measured by monetary investments made from one player ('Player 1') to another (Johnson & Mislin, 2011). This game was first designed by Berg, Dickhaut & McCabe, (1995), and commonly involves two-stages. In the first stage, Player 1 receives a certain quantity of money (e.g. £10) and can entrust, or 'invest' x amount of this ($0 \leq x \leq 10$) in another (assigned) individual in the testing group. At this stage, Player 1 is left with $10 - x$. Player 2 receives y amount, which is the donation of x increased by the experimenter by a certain factor (e.g. doubled: $y = 2x$). In the second stage of the game, Player 2 decides what portion of y to return to Player 1. The amount initially donated (x) is interpreted as an indicator of trust or a belief in Player 2's likelihood to reciprocate (i.e. a large investment by Player 1 is interpreted as signalling a high level of trust), and the amount returned ($\leq y$) is interpreted as a measure of Player 2's trustworthiness (Johnson & Mislin, 2011). Overall there is more profit to be made if Player 1 donates more (due to the multiplication), but Player 1 is not guaranteed this pay-out as it depends on the decision by Player 2, who is under no obligation to reciprocate.

According to some studies, Player 1 invests more initially (i.e. exhibits more trusting behaviour) if they have social connections to the other players, and this measure of trust is sensitive

to manipulations of connectedness (Buchan, Johnson, & Croson, 2006; Glaeser, Laibson, Scheinkman, & Soutter, 2000). The trustee game has been used to confirm that trusting behaviour increases under a range of circumstances (Berg et al., 1995; Johnson & Mislin, 2011). For example, Launay et al. (2013) used the trustee game to demonstrate that dyadic synchronous movements (tapping to sounds) led to higher contributions. As a result, it is expected that contributions made in this economic game will be affected by a manipulation of synchrony.

Prosociality between strangers rather than acquaintances

Chapter 3 was concerned with investigating the social bonding effects of synchrony between people who already knew each other, and the results indicate that dance synchrony can contribute towards maintenance of these relationships by increasing feelings of closeness. However, as outlined in Chapter 1 ('Mechanisms of social bonding: The EOS', pg. 20), bonding activities such as dance are likely to play a role in both maintaining and establishing relationships.

The present study focussed on the effect of group synchrony in groups of strangers. In order to avoid biasing participants prior to the movement session (and given that participants were purposefully placed in a testing group with individuals they had never met), it was decided that prosociality measures would not be collected at the start of the experiment, but only after the movement activity. In Chapter 3, multilevel analysis of the before and after prosociality data helped to control for individual variation in participants' interpersonal relationships. In the present experiment, it was decided that a personality scale (Mini-IPIP five factor scale: Cooper, Smillie, & Corr, 2010) should be included to check that there were no chance differences in the types of people allocated to the different movement conditions.

Personality has been shown to affect music preference (e.g. extraverts prefer stimulating music: McCown, Keiser, Mulhearn, & Williamson, 1997), and there is some evidence that personality traits are a significant predictor of some neurohormonal responses to music (e.g. those with novelty-seeking temperament and low harm avoidance tendencies demonstrate significantly higher changes in beta-endorphin and other neurotransmitters when listening to techno music: Gerra et al., 1993). Although a large enough sample size and random allocation to movement condition is expected to avoid any potential affect of personality on the outcome measures in the present study, a personality scale was included as a precautionary measure.

4.3 Hypotheses and predictions

Hypothesis 1: Pain threshold is significantly affected by whether the movement condition is synchronous, partially synchronous or asynchronous.

Predictions:

- A) Individuals moving in synchrony will have a greater elevation in pain threshold compared to the partial synchrony and asynchrony conditions.

In addition, partial and asynchrony conditions may or may not differ.

Hypothesis 2: Social bonding (as measured by self-report prosociality questions, and economic games) is significantly affected by whether the movement condition is synchronous, partially synchronous or asynchronous.

Predictions:

- A) Individuals moving in synchrony will give higher ratings on the self-report measures of prosociality compared to those in the partial synchrony or asynchrony conditions.
- B) Individuals moving in synchrony will contribute more money on average, and will reach a higher equilibrium of donations in the weak link coordination game compared to those in the partial and asynchrony conditions.
- C) In the trustee game, when acting as Player 1, individuals moving in synchrony will be more trusting (i.e. donate more money to Player 2). As Player 2, they will be more trustworthy, and return more money to Player 1, compared to those in the partial and asynchrony conditions.

In addition, partial and asynchrony conditions may or may not differ for these various prosociality measures. Furthermore, by measuring personality type, participants' perception of success, fun, enjoyment, difficulty, embarrassment, positive and negative affect, or confidence levels in their ability to remember the dance moves, it is possible to test whether any effects of synchronisation are independent of these factors. Additionally, it is expected that the main effect of movement condition on PTT and prosociality will be independent of any effect of exertion (as measured by the Actiwatches).

4.4 Methods

4.4.1 General

The study was advertised as 'Silent Disco Experiment: a study on physical coordination, and memory', with no mention of the hypotheses relating to synchrony and bonding. Data were collected between October 2012 and June 2013 at Oxford University. A total of twenty-seven

testing sessions were conducted, with 103 participants in total (see Table 2.1). Age of participants ranged from 18 – 52 years ($M = 24.17$, $S.D = 5.155$). The sample included 27 males and 76 females.

Table 4.1 Outline of experimental conditions. Total $N = 103$ participants.

Condition	Number of testing groups	Number of participants
Synchrony	13*	$n = 57$
Partial Synchrony	6*	$n = 22$
Asynchrony	6	$n = 24$

**on three occasions testing groups were short of one participant due to a last minute cancelation.*

4.4.2 Data structure

The dependent variables of interest are similar to those in Chapter 3 (Data structure', pg. 104):

- 1) Pain threshold test (as a proxy for endorphin release, measured at the start of the experiment and at the end, after physical activity, referred to as 'PTT start' and 'PTT end' respectively); and
- 2) Prosociality measures (only measured after the movement session). These questions included measures of IOS, connectedness, likeability, and similarity in personality (see Appendix 7.3.1). Each participant rated these five measures (on a scale of 1 – 7) with respect to their testing group, and data were combined to create a Prosociality Index (see Section 4.5.2). A subset of the participants also played two economic games: the weak link coordination game, and the trustee game.

The independent variable is movement condition (synchrony, partial synchrony or asynchrony). Other variables of interest are (for the exact questions used see Appendix 7.3.1):

- 1) Activity score, acquired from Actiwatches, which measured the intensity of participant's physical activity during the training and silent disco section of the experiment.
- 2) 10-point Positive And Negative Affect Scale (PANAS) determining self-reported affect before and after the activity, calculated according to (Mackinnon et al., 1999).
- 3) Mini – International Personality Item Pool (IPIP) five factor scale (Cooper et al., 2010).
- 4) Confidence measure (ability to remember how to do the dance moves).
- 5) Self-reported success measures (after the silent disco): success at following the audio instructions (termed 'Instruction Success' score and asked to participants in all movement conditions); and success at synchronising movements, to either the musical beats (termed 'Music Synchrony Success' score and asked to those in the partial synchrony and asynchrony conditions) or with the other participants and to the musical beat (termed 'Overall Synchrony Success' score and asked only to those in the synchrony condition).
- 6) Self-reported measures of fun; embarrassment; difficulty; and enjoyment during the silent disco.
- 7) Hypothesis check to determine if any of participants had guessed the purpose of the research.

4.4.3 Participant selection and allocation of condition

Participants included University students and staff, and members of the general public recruited from the local area. Prior to participation, those interested were asked to complete an online screening questionnaire. Based on individuals' answers to the online screening, suitable participants were included according to their age (18 – 55), and excluded from the study if they were

pregnant, lactating or diabetic as individuals in these situations have been shown to have higher pain thresholds (McKinney, Tims, et al., 1997). Participants were advised to not smoke or drink within the two hours prior to their experiment slot to avoid moderation of baseline pain threshold.

Testing groups were randomly allocated to a movement condition prior to their experimental slot. Research assistants (undertaking the pain threshold measures), were blind to the condition.

4.4.4 Actiwatch motion monitor

After giving informed consent, an Actiwatch was attached to each participants right wrist. The right wrist was chosen because the dance movements selected for the present study specifically involved arm activity, and in the event of only one arm being used, the participants were instructed to use their right hand. The Actiwatches were programmed to store an activity score every 15 seconds (the lowest possible epoch). The Actiwatch data were downloaded from the watches using ‘Actiwatch Activity and Sleep Analysis’ software (Actiwatch software version 5, CambridgeNeurotechnology, 2008).

4.4.5 Pre- and post-disco pain threshold measure (PTT)

Following the attachment of the watch, each participant was taken to a private cubicle where their pain threshold (PTT) was measured using the same method described in Chapter 3 (‘Pre- and post-movement session pain threshold measure (PTT)’, pg. 106). As in Chapter 3, PTT was measured twice during the data collection session: at the start of the experiment (‘PTT start’), and at the end (immediately after the silent disco: ‘PTT end’). Similar to the protocol followed in Chapter 3, the pain threshold test was administered to all four participants simultaneously (one research

assistant per participant) and each researcher attended to the same participant for the PTT start and end measures.

4.4.6 Pre-disco questionnaire

Following the PTT start measure, each participant completed a questionnaire on a computer in a private cubicle. This questionnaire included basic demographic information, mini-IPIP personality scale, and the Positive And Negative Affect Scale (PANAS). Full details of this questionnaire are given in Appendix 7.3.1).

4.4.7 Movement training

Following the questionnaire, participants learnt four basic dance moves under the instruction of a pre-recorded video, which they viewed in private in their cubicle. Each move was named (e.g. 'Driving'; 'Point') and the training video lasted eight minutes, during which each movement was taught slowly and then practised (at first with a metronome and then to music) so that participants would be able to perform the moves independently when prompted only by the name of the dance moves (see Appendix 7.6.2, and the DVD: Chapter 4, folder 4.1 Silent Disco training videos). Before moving on to the silent disco session, they were asked to rate their confidence in their ability to remember the dance moves.

In the synchrony and partial synchrony conditions, all participants learnt the same dance moves. In the asynchronous condition each dancer was taught a unique repertoire of dance moves.

4.4.8 Silent disco

Following the training period, participants stood facing inwards, each on a marked space separated from each other by 1 meter (see Figure 4.2). Each participant received a set of wireless

headphones, which played music tracks, with pre-recorded auditory instructions (indicating which dance move to perform) layered over. Music was selected and edited on the basis of a clear quadruple beat in order to allow ease of entrainment. In the synchrony condition, all four participants listened to the same audio channel, i.e. they all heard the same music, with the same auditory instructions at the same time (see Figure 4.1).

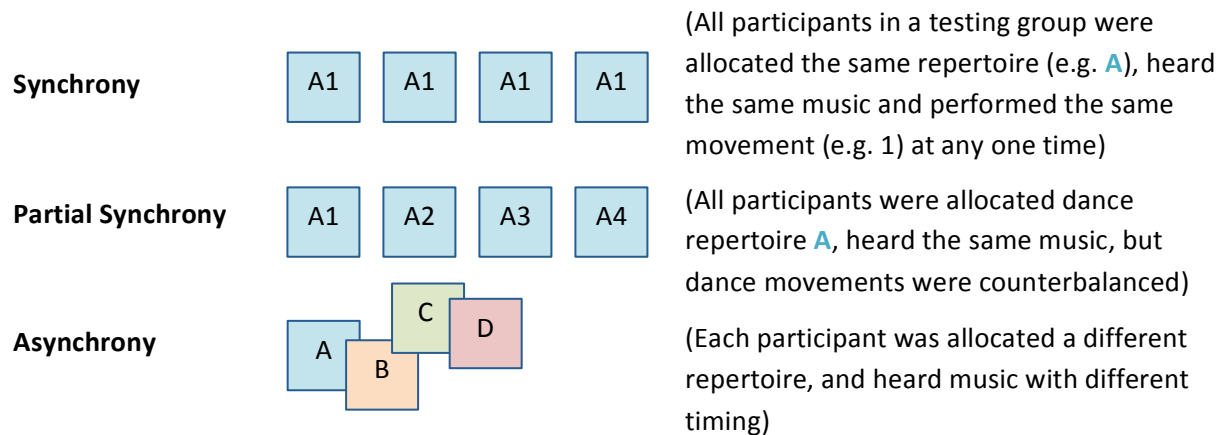


Figure 4.1 Outline of the dance repertoires (A, B, C or D), and moves (1, 2, 3, or 4) allocated to each of four participants in a testing group in the synchrony, partial synchrony and asynchrony movement conditions. The spacing of the boxes indicates the timing of the musical stimulus.

In the partial synchrony condition, the auditory instructions differed for each participant (i.e. the dance movements were counterbalanced such that no two participants were performing the same dance move at any one time) but all still heard the same music. In the asynchrony condition, each participant heard a different music track (resulting in no rhythmic or tempo congruity between participant’s stimuli) and heard instructions tailored for their unique repertoire. Across all movement conditions the same musical stimuli were used, but in the asynchrony condition the order of the music tracks was different for each participant. The silent disco lasted 13 minutes and the experimenters were not in the room during this time (see Appendix 7.6.2 for the instructions, and DVD for the stimulus material: folder 4.2 Silent Disco movement session tracks).

a)



b)



Figure 4.2 Participants taking part in the a) synchrony condition, and b) a non-synchrony (either partial or asynchrony) condition (for examples of the silent disco see DVD: folder 4.3 Silent Disco movement session video samples).

4.4.9 Post silent disco questionnaire

Following the silent disco and PTT end measure, participants returned to their cubicles and answered a questionnaire (see Appendix 7.3.1), where they rated various prosociality questions, questions relating to success, fun, embarrassment, difficulty, enjoyment, and the PANAS. Participants also played two economic games: the weak link coordination game and the trustee game (see below). The games and questionnaire were programmed and conducted with the experiment software z-Tree (Fischbacher, 2007). At the end of the experiment, participants were asked to report what they thought the experiment was about (i.e. a check for demand characteristics), and no individuals guessed the correct hypothesis.

The weak link coordination game

This game was played using (electronic) tokens to represent money. Each participant was given an endowment of 20 tokens at the start of each of 5 rounds. They could keep as many tokens as they wanted, but could decide to donate any number of the tokens to a public pot. The lowest contribution to the public pot was doubled and then paid back out to each participant. This was repeated each round. The assumption is that people will decide to donate more if they expect others in the group to also donate generously, i.e. the game provides a measure of coordinated trust. At the end of each round the participants receive information about the minimum contribution made so they can adjust their next decision accordingly. Over the 5 rounds, a well-coordinated group will demonstrate a consistent average donation, with smaller standard deviation, indicating that the group has established a joint strategy. The game was adapted from Wiltermuth and Heath 2009, and the instructions are included in Appendix 7.3.2).

Trustee game

The trustee game had two stages. In the first stage participants acted as Player 1: they were each told they had been allocated 5 pounds (electronically) and were asked to decide how much to donate to Player 2, a randomly assigned individual from their testing group. Player 1 could only donate full numbers to Player 2 (i.e. £1, £2, £3, £4 or £5), and before receiving Player 1's donation, the experimenter doubled the amount donated. In the second stage, each individual acted as Player 2: they were asked to fill out a table indicating how much money they would return to Player 1. Given that Player 1's donation was doubled by the experimenter before being received by Player 2, the table included the hypothetical donation options (i.e. £2, £4, £6, £8 or £10). Player 2 filled out how much they would return to Player 1 for each of the possible amounts. Participants were told that at the end of the experiment they would receive their earnings in cash, but in reality the amount of money each participant received was standardised (to an average amount that one could plausibly earn during the economic games).

4.5 Analyses

Analyses were conducted in R64-3.03 (for the multilevel analyses) and SPSS 20 for all other analyses.

4.5.1 Pain threshold data exclusion

As described in Chapter 3 ('Pain threshold data exclusion', pg. 110) participants were excluded from the pain threshold analyses if they reached the maximum PTT at either the start or end time point (reducing the sample size ($N = 103$) to 94 participants). On occasions when this influenced the trend in significance between conditions, I report these differences.

4.5.2 Prosociality Index

As described in Chapter 2 ('Prosociality index', pg. 71) a Prosociality Index was created by averaging the scores for the four prosociality measures which were measured using a 7-point Likert scale (IOS, connectedness, likeability and similarity in personality). The index was justified on the basis of Cronbach's reliability test. As these same measures were used in an identical experimental design in Chapter 5, calculation of the reliability of the index included all the data from both this chapter and Chapter 5. The four measures had sufficiently high reliability ($\alpha = 0.754$; Field, 2009), and removal of any of the prosociality questions did not improve the alpha value (see Appendix 7.3.3, Table 7.10).

4.5.3 Actiwatch data

The output files were converted into comma-delimited text files and trimmed to provide each participant's activity score data for both the training period and silent disco period of the experiment. The mean activity count for each of the two movement episodes (training and silent disco sections) were calculated for each participant.

4.5.4 Normality testing and homogeneity of variance

Data were tested for normality and homogeneity of variance using Kolmogorov-Smirnov tests and Levenes' tests respectively. All data had homogeneous variance, and occasionally, the distributions of the data were significantly different from normal (see Appendix 7.3.4). Log transformation did not change the distributions, and as with the previous chapters, multilevel modelling was used chosen as the most appropriate for of analysis due to the fact that it is robust, and equivalent non-parametric tests are not available (as mentioned in the previous chapter, 'Multilevel linear modelling', pg. 111).

4.5.5 Multilevel linear modelling

As in the previous chapters, data in the present chapter is hierarchical in structure. Participants' pain thresholds were measured multiple times, and were assigned a particular dance repertoire and movement condition, and took part in testing groups (of four individuals). Many of the dependent variables (e.g. prosociality measures and success scores) involve participants rating their fellow participants. This means that the data collected within each testing group are non-independent (i.e. participants within a testing group are likely to have more similar ratings than participants across different testing groups, reflecting some of the shared experience of bonding that occurs within a testing session). Including testing group as a second level in the MLM accounts for the non-independence of group membership.

The repeated measure dependent variables (i.e. within-subject measures of PTT and PANAS) were modelled using the fixed factors of time point (i.e. at the start and end), and movement condition (synchrony, partial synchrony and asynchrony), including interactions between these effects. Participant ID was added as a Level 1 random intercept (effectively accounting for the individual variation in the repeated measure), and testing group was added as a Level 2 random intercept (accounting for testing group effects). As with data presented in Chapter 2, χ^2 analysis was used to determine which model had the best fit, and where the models were not statistically different only the results for the model that included both individual and testing group as levels in the analysis are presented.

The variables which were only measured after the synchrony manipulation (i.e. the between subject measures of prosociality index, the silent disco activity score, success measures and measures of fun, enjoyment, difficulty, embarrassment, confidence and the various personality measures) were also analysed using MLM analyses which included testing group as a level. The MLM was compared

to a linear model which did not include testing group in the analysis, and when both suggested similar trends in significance only the results for the MLM are reported because this analysis is theoretically most appropriate for the design. The activity score, and any personality or other baseline measures which were significantly different between participants in different movement conditions were included as covariates in the subsequent analyses.

4.5.6 Additional analyses

In addition to the above analyses testing the differences between conditions relative to each other, a one-sample T-test was conducted on the change in PTT data (end score – start score) in order to determine how each movement condition compared to zero change. When data were significantly non-normally distributed, an equivalent Wilcoxon signed ranked test was used instead.

4.6 Results

4.6.1 Baseline differences between movement conditions

Personality types

The participants in the various movement conditions did not differ according to the personality measures of agreeableness, neuroticism, intellect and extraversion (see Appendix 7.3.5, Table 7.11). However, there was a difference in conscientiousness between participants in the different conditions ($F(2) = 3.654, p = 0.029$) and posthoc pairwise comparisons indicated that those in the synchrony condition scored significantly higher on the conscientious scale ($M = 14.389$) than those in the partial synchrony condition ($M = 12.136; t = -2.623, p = 0.010$). Given that we would not expect self-reported conscientiousness to have been influenced by the experimental conditions these differences were assumed to reflect baseline personality differences and the

conscientiousness score was included as a covariate in all subsequent analyses of pain threshold and prosociality index.

Confidence level prior to the movement activity

After the training period, but prior to the silent disco, participants were asked how confident they felt in their ability to remember the dance movements. Confidence was significantly different between the different condition groups ($F(2) = 4.305, p = 0.016$). Pairwise comparisons of coefficients indicated that those in the synchrony condition felt significantly less confident ($M = 3.719$) compared to those in the partial synchrony condition ($M = 4.318; t = 2.910, p = 0.005$). Given this baseline difference between the movement conditions, confidence score was included as a covariate in subsequent analyses.

Activity score and exertion

The average activity score was significantly higher on average during the silent disco ($M = 659.98, S.D. = 204.298$) compared to the training period ($M = 441.72, S.D. = 153.383; (F(1) = 440.19, p < 0.001)$), suggesting that when participants were performing the movements in the presence of others they moved more intensively, which could be because they were moving more continuously or because they exerted themselves significantly more during the silent disco. The activity scores were strongly correlated between these two periods for each of the movement conditions ($r(99) = 0.916, p < 0.001$; see Figure 4.3). Given this high correlation, and the fact that the silent disco section was in theory the relevant period for investigation into the various dependent variables, only the activity score from this period was considered in further analyses.

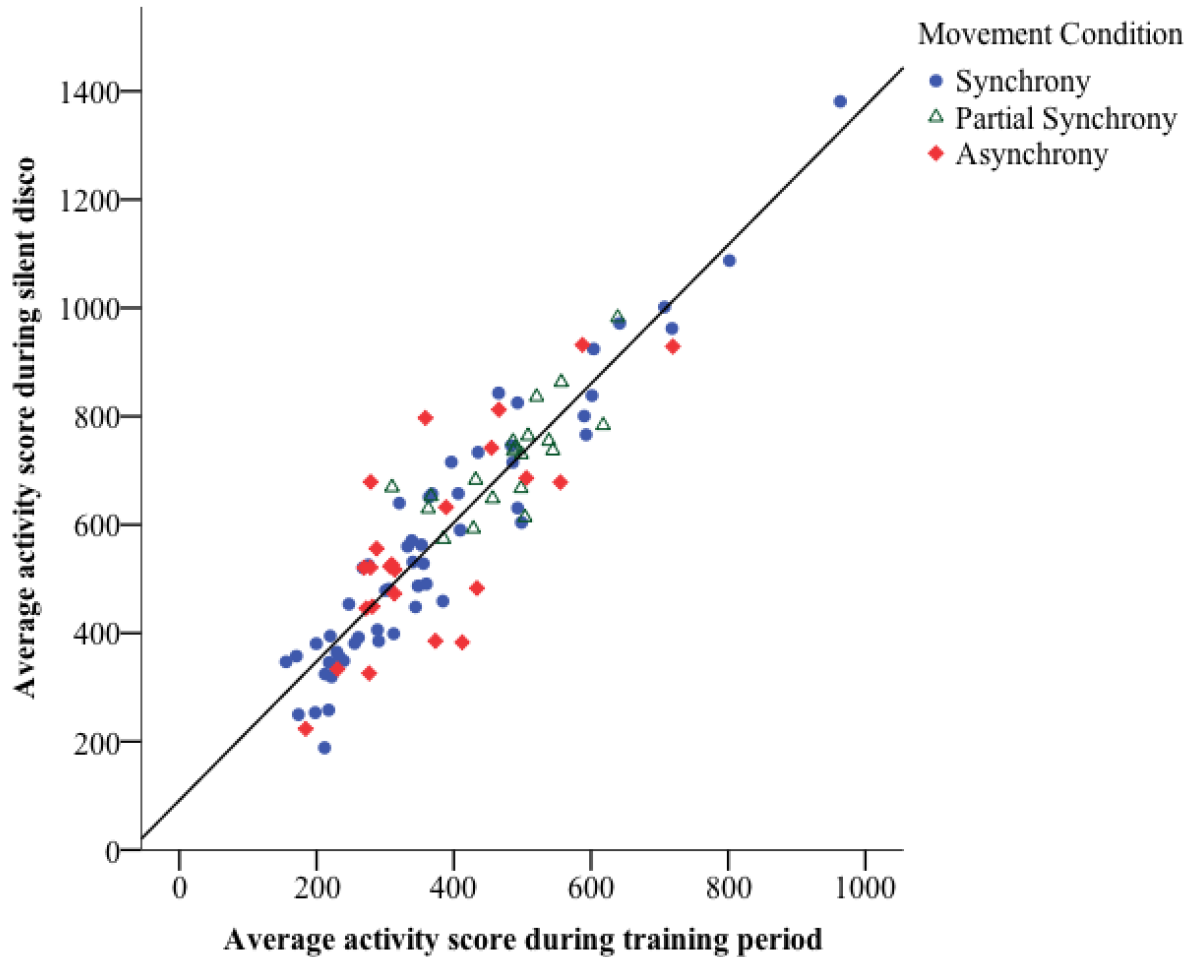


Figure 4.3 Correlation between the activity score during the training period and silent disco ($R^2=0.839$).

There was no significant main effect of movement condition on the average activity score during the silent disco section when group was included as a level ($F(2) = 2.522, p = 0.102$; see Figure 4.4). However, considering that the asynchrony condition involved each participant performing a different dance repertoire (A, B, C and D, see Figure 4.1), and these appeared to have differed in terms of how physically demanding (i.e. exertive) each repertoire was (see Appendix 7.3.6), in order to control for any effect of exertion in subsequent analyses, the activity score was included as a covariate in the analyses of pain threshold and prosociality index data.

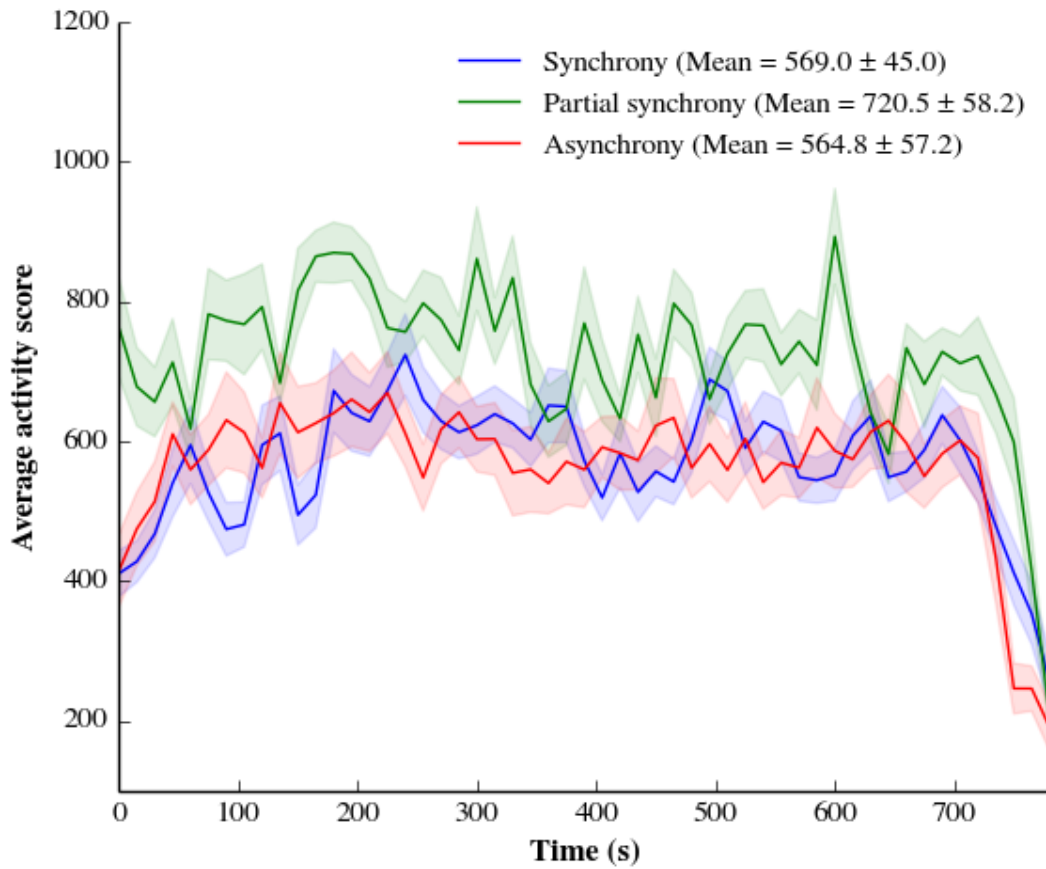


Figure 4.4 Average activity score at each time epoch during the silent disco for each movement condition (± 1 SE).

Total N = 99 participants.

4.6.2 Differences in dependent variables

Pain threshold

Hypothesis 1: Pain threshold is significantly affected by movement condition such that those in synchrony will have significantly higher pain threshold increase (1A), and there may be a significant difference between the partial and asynchrony conditions.

Multilevel linear modelling demonstrated that there was a significant main effect of movement condition on change in pain threshold $F(2) = 3.706, p = 0.029$, and according to the maximum likelihood comparison, the model fit did not significantly improve when testing group was added as a level. Pairwise comparisons of coefficients indicated that the interaction between movement condition and change in PTT was significant only between the synchrony ($M = 12.000$) and partial synchrony conditions ($M = -12.409; t = -2.576, p = 0.012$; see Figure 4.5).

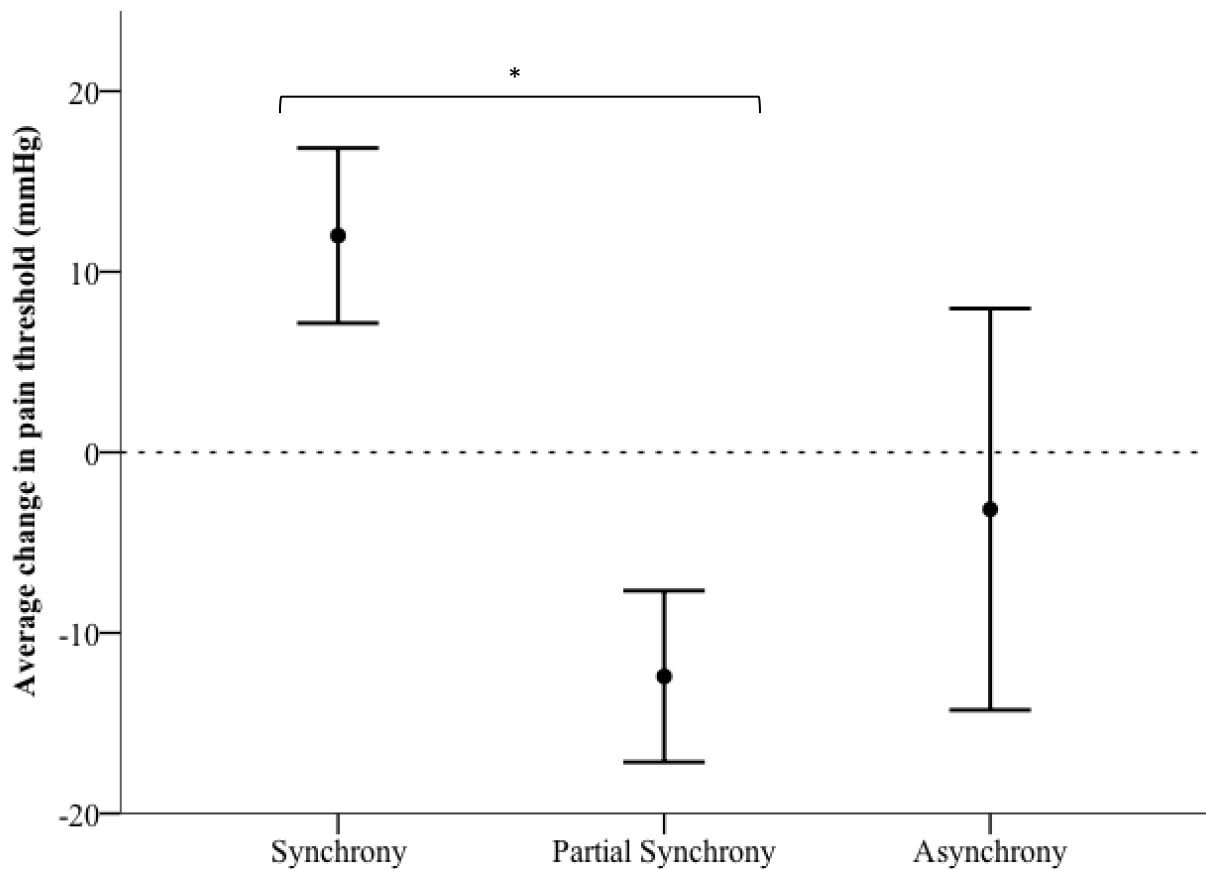


Figure 4.5 Average change in PTT (end - start) for each movement condition (\pm ISE).

*Excluding participants who reached 300mmHg ($N = 94$); * indicates significance of $p \leq 0.05$ in MLM analysis with testing group included as a level.*

As predicted, the synchrony condition resulted in an increase in pain threshold following the silent disco (see Figure 4.5). This change in PTT was significantly different from zero (Wilcoxon

signed ranks test: $Z = -2.197, p = 0.028$), indicating a significant increase in PTT scores from the start ($Mdn = 140.00$) to the end measures ($Mdn = 155.00$).

Participants in the partial synchrony condition demonstrated a lower PTT after the silent disco ($Mdn = 104.00$) compared to at the start ($Mdn = 125.00$), and this change was significantly different from zero ($Z = -2.138, p = 0.033$). Participants in the asynchrony condition did not demonstrate any significant change in PTT from the start of the experiment ($Mdn = 150.00$) to the end of the experiment ($Mdn = 120.00; Z = -0.501, p = 0.616$).

Prosociality measures

Hypothesis 2: Social bonding (as measured by self-report prosociality questions (2A), and contributions to the weak link coordination game (2B) and trustee games (2C)) will be significantly affected by movement condition.

2A) Prosociality index

As predicted, there was a significant main effect of movement condition on the prosociality index ($F(2) = 3.634, p = 0.041$), and the pairwise comparisons of coefficients indicated that the synchrony ($M = 5.018$) and partial synchrony ($M = 4.227$) conditions differed significantly ($t = -2.605, p = 0.015$; see Figure 4.6).

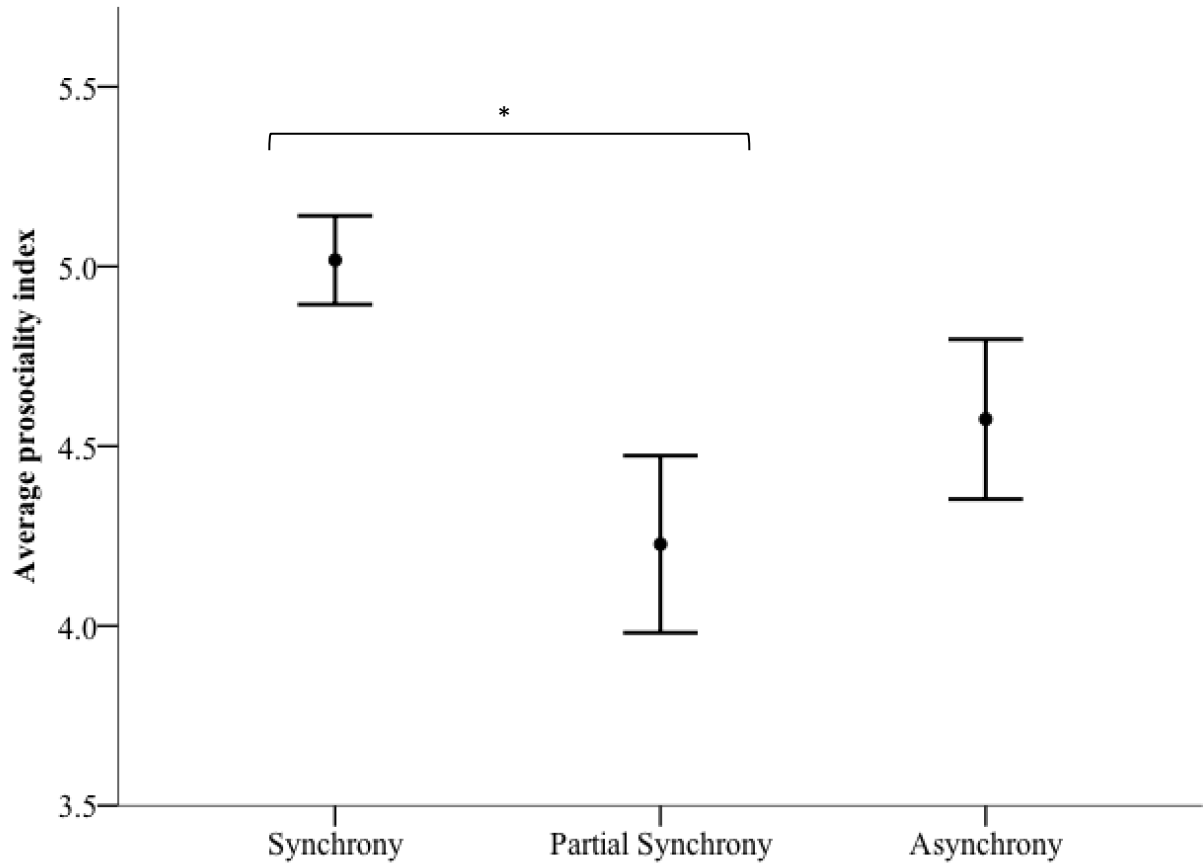


Figure 4.6 Average prosociality index for each movement condition (± 1 SE).

All participants ($N = 103$); * indicates significance of $p \leq 0.050$ in MLM analysis where testing group was included as a level.

2B) Weak link coordination game

Maximum likelihood analysis of the weak link coordination game data indicated that there was a significant difference between the models when testing group was included as a level ($\chi^2 = 7.108$, $d.f = 1$, $p = 0.008$). Contrary to predictions, there was no significant interaction between round and decision of how much money to contribute to the public good. In the first round, there was no significant main effect of movement condition ($F(2) = 0.060$, $p = 0.941$; see Figure 4.7), and although the general trend indicated that those in the asynchrony condition were on average donating more by the last round, there was no main effect of movement condition when testing group was included as a level in the analysis ($F(2) = 0.921$, $p = 0.421$), although removal of testing

group level in the analysis indicated that this difference was significant ($F(2) = 3.745, p = 0.030$).

Given that this game involves receiving information about other participants' decisions, the inclusion of testing group is theoretically the more correct model.

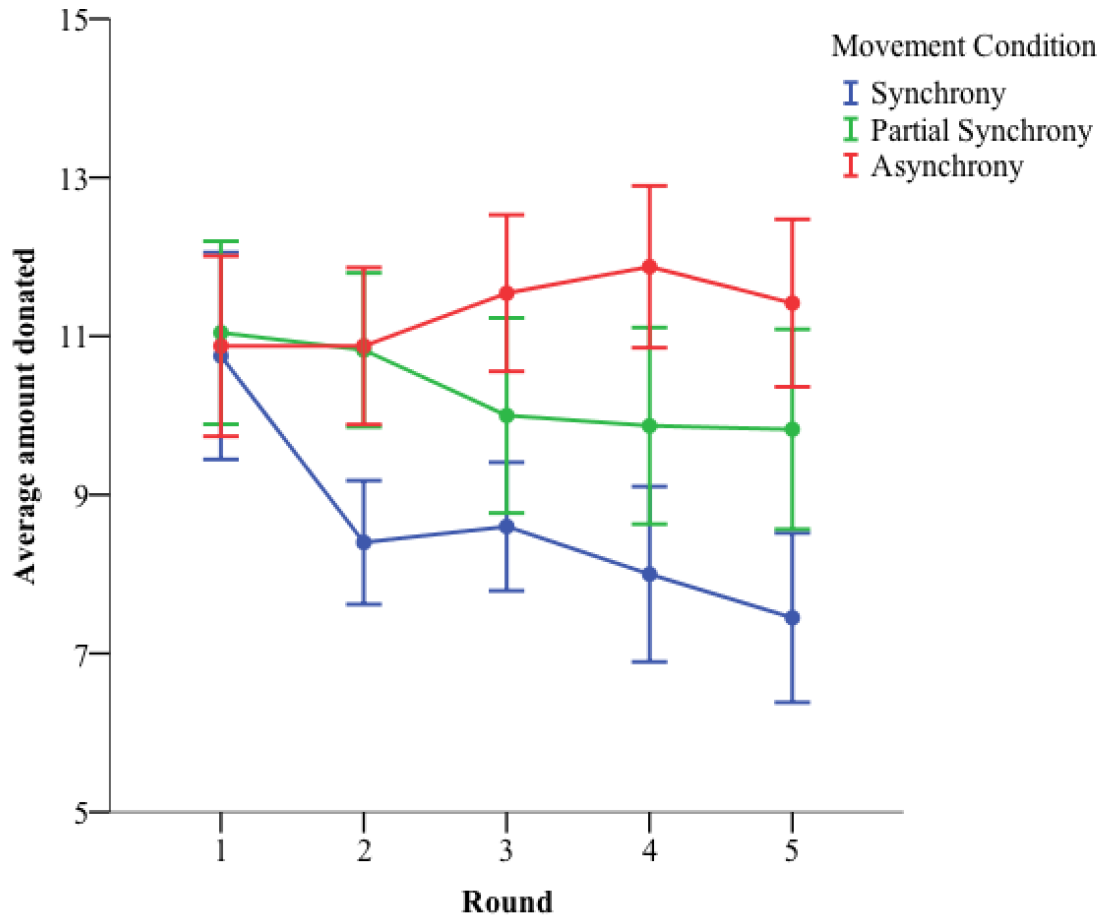


Figure 4.7 Average amount donated (out of an endowment of 20 tokens in each round) in the weak link coordination game as a function of round for each movement condition (\pm ISE).

All participants ($N = 63$).

2C) Trustee game

Contrary to predictions there was no significant main effect of movement condition on the Player 1 decision regarding how much money was entrusted to Player 2 ($F(2) = 0.834, p = 0.440$).

In terms of Player 2's trustworthiness, there was no significant interaction between movement condition and the amount of money returned to Player 1 ($F(2) = 1.96, p = 0.143$, see Figure 4.8).

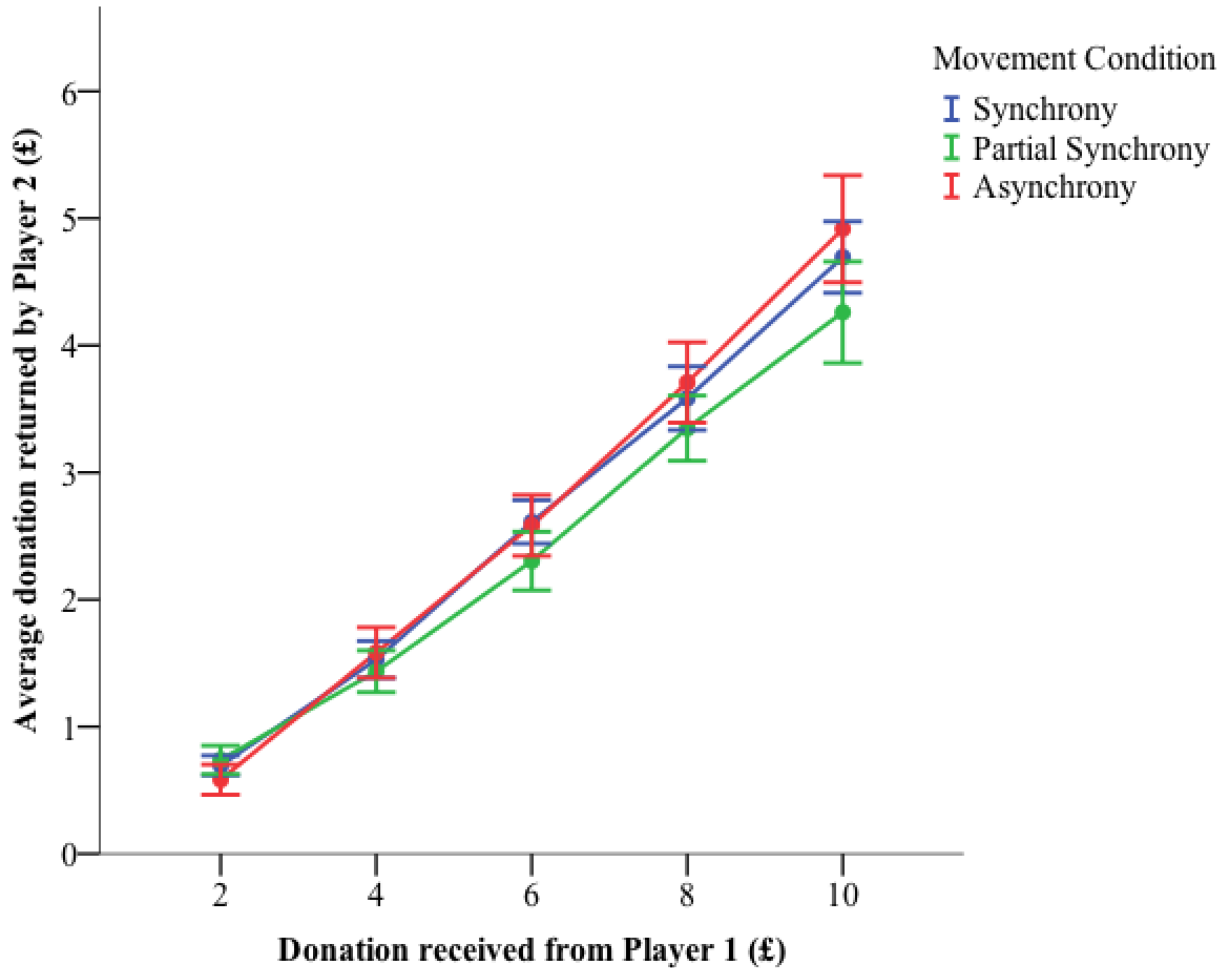


Figure 4.8 Mean amount of money returned by Player 2 for each amount received from Player 1 (£2 - £10) in the trustee game for each movement condition ($\pm 1SE$).

All participants (N = 63).

Inter-item reliability between the prosociality index and economic games

Given that there were significant main effects of movement condition on the prosociality index, but not the economic game data, Cronbach's reliability test was used to determine whether these three measures were related or not. The prosociality index score, Player 1's donation decision in the trustee game and the cumulative profit achieved in the weak link coordination game were

compared for inter-item reliability, and yielded a very low Cronbach's alpha ($\alpha=0.037$) suggesting that these three measures were not measuring the same thing.

Correlation between prosociality index and pain threshold

A Pearson's r correlation was used to assess the relationship between the change in pain threshold and prosociality index scores. Despite the fact that both variables displayed similar statistical trends (with both significantly effected by movement condition), overall, these two variables were not correlated ($r = 0.086$, $N = 94$, $p = 0.412$; with $R^2_{\text{Synchrony}} < 0.001$, $R^2_{\text{Partial synchrony}} = 0.054$, $R^2_{\text{Asynchrony}} = 0.033$).

Participants' experience of the experiment

MLM analysis indicated that there was no significant main effect of movement condition on participants' ratings of fun, difficulty, embarrassment, or enjoyment of the silent disco (see Appendix 7.3.5, Table 7.12). Similarly, there was no significant main effect of movement condition on the Instruction Success score ($F(2) = 1.363$, $p = 0.261$) indicating participants in all three movement conditions felt they were similarly successful at following the auditory instructions during the silent disco. On a scale of 1-7, those in the synchrony condition reported that they felt they had been reasonably successful at synchronising their movements to the other participants and to the musical beat ($M = 4.860 \pm 0.159$). There was no significant difference between the partial synchrony and asynchrony conditions on their rating of how successful they had been at synchronising to the musical beat ($F(2) = 0.009$, $p = 0.925$).

There was a significant overall increase in positive affect, independent of movement condition ($F(1) = 102.318$, $p < 0.001$), but there was no significant interaction between this change and movement condition ($F(2) = 0.401$, $p = 0.674$, see Figure 4.9).

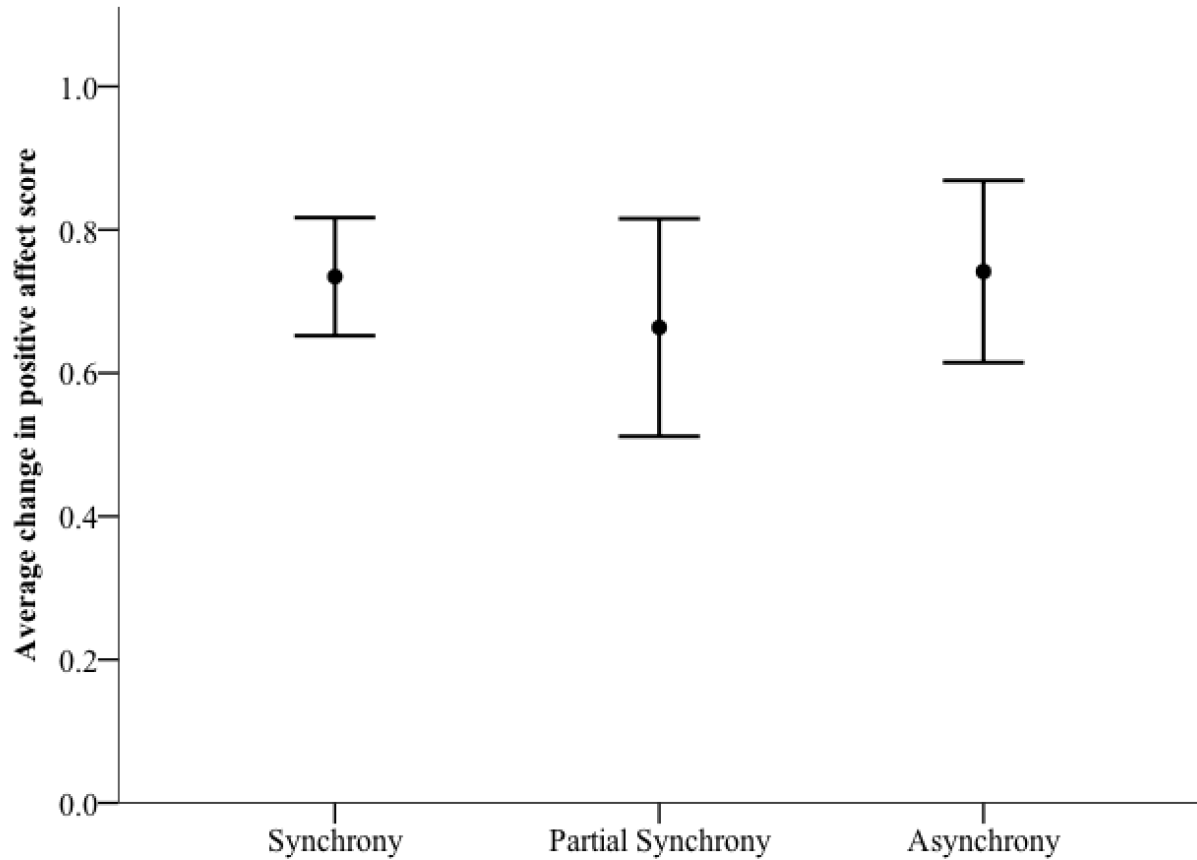


Figure 4.9 Average change (end - start) in positive affect scores for each movement condition (± 1 SE).

Similarly, there was an overall significant decrease in negative affect ($F(1) = 39.389, p < 0.001$), but this effect did not interact with movement condition ($F(2) = 0.102, p = 0.903$, see Figure 4.10).

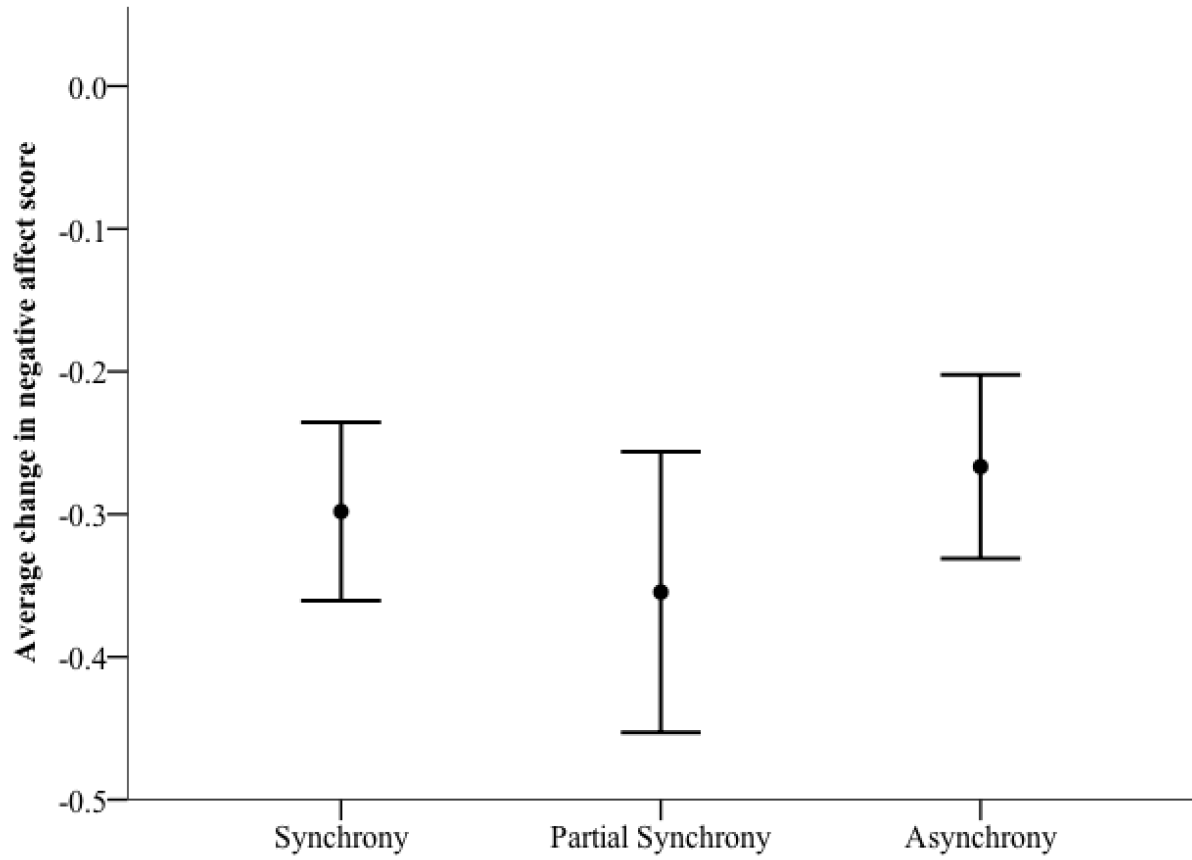


Figure 4.10 Average change (end - start) in negative affect scores for each movement condition (± 1 SE).

4.7 Conclusion and discussion

Pain threshold

Hypothesis 1: Pain threshold is significantly affected by movement condition such that those in synchrony will have significantly higher pain threshold increase (1A), and there may be a significant difference between the partial and asynchrony conditions.

As predicted, movement condition significantly affected the change in PTT, and on average those in the synchrony condition experienced an analgesic effect (significantly higher pain thresholds following the silent disco; see Figure 4.5). In contrast, those in the partial synchrony and asynchrony

conditions did not experience a comparable increase in PTT on average, and interestingly, those in the partial synchrony condition experienced greater pain sensitivity on average following the silent disco (hyperalgesic effect), while on average there was no significant change in pain thresholds for those in the asynchrony condition.

Of the three movement conditions the partial synchrony condition was the least conducive to endorphin release as measured by pain threshold. As predicted by previous studies on rowing (e.g. Sullivan et al., 2014) individuals moving in synchrony experience elevated pain threshold. Although those in the asynchrony condition did not experience hyperalgesia (as demonstrated by the partial synchrony condition), overall these results demonstrate that synchrony can result in an elevated pain threshold, whereas partial and asynchrony conditions were associated with no change or a decrease in pain threshold.

The Actiwatches used in the present study allowed measurement of the intensity of physical exertion, an important consideration given the results from the previous chapter which demonstrated that exertion and synchrony both have significant and independent effects on pain threshold. The inclusion of the Actiwatch data as a covariate in the analyses means that the results reported are due to the synchrony manipulation rather than varying levels of exertion.

Prosociality measures

Hypothesis 2: Social bonding (as measured by self-report prosociality questions (2A), contributions to the weak link coordination game (2B) and trustee games (2C)) will be significantly affected by movement condition.

Weak link coordination and trustee game

Contrary to predictions, those in the synchrony condition did not behave more prosocially in either of the economic games. These results are in contrast to previous research which has supported a causal relationship between synchronous activity and higher cooperation in the weak link coordination game (e.g. Wiltermuth & Heath, 2009) and trustee game (Launay et al., 2013). The contrary results in the present study warrant some consideration: specifically, why might participants in the asynchrony condition have cooperated more efficiently (i.e. on higher donations), and why did those in the synchrony condition contribute less?

The results in the weak link game were unexpected in that there was no significant overall effect of movement condition on cooperation, unless testing group was excluded as a level in the analysis. In addition, those in the asynchrony condition demonstrated higher (non-significant) average donations in the final rounds compared to those in the other movement conditions (see Figure 4.7). Participants in the asynchrony condition were generally better at coordinating with a higher level of contribution to the public good, which seems to contradict findings that suggest that being out of time should result in less cooperation. It is possible that the reason for this is that the experience of being out of synchrony was not as strong for those in the asynchrony condition due to the fact that participants were performing different movements. These different movements (unfamiliar to the other participants) may have masked the temporal dissonance that is evoked when people are making the same movements at different times (as in e.g. Wiltermuth & Heath, 2009). It is also plausible that the asynchrony condition was less distracting than the partial synchrony condition. In the former, participants each performing their own repertoire may have switched off from each other, and therefore avoided experiencing a negative effect. This and alternative asynchronous conditions worth considering are discussed in more detail below ('Improved manipulation of synchrony', pg. 171).

Still to be discussed is why those in the synchrony condition underperformed in the economic games. Possible reasons include a) systematic confounds associated with the way the trustee game was presented, b) the synchrony manipulation was too subtle, and did not act as a sufficient primer for cooperative behaviour during the economic games, and c) economic games are an inadequate measure of the bonding that arises during group movement activities such as the silent disco.

In the trustee game, it is likely that insufficient pay-offs meant that those acting as Player 1 were less likely to entrust any money to Player 2. Although the use of a multiplication factor of two (as used in this study) is evident in some other studies (e.g. Glaeser et al., 2000; Gneezy, Güth, & Verboven, 2000; Greig & Bohnet, 2008; Karlan, 2005), conventional trustee games triple the payoff (for a meta-analysis and review see: Johnson & Mislin, 2011). Arguably, a lower multiplication factor is likely to decrease the likelihood of Player 1 entrusting money, thereby biasing the game (Johnson & Mislin, 2011). Furthermore, in order to maximise the data collected during the trustee game, the present study followed the standard protocol of having each participant play the role of both Player 1 and Player 2 (e.g. Anderson & Dickinson, 2010; Hargreaves-Heap & Zizzo, 2009). However, when participants begin the game knowing that they will play both roles, they tend to reduce their contributions, likely because their sense of responsibility towards their partner is split over two interactions (Burks, Carpenter, & Verhoogen, 2003). These systematic confounds may have caused the null results in the trustee game in the present study.

In the weak-link game a possible consideration is that the experience of synchrony was not sufficient to prime cooperation. Successful primes of economic game behaviour range from very minimal priming such as watching eyes (Bateson, Nettle, & Roberts, 2006; Haley & Fessler, 2005; Nettle et al., 2013), three dots in the shape of a face (Rigdon, Ishii, Watabe, & Kitayama, 2009),

belief in a supernatural presence in the room (Bering, Mcleod, & Shackelford, 2005), and priming of religious concepts (Atkinson & Bourrat, 2011; Shariff & Norenzayan, 2007). The pre-game manipulation in the present study is far less subtle than these examples, and is better compared to Wiltermuth and Heath (2009), for whom marching, singing and gesturing in synchrony sufficiently primed individuals to act more cooperatively in the weak link coordination game, compared to non-synchronous activities. However, in a replication of Wiltermuth and Heath (2009), Schachner and Garvin (2010) reported no such differences between cooperation in the weak link game. The latter study used identical manipulations of synchrony and measures of social bonding, but unlike Wiltermuth and Heath (2009), the experimenters in the replication study were blind to the hypothesis. In the present experiment, all research assistants (executing the experiment and interacting with the participants) were blind to the hypothesis, and in Schachner and Garvin's study, the synchrony condition was not associated with higher cooperation.

The economic game data and prosociality index were not inter-related, suggesting that they were not measuring the same thing. It is possible that economic games are not suitable for accurately assessing affiliative behaviour (e.g. Winking & Mizer, 2013), particularly in circumstances where individuals are strangers taking part in a between-subject experimental design (Launay et al., in press). These economic games assume a trade relationship between participants which is in fact more likely to reflect societal norms (Henrich et al., 2005) than social bonding, and consequently within-subject testing is more likely to capture any differences in cooperation as a result of manipulation of synchrony (as in: Launay et al., 2013). In the present chapter, decisions in the economic games were likely subject to large between-subject variation, rather than condition-driven differences.

Explicit prosociality questions

As predicted, there was a significant main effect of movement condition on participants' rating of various prosociality measures, with those in the synchrony condition reporting higher feelings of social closeness (Figure 4.6). Similar to the PTT results, the significantly lower bonding experienced in the partial synchrony condition compared to the synchrony condition suggests that the combination of performing the same movements at different times is the least conducive to encouraging social bonding between individuals. It is interesting to note that the asynchrony condition was not significantly different from the synchrony condition. Possible reasons why the particular manipulation of synchrony used in the present study may have resulted in these trends include differential levels of joint attention and shared intentionality in the various movement conditions.

Manipulating synchrony, joint attention, and shared intentionality

In the present study, synchrony and non-synchrony were manipulated through a by-product of individual activity, determined by each participant's personal auditory instructions relayed through the wireless headphones. Due to this design, synchrony (and non-synchrony) arose incidentally (at least in part), rather than necessarily arising due to shared intentionality. Shared intentionality is known to improve social closeness, particularly when in combination with synchrony (e.g. Knoblich & Sebanz, 2008; Reddish et al., 2013). For example, participants who work together to create synchrony reportedly identify more strongly with the group, and score higher on self-report prosociality measures (Reddish et al., 2013). Joint attention and inter-individual entrainment result in "attentional union" (Macrae et al., 2008), which facilitates self-other merging, and synchrony induced cooperation (Kirschner & Tomasello, 2010). In the present study, participants in all movement conditions were instructed to synchronise with the music, to follow their own audio

instructions, and to make eye contact with the other participants. However, in the synchrony condition, participants were also told to synchronise their movements with the other participants. Based on the results of Reddish et al. (2013), it is possible that the prosociality evident in the synchrony manipulation in the present study was in fact reinforced by a shared goal of interpersonal entrainment.

However, based on the instructions provided to participants, the synchrony condition should have led to higher levels of prosociality compared to *both* the asynchrony and partial synchrony conditions, rather than just the latter. A possible difference between these two non-synchrony conditions is differential attention, for example varying degrees of time spent making eye contact and watching other people's movements. Whilst all participants were instructed to pay attention to each other and make eye contact, the study did not include a direct measure of attention. Previous research on audio-visual manipulations of synchrony indicate that participants are less likely to look at another participant if they are moving out of time (Hadley et al., 2012; Woolhouse & Tidhar, 2010), which is believed to negatively affect social perception and likeability (Kleinke, 1986). The synchrony manipulation in Woolhouse & Tidhar's (2010) silent disco experiment (discussed in detail earlier, Introduction section 4.2 'Silent-disco technology' pg. 132), is comparable to the partial synchrony condition in the present study as it involved participants hearing the same music but performing different (in their case improvised) movements. Based on their results, there should have been more interpersonal attention in the partial synchrony condition compared to the asynchrony condition. Precisely how this may have translated into the different levels of bonding between these two conditions is unclear, and may have depend on a) whether participants could in fact perceive that they were listening to the same music or not (and therefore made less eye contact), and b) differential expectations from participants regarding the activity task, and what constituted 'success'.

In the partial synchrony condition, individuals experienced their fellow participants doing the same movements that they had learnt personally, but at different times. It is not clear whether visual feedback was in fact sufficient to signal that all participants in the testing group were listening to the same music. It is possible that the fact that participants' movements were familiar, but not performed in unison, may have led participants to feel more frustrated with one another compared to those in the asynchrony condition where it was immediately apparent that participants were performing a unique combination of movements. One indication of this may be participant's sense of success following the silent disco. According to the 'warm glow of success' hypothesis, an individual's experience of success predicts subsequent prosocial tendencies (such as generosity, helpfulness, attention to the social environment: Isen, 1970), and evidence suggests that both perceived synchronisation and perceived success can have independent influences on trust (Launay et al., 2013).

However, in the present study, the partial synchrony and asynchrony conditions did not differ in terms of how successfully participants felt they had followed the instructions, or in their perception of how successful they had been at synchronising their movements to the musical beat. As such, these data do not further elucidate why participants in the partial synchrony (but not the asynchrony) condition experienced significantly lower levels of bonding. It would have been useful to ask participants whether they thought they had heard the same music or not, and to determine a measure of success in synchronising their movements with each other. It is likely that an external measure of synchrony (not based on self-report measures) would also be valuable in determining precisely whether the participants' movements were indeed a perceivable indicator of synchrony. However, given that this study (and the others in this thesis) are concerned with the self-reported effects of perceived synchrony, rather than the accuracy of synchrony per se, an external measure of synchrony was not included (discussed in more detail in 'Accuracy of synchronisation' in the final

chapter, pg. 236). Furthermore, an alternative manipulation of asynchrony might also be necessary, as discussed in the next section.

Improved manipulation of synchrony

The asynchrony condition in the present study had different participants moving to musical stimuli of different tempos, and performing different movements. Considering the role that the different movements played in influencing activity scores, an improved manipulation of asynchrony could involve a standardised dance repertoire with a more precise manipulation of the timing of the movements than provided by the partial synchrony condition. For example, having participants perform the same movements, but to different songs at different times may have a different effect than the partial synchrony (and synchrony) conditions used in the present study. Such a manipulation would be comparable to the asynchrony condition in Reddish et al. (2013), which demonstrated that participants performing actions in a group but at different speeds gave significantly lower cooperation and prosociality scores, compared to a synchrony condition.

Alternatively, a ‘frequency-locked’ non-synchrony condition in which participants’ actions are offset by a small degree, but with the same tempo is also worth considering. Reddish et al. (2013) demonstrate that this manipulation (where participants perform the same action at the same rate, but sequentially), significantly lowers scores on various prosocial measures compared to a synchrony condition, though only when group goal is emphasised. However, it is important to consider the fact that a control condition which involves similar movements but at slightly different times may be particularly distracting, resulting in negative bonding as found in the partial synchrony condition in the present study. It is possible that synchrony effects reported in other studies may in fact be biased due to the control conditions producing a (relative) negative effect on bonding measures, thereby overestimating of the effect of synchrony. This suggestion is supported by the fact that the

asynchrony condition in the present study did not demonstrate as strong a negative effect as partial synchrony in terms of social bonding and pain threshold. Variations on the partial and asynchrony manipulations would provide more accurate insight these effects.

Conclusions

The results from this chapter support previous studies demonstrating that acting in synchrony with strangers elevates pain threshold (e.g. Sullivan & Rickers, 2013) but demonstrates this in relation to partial and asynchronised conditions, which showed hyperalgesic and non-significant changes to pain threshold respectively. Furthermore, the synchrony condition was associated with more feelings of social closeness, in accordance with previous studies (e.g. Hove & Risen, 2009; Reddish et al., 2013; Wiltermuth, 2012).

This chapter built on the previous chapter by demonstrating that certain social bonding and pain threshold effects do not depend on participants sharing an auditory experience. The results from Chapter 3 indicate that when synchronising to music but with mismatched movements (in the partial synchrony condition), participants did not experience increased social closeness, or elevated pain threshold. In that experiment, participants synchronised in the presence of a mutually shared externalised beat provided by music. By virtue of design, the present chapter investigated whether social bonding (and pain threshold) effects still arise when participants do not know what co-actors can hear, but have visual feedback regarding their movements relative to others. From these data it appears that visual feedback of matched movements is sufficient for reinforcing the social bonding effects of synchrony, as suggested by some studies (e.g. Demos et al., 2012). The fact that the economic games did not reveal significant differences between the movement conditions may be explained by systematic confounds (e.g. too low multiplication factor in the trustee game), or because these games are not suitable for between-subject designs such as this. The curious trend of

participants in the asynchrony condition appearing more cooperative in the weak link coordination game was likely due to attentional differences between the movement conditions, although future studies may benefit from additional investigation into suitable controls for synchrony.

Although the pain threshold data and prosociality index scores did not correlate, the results from this chapter, in combination with that of Chapters 2, and 3 provide *prima facie* evidence to suggest that the EOS is activated during dance synchrony, and that endorphins might underpin the social bonding experienced in synchronised conditions. The next chapter builds on these results by using an endorphin blocker to directly manipulate the EOS, rather than relying entirely on pain thresholds to infer the possible relationship between synchrony, EOS activation and social bonding.

Chapter 5 – Naltrexone silent disco experiment

5.1 Chapter abstract

The previous two chapters demonstrated that compared to those in a non-synchronised conditions, synchronous dancing elevates pain thresholds and increases social bonding amongst participants. Whilst the data reported in these chapters suggest that the EOS is triggered during exertive synchronous activities, and is associated with self-reported social bonding, a more direct measure of endorphins or manipulation of the EOS would better test the possible causal links between movement synchrony, the EOS, and social bonding. This chapter uses the same silent disco paradigm described in Chapter 4, with two major changes: 1) all participants performed movements in synchrony; and 2) an opioid antagonist (naltrexone) was used to block endorphins from attaching to opioid receptors in the brain, thereby blocking any effects (pain or social bonding) causally associated with endorphins. The between-subject double blind experiment involved 103 participants in testing groups of four participants each. Testing groups were randomly allocated to either a placebo, naltrexone or no-pill (control) treatment. Due to the role of the EOS in pain reduction, naltrexone-treated participants were expected to experience minimal analgesic effects following the silent disco, compared to the placebo- and control-treated participants. Furthermore, given evidence that endorphins may play a role in social bonding, naltrexone-treated participants were expected to score lower on the self-report prosociality index. The results confirmed that naltrexone suppresses analgesia following exertive synchronous movement, suggesting that the EOS is involved during the synchronous movement task used in this chapter and Chapters 3 and 4. However, placebo-treated participants suffered increased pain sensitivity, a ‘nocebo’ or ‘placebo hyperalgesic’ effect. This is a well-known problem that sometimes affects placebo trials and makes the interpretation of the results less straightforward. Furthermore, contrary to predictions, there was no significant main

effect of treatment on the prosociality index score suggesting that either a) the bonding measures used in this chapter may not be sensitive to opioid intervention; or b) the social bonding that arises during synchronous movement is not solely due to endorphins; or c) that a higher dose of naltrexone should have been used.

5.2 Introduction

Previous chapters in this thesis included a review of evidence linking synchrony and bonding (Chapter 1: ‘Literature relating to synchrony and social bonding’, pg. 34), synchrony and pain threshold (i.e. endorphin activation; Chapter 1: ‘Literature relating the EOS to social bonding in humans’, pg. 44), and endorphins and bonding (Chapter 1: ‘Mechanisms of social bonding: The EOS’, pg. 20). Chapter 3 demonstrated that pain threshold and in-group social bonding effects are not limited to exertive synchrony, but that low exertive synchronous tasks can have a similar effect. Chapter 4 demonstrated that exertive synchrony is associated with elevated pain thresholds and self-report measures of prosociality. These studies used a proxy measure of endorphin release (pain threshold) to provide putative evidence that the EOS is involved in the social bonding that arises during group movement synchrony. However the causal relationship between endorphins released during synchronous movement and the associated social bonding remains to be tested directly. The most robust means of testing EOS activity is by scanning the brain (e.g. PET: Boecker et al., 2008; fMRI: Wager et al., 2004), or via endorphin titres following lumbar spinal extraction (Dearman & Francis, 1983). These methods are expensive and invasive, and a more cost-effective and convenient method for testing the EOS theory of social bonding is the use of opioid antagonists, which block opioid receptors, thereby antagonising the effects of endorphins. In this chapter the opioid antagonist naltrexone was chosen to confirm that the findings from earlier chapters relating to synchrony, pain threshold, and bonding, are indeed linked to endorphins.

Opioid antagonists and hyperalgesia

As reviewed in Chapter 1 ('The EOS and (physical) pain', pg. 26), there is a wealth of intervention based studies which demonstrate the role of the EOS in the pain management system, showing that opioid blockers antagonise analgesia (i.e. reduced pain tolerance), or produce hyperalgesia (i.e. increased pain sensitivity; e.g. rodents: D'Amato & Pavone, 1993; humans: Jamner & Leigh, 1999). The two most commonly used opioid antagonists are naloxone and naltrexone, which reversibly block endorphin molecules' access to opioid receptors in the brain (Barnett, Twycross, Mihalyo, & Wilcock, 2014).

Naloxone is known both to cause hyperalgesia compared to placebo treatments (Levine, Gordon, Bornstein, & Fields, 1979) and reduce the analgesia experienced due to expectation of pain relief, and prior opioid conditioning (Amanzio & Benedetti, 1999; Petrovic, Kalso, Petersson, & Ingvar, 2002). Similarly, naltrexone, the other commonly used opioid blocker, has a high affinity to μ - and κ - opioid receptors (ORs), blocking the effects of exogenous opioids, reducing craving for drugs and alcohol, and suppressing analgesia (Greeley, Poulos, & Cappell, 1988; Kirchgessner, Bodnar, & Pasternak, 1982; Mayer, 1983). Naltrexone has been widely used in experimental medicine studies of ingestive behaviour and the EOS (for a review see: Yeomans & Gray, 2002), treatment of alcoholism or opioid dependence (for a review see: Barnett et al., 2014), and as a hyperalgesic-inducing intervention for individuals with Autism Spectrum Condition (ASC) engaging in self-harm (Symons, Thompson, & Rodriguez, 2004). Autistic individuals often have higher than average pain thresholds and engage in repetitive stereotyped patterns of behaviours which are sometimes self-injurious (H. M. Feldman, Kolmen, & Gonzaga, 1999; Sandman & Kemp, 2011). ASC self-harmers reportedly respond significantly well to naltrexone treatment, which lowers pain threshold (ElChaar, Maisch, Augusto, & Wehring, 2006). Similar results are evident in non-ASC diagnosed individuals who self-injure (Symons et al., 2004), supporting the hypothesis that

dysregulation of the EOS contributes to the tendency to engage in pain-inducing behaviours (Sandman & Kemp, 2011).

According to widespread evidence that individuals treated with opioid antagonists experience reduced pain thresholds, it is predicted that naltrexone-treated individuals in the present study will experience limited analgesic effects or hyperalgesia following synchronous group movement (Hypothesis 1). Furthermore, given that synchronous activities are also associated with subsequent social bonding (Chapters 3 and 4), and that endorphins play a role in the bonding experienced by other primates, naltrexone-treated individuals are not expected to experience the same bonding effects during the silent disco (Hypothesis 2). This hypothesis is based on the BOTSA theory (see Chapter 1: 'Brain Opioid Theory of Social Attachment: opioids and bonding', pg. 24 for a review), and evidence linking the neurological underpinnings of social and physical pain (e.g. Eisenberger, Lieberman, & Williams, 2003, and see Chapter 1: 'Similarities between social and physical pain', pg. 27 for more details). Although the effects of opioid antagonists on self-reported prosociality measures as used in the present study have not been investigated, many studies have documented the effects of opioid interventions on social behaviours (for a more extensive review see Chapter 1: 'Opioid interventions and social behaviour', pg. 24).

Opioid antagonists and social behaviour

In addition to the role of the EOS in pain-related behaviours in individuals with ASC, Panksepp (1979) suggested that EOS dysregulation may explain the social challenges experienced by those diagnosed with autism. His proposition was based on the observation that many of the defining symptoms of autism (such as reduced socialisation and eye contact, negative emotions, motor hyperactivity) mirror behaviours often associated with administration of an opioid agonist (H. M. Feldman et al., 1999). The suggestion is that the social withdrawal associated with autism may be

due to abnormalities in the EOS has been investigated via direct measurement of neuropeptides and interventions which block opioid receptors (Willemsen-Swinkels, Buitelaar, & van Engeland, 1996).

Single dose administration of naltrexone has been shown to increase verbal production and reduce social withdrawal (e.g. Leboyer, Bouvard, & Dugas, 1988) and improve ratings on various Autism scales (e.g. Kolmen, Feldman, Handen, & Janosky, 1995; Leboyer et al., 1992) in autistic children. However, these studies are generally faulted for their small sample sizes and weak effect sizes (for a general review see: Willemsen-Swinkels et al., 1996). Evidence that an antagonist drug directly mitigates social withdrawal and other core features of autism is mixed (ElChaar et al., 2006; Willemsen-Swinkels et al., 1996), suggesting that abnormalities in the EOS may contribute to ASD in only a subgroup of diagnosed children.

In non-autistic individuals, animals and humans alike, there are many studies demonstrating that naltrexone treatment can significantly affect various social behaviours (see Chapter 1: ‘Opioid interventions and social behaviour’, pg. 24). Broadly speaking, based on this evidence, naltrexone as used in the present study is likely to effect individuals’ social behaviours, for example their engagement in the synchronous movement task. It is unclear precisely how this will in turn affect self-report measures of prosociality, as these measures have not previously been tested in any human-based naltrexone trials. However, assuming that opioids contribute to bonding as measured by these self-report questions, a logical predication is that naltrexone-treated participants will feel less bonded compared to control- or placebo-treated participants (Hypothesis 2). In addition to the main hypotheses relating to pain threshold and prosociality, given that endorphins also effect mood (Koepp et al., 2009; Zubieta et al., 2003), it is expected that naltrexone-treated participants will report different levels of positive and negative affect, compared to control and placebo treatments (Hypothesis 3).

Opioid antagonists and affect

Some studies have reported no observable differences in affect between placebo and opioid-blocked treatments following physical activity (e.g. De Meirleir et al., 1985; Farrell et al., 1986; Goldfarb et al., 1987; Grossman, Bouloux, Price, & Drury, 1984; Markoff et al., 1982). However, other studies report a significantly higher increase in positive affect in placebo versus antagonist treated participants who exercise whilst under the influence of the drug or placebo (e.g. Janal et al., 1984). In a more recent randomised within-subject experiment, Daniel et al. (1992), confirmed that high intensity (75 minutes) exercise induces calmer, more peaceful, relaxed and pleasant mood states in placebo-treated but not naltrexone-treated participants. This suggests that changes in affect during physical activity is mediated through the EOS, and although Daniels et al. (1992) used a different scale for assessing mood, it is expected that scores on the PANAS scale used in the present study will also be affected by naltrexone treatment (Hypothesis 3). One potential issue, however, is that the effect of antagonist treatment on mood is thought to be dose-dependent (e.g. Cohen, Cohen, Pickar, Weingartner, & Murphy, 1983).

Naltrexone: dose, side effects and experimental design

Both naltrexone and naloxone are commonly used opioid antagonists licensed for the management and treatment of alcohol and opioid drug dependence. In the present study, I decided to use naltrexone as, unlike naloxone, it does not require subcutaneous or intravenous administration. Naltrexone's onset of action occurs 15-30 minutes after oral ingestion (Roy, Roy, Deb, & Unwin, 2014), and in the present study the movement activity and test interval started after a 60 minute waiting period to ensure that these activities coincided with the maximum plasma concentration of a 50mg oral dose of naltrexone (Chelnokova et al., 2014). This dose of naltrexone

is commonly used (e.g. for a review: Yeomans & Gray, 2002), and a single-administration of the drug is known to affect the EOS significantly (Chelnokova et al., 2014).

In people who are not currently using opiates, naltrexone is generally safe and well-tolerated (Lobmaier, Kunøe, Gossop, & Waal, 2011). The drug has a short-half life (about 4 hours), is expelled from the body quickly, and is associated with only minor side effects (Oncken, Kirk, & Kranzler, 2001; Yeomans & Gray, 2002). The most common side effects of regular and continuous naltrexone use include nausea (in 10% of subjects), headache (7%), dizziness (4%), nervousness (4%), and fatigue (4%; Croop, Faulkner, & Labriola, 1997). Croop et al. also report sleep disorders, restlessness, abdominal pain/cramping, general joint muscle pain and feebleness as side effects, but notably these effects were associated with administration of a 50mg naltrexone pill every day for 12 weeks. A medical advisor and relevant ethics panel assessed the risk associated with administration of a once-off dose of a 50mg pill and it was considered suitable for purposes of the present study.

5.3 Hypotheses and predictions

Hypothesis 1: Pain threshold following synchronisation is significantly affected by naltrexone, an endorphin blocker.

Predictions:

- A) Individuals treated with naltrexone will experience a suppressed analgesic effect.
- B) Individuals in the control and placebo treatments will experience greater elevation in pain threshold compared to the naltrexone treatment.

Hypothesis 2: Self-reported social bonding (as measured by prosociality questions) following synchronisation is significantly affected by naltrexone.

Prediction:

- A) Individuals treated with naltrexone will report feeling less socially bonded with those in their testing group compared to the social bonding reported in the placebo and control treatments.

Hypothesis 3: Participants' self-reported affect is significantly influenced by naltrexone.

Prediction:

- A) Individuals treated with naltrexone will experience a lower increase in positive affect, and possibly a greater increase in negative affect compared to the control and placebo treated individuals.

In addition, participants' personality type, perception of success, fun, enjoyment, difficulty, embarrassment and confidence in ability to remember the dance moves were measured to test that any effects of treatment were independent of these factors.

5.4 Methods

5.4.1 General

The study was advertised as 'Physical coordination, memory and endorphins', with no mention of the hypothesis relating to synchrony and bonding. Data were collected between October 2013 and February 2014 at Oxford University in the same research lab as the silent disco experiment described in Chapter 4 ('Methods', pg. 141). A total of 103 participants (mean age 21.80, $S.D = 3.22$ years) took part in the experiment. The sample included 29 males and 74 females, and testing groups mainly consisted of a mixture of males and females.

Table 5.1 Outline of experimental conditions. Total $N = 103$ participants.

Treatment	Number of testing groups	N
Control	8	$n = 32$
Placebo	9	$n = 36$
Naltrexone	9	$n = 35$

5.4.2 Data structure

The dependent variables in this chapter are identical to those of Chapter 4 ('Data structure', pg. 142): pain threshold and prosociality index, but due to time constraints and the results from the previous chapter, the two economic games were not included in the present study design.

Furthermore, unlike Chapter 4, in the present study all participants performed movement tasks in synchrony, and the independent variable is treatment (either no pill (control); placebo pill (negative control); or naltrexone pill).

All other variables included in Chapter 4 were included in the present study, as well as the computed change in PTT and PANAS.

5.4.3 Participant selection and treatment allocation

Participants underwent a screening process similar to that described in Chapter 4. Due to the possibility that participants would receive a naltrexone pill in the double blind experiment, a medical collaborator (Dr. Catharine Benson, GP) reviewed the online screening questionnaire to ensure that individuals were excluded if they were a smoker, had any medical problems such as diabetes or hypertension, were pregnant or lactating (due to their higher pain threshold; McKinney, Tims, et al., 1997), or if they had a chronic disease (e.g. of the liver, brain, or kidneys). On the recommendation of the medical collaborator, individuals were excluded if they had drunk alcohol on the day of the

experiment (they were reminded on the day not to do so), suffered from any rare hereditary problems (including galactose intolerance, Lapp lactase deficiency or glucose-galactose malabsorption), those with a history of clinical depression, mania or psychosis, individuals who reported the current use of anti-depressant medication or any other medication (with the exception of contraceptives and asthma inhalers), the use of cannabis or another illicit drug within the previous three months, or the use of cannabis or illicit drugs more than four times in the past year. Furthermore, individuals who had ever met criteria for cannabis dependence or harmful use, a history of any life-time use of opiate drugs recreationally, or any individuals who suffer from any physical, visual or hearing disability that would have prevented them from performing the physical activities required in the experiment, were excluded.

After informed consent, and before the initial pain threshold measure, a double-blind method was used to administer either the placebo, naltrexone or no pill (control). In order to ensure the double blind-nature of the experiment, the medical collaborator (who was not present during the experimental sessions) allocated reference numbers to the pills, which were subsequently placed in black zip lock bags. Each testing group was randomly allocated a reference number, which determined if the participants all received either a naltrexone or placebo pill, or no pill. All participants in a testing group received the same treatment allocation at the start of the experiment. As a result of these precautions, the research assistants, principal investigator and participants were double-blind to the treatment allocation.

5.4.4 Pre- and post-disco pain threshold measure (PTT)

Following the method outlined in Chapter 4 ('Pre- and post-disco pain threshold measure (PTT)', pg. 144), participants underwent pain threshold tests at the start and end of the experiment, referred to as 'PTT start' and 'PTT end'. An additional 'PTT mid' measure was included after the 1

hour wait period but before any movement. This extra measure was added as a precaution due to the difference in protocol between the two experiments (where in the former experiment, pain threshold taken at the start of the experiment was also close to the time of the silent disco).

5.4.5 Pre-disco questionnaire

Following the PTT start measure, participants answered a questionnaire identical to that described in Chapter 4 ('Pre-disco questionnaire', pg. 145, and Appendix 7.3.1).

5.4.6 Rest period

Unlike Chapter 4, participants did not undergo movement training immediately after the questionnaire. In order to allow for the naltrexone to take effect, participants remained seated for 60 minutes following their ingestion of the pill. The PTT mid test which followed this waiting period coincided with the maximum plasma concentration of naltrexone (Gonzalez & Brogden, 1988; Vereby, Volavka, Mule, & Resnick, 1976). During the waiting time they performed an online reading task or did their own reading.

5.4.7 Movement training and silent disco

These sections of the experiment were identical to those described for the synchrony condition in Chapter 4 ('Movement training', pg. 145, and 'Silent disco', pg. 145), i.e. all testing groups were allocated to perform dance movements in synchrony.

5.4.8 Post-disco questionnaire

The post-disco questionnaire was identical to that of Chapter 4 ('Post silent disco questionnaire', pg. 148), except that it did not include the two economic games, and was presented in SurveyGizmo, an online survey program.

5.5 Analyses

5.5.1 Pain threshold data exclusion

As in previous data chapters, participants who reached 300mmHg were removed from the pain threshold analyses to account for the methodological bias associated with the assessment of pain (see Chapter 4: ‘Pain threshold data exclusion’, pg. 149 for more details). This reduced the sample size to 86 participants. On the occasion when this influenced the trend in significance between conditions, I report these differences.

5.5.2 Prosociality index

As per earlier chapters, the prosociality index was created by averaging the scores for the four prosociality measures (IOS, connectedness, likeability and similarity in personality), which were all tested using a 7-point Likert scale. The justification for this index is provided in Chapter 4 (‘Prosociality Index’, pg. 150), where exactly the same measures of prosociality were used.

5.5.3 Normality testing and homogeneity of variance

As in previous chapters, normality of data was tested using the Kolmogorov-Smirnov test. Levene’s test was used to compare the homogeneity of variance. All data had homogenous variance, and on occasion the distributions of the data were significantly different from normal (see Appendix 7.4.1). Log transformations did not change the distributions and similar to the previous chapters, MLM analyses were used throughout.

5.5.4 Multilevel linear modelling

As in previous chapters, MLM was used to account for non-independence of data points, namely individual variation in the repeated measures (of PTT and PANAS), and testing group membership (all variables). The repeatedly measured dependent variables (PTT and PANAS) were modelled using the fixed factors of time point (i.e. before or after testing), and treatment (control, placebo and naltrexone), including interactions between these effects. Participant ID was added as a Level 1 random intercept (effectively accounting for the individual variation in the repeated measure), and testing group was added as a Level 2 random intercept (accounting for group-level effects). The results from models with and without testing groups were contrasted, as per the outline in Chapter 4: ‘Multilevel linear modelling’ (pg. 151). Unless otherwise stated, the results reported in this chapter include testing group in the analysis, as theoretically this is the most relevant statistical analysis.

5.5.5 Additional analyses

In addition, the average change in PTT (calculated as the end-start scores) for each treatment was compared to zero change using a one sample T-test (conducted on each treatment separately; for more details see Chapter 4: ‘Additional analyses’, pg. 152).

5.6 Results

5.6.1 Baseline differences between treatments

Personality types and confidence level prior to the movement activity

There were no significant differences between treatments in terms of the various personality measures, nor how confident participants felt regarding their ability remember the moves after the training session (see Appendix 7.4.2, Table 7.13).

Activity score and exertion

The activity score was significantly higher on average during the silent disco ($M = 719.21 \pm 18.797$) compared to the training period ($M = 489.404 \pm 13.980$; $t = -21.592$, $df = 85$, $p < 0.001$).

The activity scores were strongly correlated between these two periods for each of the movement conditions ($r(86) = 0.829$, $p < 0.001$), and as with the previous chapter, the silent disco section and corresponding activity scores were the focus of subsequent analyses.

There was no significant main effect of movement condition on the average activity score during the silent disco section when group was included as a level ($F(2) = 0.959$, $p = 0.399$; Figure 5.1), but in order to account for any possible effects of exertion, activity score from this period (as measured by the Actiwatches) was included as a covariate in all subsequent analyses of pain threshold and prosociality index data to ensure that any conclusions regarding the main effect of treatment were not due to differences in exertion.

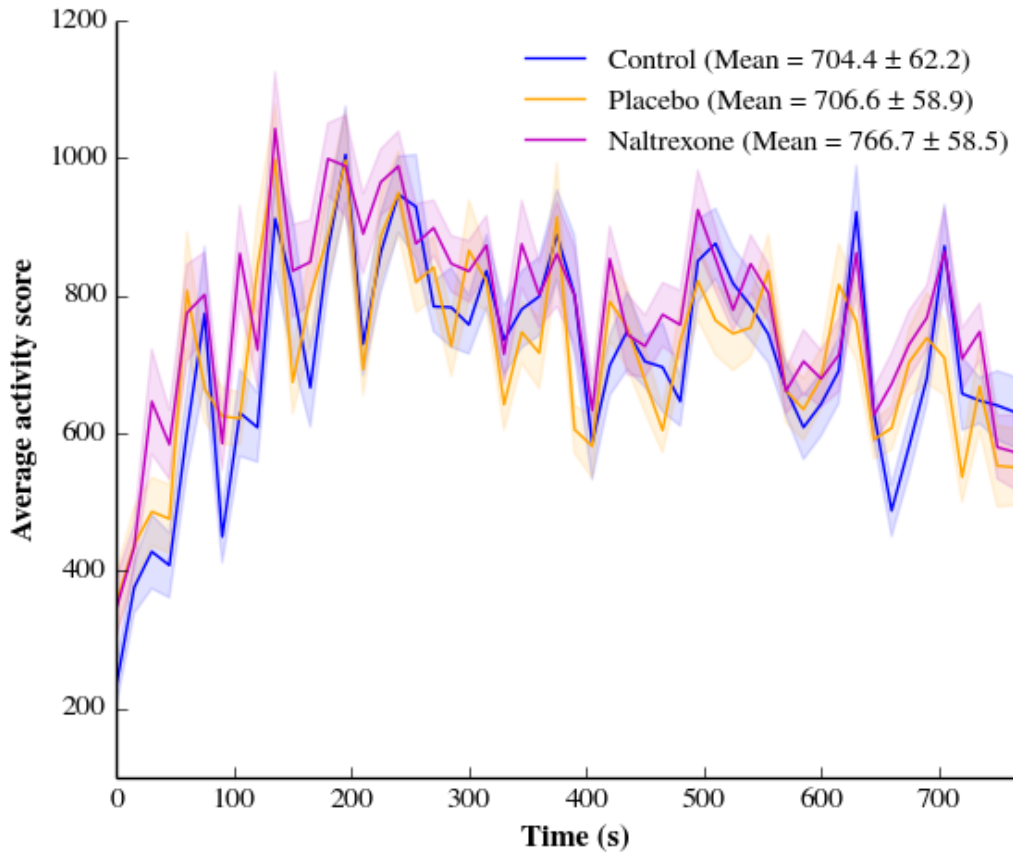


Figure 5.1 Average activity score at each time epoch during the silent disco section for each treatment (\pm 1 SE).

Total N = 102 participants, as one watch broke on one occasion.

5.6.2 Differences in dependent variables

Pain Threshold

Hypothesis 1: Pain threshold following synchronisation is significantly affected by treatment such that those treated with naltrexone will experience suppressed analgesic effects (1A), and control and placebo treatments will experience comparatively greater elevation in pain threshold (1B).

Pain threshold was plotted against time point in order to determine which time points should be compared in the MLM analysis (Figure 5.2). Analysis of the change in pain threshold compared to zero between each time point suggested that there was no significant change between the start- and mid- point measures (see Appendix 7.4.4, Table 7.16 for the results of each treatment). Given this trend, and the fact that the midpoint measure was taken after 1 hour under the influence of the pill, subsequent analyses were conducted on the PTT start and PTT end data only.

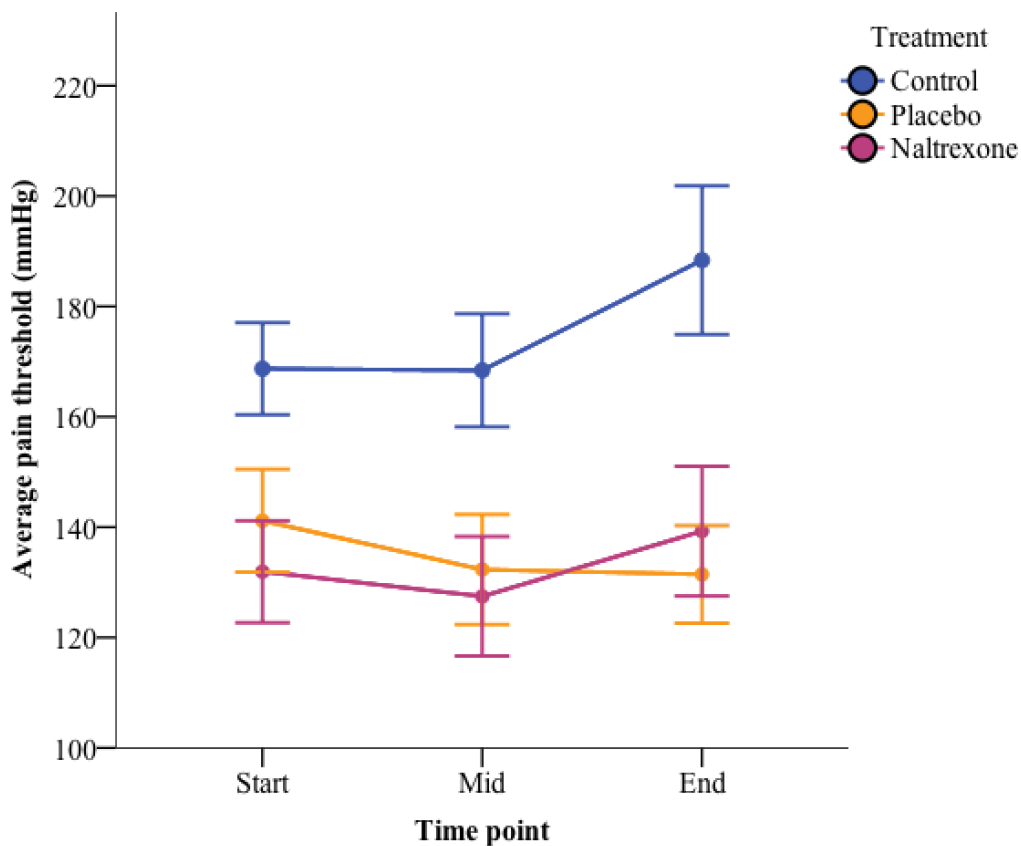


Figure 5.2 Average pain threshold (mmHg) at each time point for the control, placebo and naltrexone treatments (± 1 SE).

Excluding participants who reached 300mmHg (N = 86).

According to a maximum likelihood comparison, when analysing the PTT start and end scores, the model fit did not significantly improve when including testing group. However there were differences between some analyses that included all data and those that excluded participants

who reached 300mmHg, with the latter providing more conservative results. When there were differences in significant results, both are reported, but when both levels of inclusion resulted in similar results, the more conservative analysis is reported.

As predicted, there was a significant interaction between treatment and the change in PTT from the start to end measures ($F(2) = 3.365, p = 0.039$). Contrary to expectations, pairwise comparison of coefficients indicated that there was a significant difference only between the control ($M = 19.67$) and placebo treatments ($M = -9.71; t = -2.572, p = 0.012$; see Figure 5.3), but not the control and naltrexone treatments ($M = 7.36; t = -1.052, p = 0.296$). There was no significant difference between the placebo and naltrexone treatments ($t = 1.509, p = 0.135$).

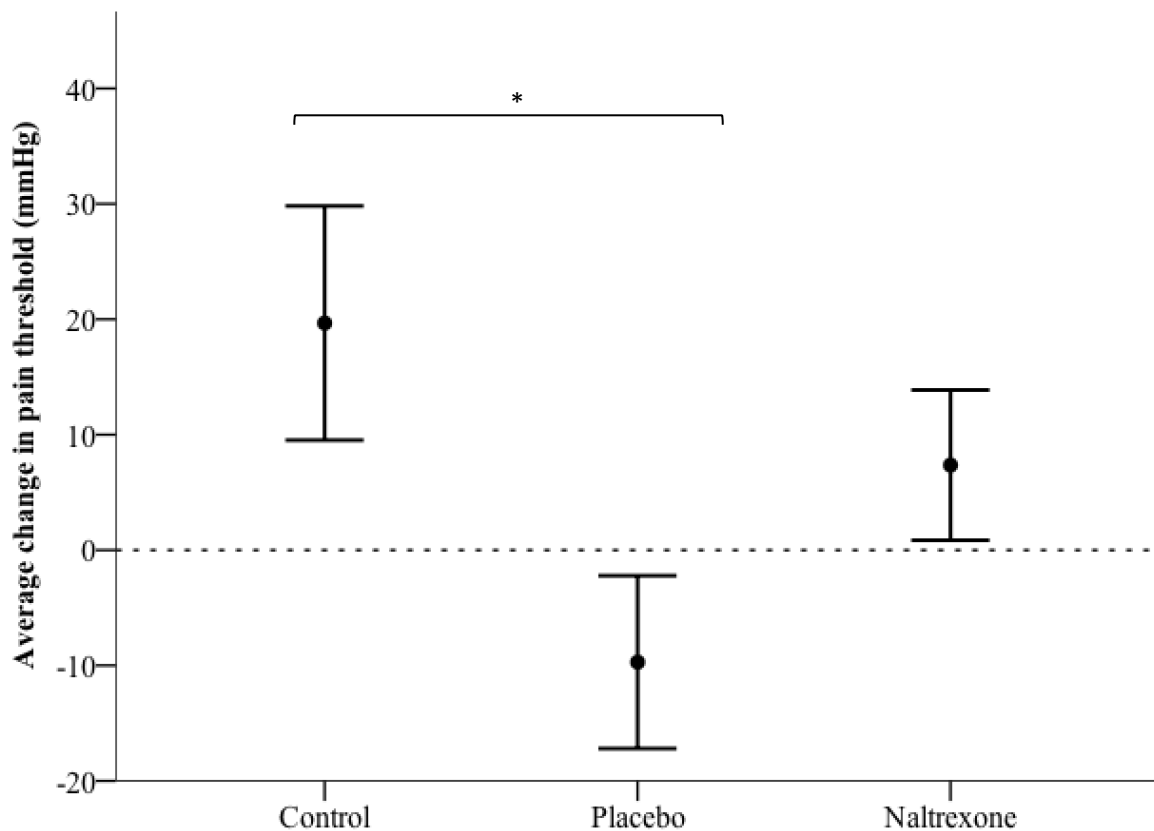


Figure 5.3 Average change in PTT (end – start) for each treatment (± 1 SE).

*Excluding participants who reached 300mmHg ($N = 86$); * indicates significance of $p \leq 0.050$ in the MLM analysis with testing group included as a level.*

Compared to no change (i.e. the dotted line in Figure 5.3), the control-treated participants on average experienced a borderline significant increase in PTT ($t(26) = 1.939, p = 0.063$), but there was no significant difference from zero for the placebo treatment ($t(30) = -1.298, p = 0.204$) or the naltrexone treatment ($t(27) = 1.131, p = 0.268$).

However, MLM indicated that there was a significant effect of treatment independent of the time point ($F(2) = 7.317, p = 0.002$), highlighting the fact that the pain threshold between treatments differed at the start: those in the control treatment had a start threshold ($M = 168.704$), which was significantly higher than those in the placebo ($M = 141.161; F(2) = -2.050, p = 0.043$) and naltrexone treatments ($M = 131.929; F(2) = -2.675, p = 0.009$).

Prosociality index

Hypothesis 2: Self-reported social bonding (as measured by prosociality questions) following synchronisation will be significantly affected by naltrexone.

Contrary to expectations, there was only a borderline significant main effect of treatment on prosociality index scores ($F(2) = 3.182, p = 0.060$; see Figure 5.4), with the control-treated participants scoring lower on average ($M = 4.109$) than the placebo- ($M = 4.821$) and naltrexone-treated participants ($M = 4.821$).

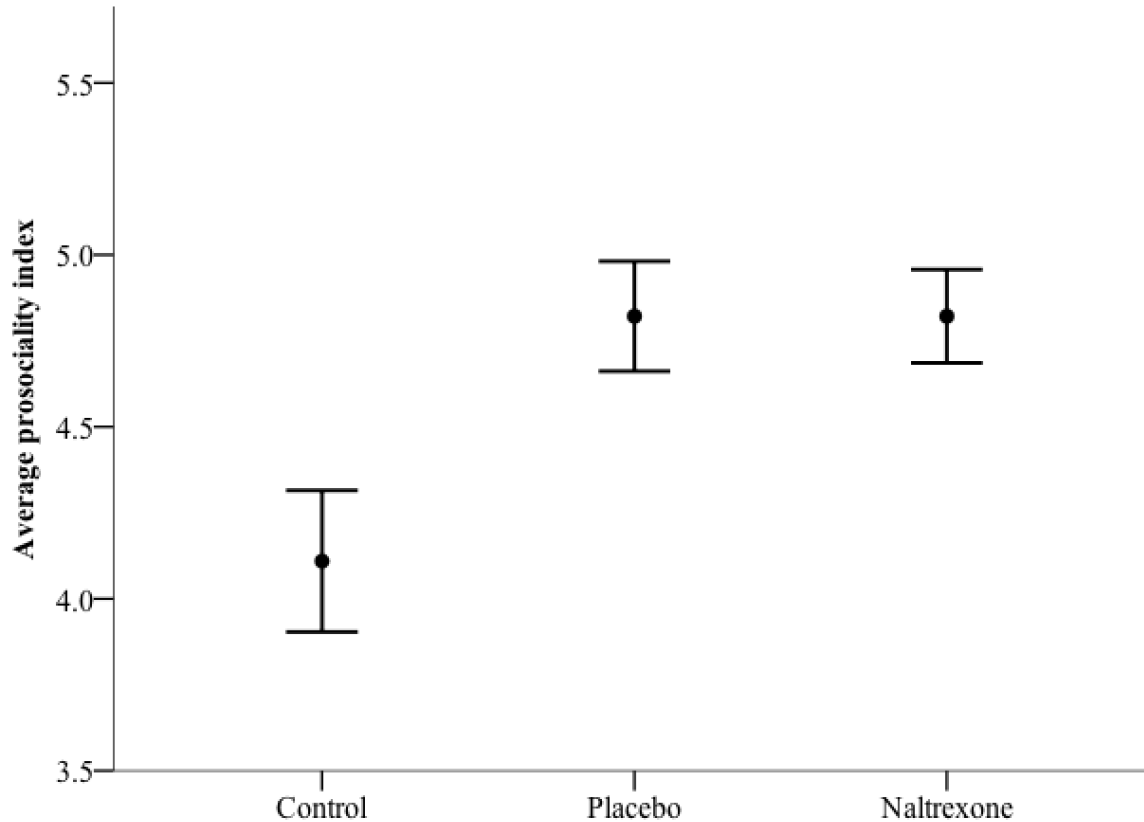


Figure 5.4 Average prosociality index for each treatment (± 1 SE).

All data (N = 103); Prosociality Index scored from 1 (low) – 7 (high).

Correlation between prosociality index and pain threshold

A Pearson's r correlation was used to assess the relationship between the change in pain threshold and prosociality index scores. Overall, these two variables showed a non-significant negative correlation ($r = -0.145$, $N = 103$, $p = 0.147$, with $R^2_{\text{control}} = 0.008$, $R^2_{\text{placebo}} = 0.013$ and $R^2_{\text{naltrexone}} = 0.035$).

Participants' experience of the experiment

Hypothesis 3: Participants' self-reported affect is significantly affected by naltrexone, but other measures of participant's experience of the experiment are not affected.

Positive and negative affect

Overall, positive affect was significantly higher after ($M = 2.818$) compared to before the movement activity ($M = 2.283$; $F(1) = 54.226$, $p < 0.001$, see Figure 5.5), and negative affect scores were lower after the activity ($M = 1.107$) compared to before ($M = 1.347$; $F(1) = 44.0224$, $p < 0.001$, see Figure 5.6). However, the MLM revealed that negative affect scores differed between conditions independently of time point ($F(2) = 3.769$, $p = 0.026$), and a pairwise comparison indicated that those in the control treatment had a marginally significantly different negative affect at the start ($M = 1.243$) compared to those in the placebo ($M = 1.383$; $F(1) = -2.004$, $p = 0.047$).

Contrary to predictions, there was no significant main effect of treatment on the change in positive affect ($F(2) = 0.961$, $p = 0.386$), nor negative affect ($F(2) = 0.118$, $p = 0.888$), suggesting that the changes in affect were independent of treatment.

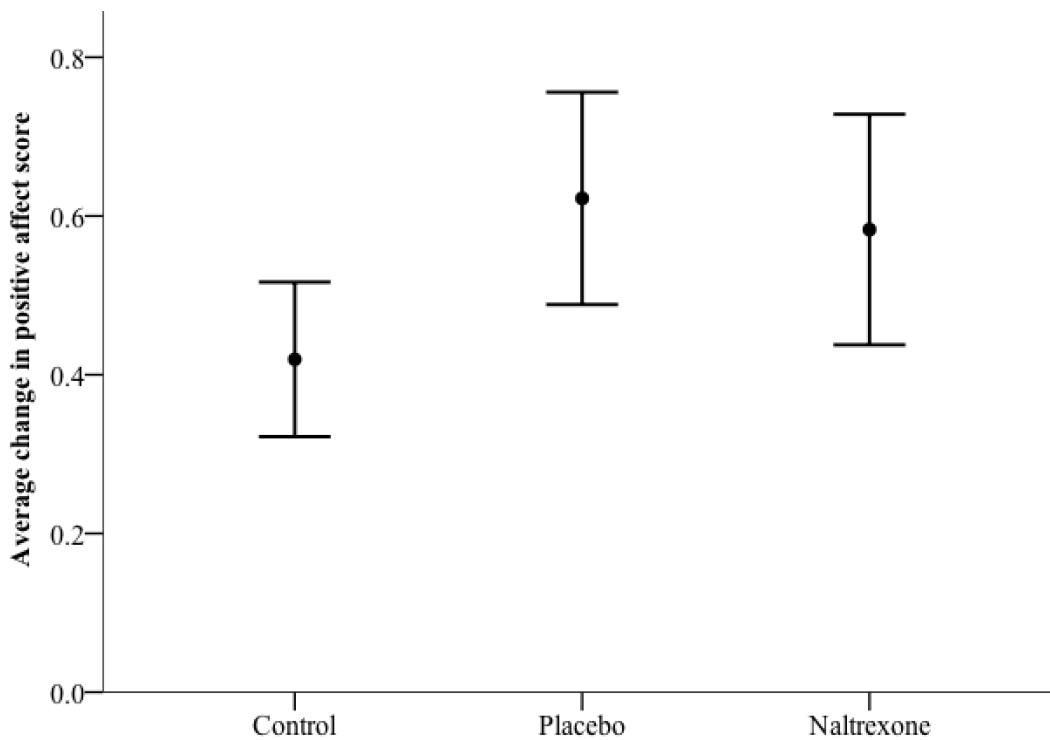


Figure 5.5 Average change (end - start) in positive affect scores for each treatment (\pm ISE).

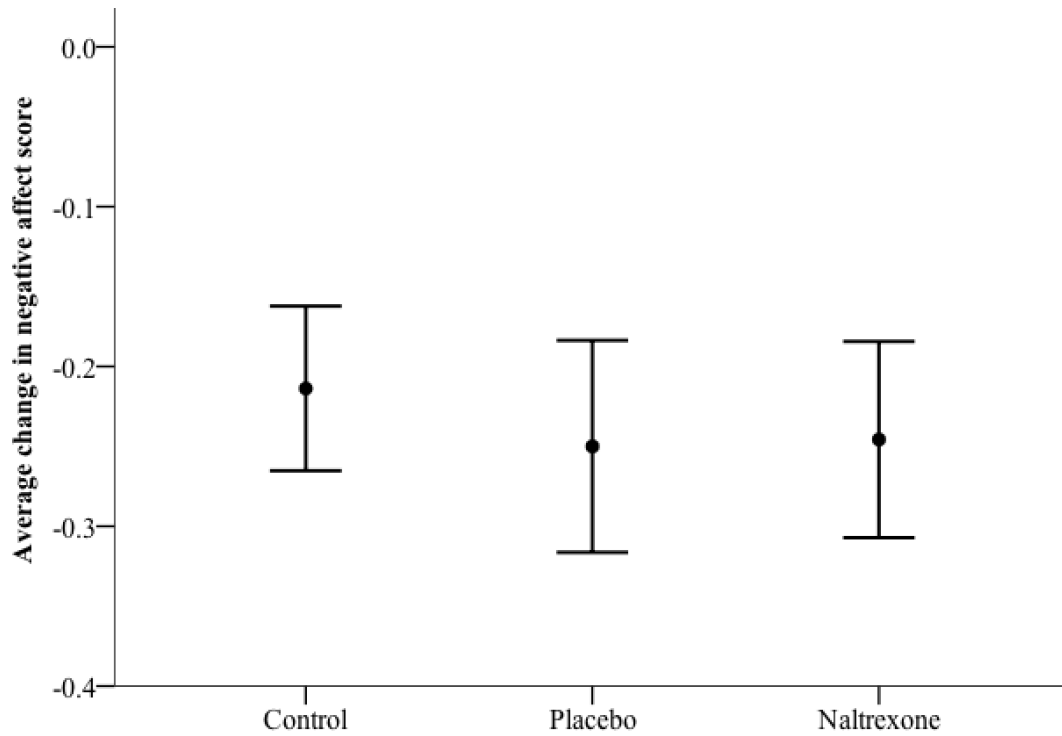


Figure 5.6 Average change (end - start) in negative affect scores for each treatment (\pm ISE).

Other measures of participants' experience

There was no significant main effect of treatment on participants' rating of how successful they had been at following the audio instructions ($F(2) = 0.408, p = 0.670$) or at synchronising their movements to each other and to the musical beat ($F(2) = 2.573, p = 0.098$). Furthermore, there was no significant main effect of treatment on the self-ratings of fun, embarrassment, difficulty or enjoyment during the silent disco (see Appendix 7.4.3, Table 7.14).

5.7 Conclusion and discussion

Pain Threshold

Hypothesis 1: Pain threshold following synchronisation is significantly affected by treatment such that those treated with naltrexone will experience suppressed analgesic effects (1A), and control and placebo treatments will experience comparatively greater elevation in pain threshold (1B).

Similar to the data presented in Chapters 3 and 4, the control data in the present study illustrate that group synchronous movement causes elevated pain threshold. As predicted, naltrexone antagonised the analgesic effect, causing a non-significant increase in pain threshold from start to end measures compared to zero (see Figure 5.3). Although these results are in the expected direction, the fact that the control treatment did not differ significantly from the naltrexone treatment was not anticipated. This could be because the naltrexone-treated participants experienced only a partially suppressed analgesic effect, rather than a full hyperalgesic effect (i.e. the average PTT was not below zero). A plausible explanation is that the naltrexone dose was too small, or that there was an interaction between the antagonist and endogenous opioids released during synchronous movement (discussed in further detail below). More puzzlingly, the placebo-treated participants experienced a hyperalgesic effect, resulting in a significantly lower change in pain threshold compared to the control treatment. The most likely explanation for this is a ‘nocebo effect’.

The nocebo effect

Positive (‘placebo’) and negative (‘nocebo’) expectation and/or conditioning is known to have a significant effect on behaviour (e.g. Enck, Benedetti, & Schedlowski, 2008; Scott et al., 2007; Sher, 1997). In the context of the present study, the nocebo effect refers to a placebo-induced

negative effect on pain threshold (i.e. hyperalgesia), and is best understood in relation to the opposite placebo-induced analgesic effect.

Evidence of placebo-induced analgesia indicates that prior expectation of an analgesic effect causes the NAcc to release dopamine (DA), thus engaging the reward and motivational circuits in the brain (Scott et al., 2007). The activation of DA release in the NAcc also correlates with activation of the EOS (Scott et al., 2008). Conversely, those who *expect* pain demonstrate significantly *lower* activation in these brain areas (Scott et al., 2008), a pattern which is associated with greater pain sensitivity (i.e. a hyperalgesic effect: Benedetti, 2013; Swider & Babel, 2013; Vögtle, Barke, & Kröner-Herwig, 2013). Interestingly, the nocebo hyperalgesic effect appears to depend to some extent on individual variation in the response of the motivational circuit and the EOS (Scott et al., 2008), as well as opioid receptor availability (Mueller et al., 2010) and personality type (Benedetti, 2013; Colloca & Benedetti, 2009).

In relation to personality, individuals who score high on empathy on the Interpersonal Reactivity Index are more prone to a nocebo hyperalgesic effect (Benedetti, 2013; Colloca & Benedetti, 2009). Although the present study did not include a measure of self-deception, there were no significant differences in personality types (including empathy) between the treatments, indicating that variation in personality type is unlikely to explain the nocebo effect in these data.

Hyperalgesic effects appear to occur when nocebo suggestions (e.g. verbal indication that pain will be worse) induce anticipatory anxiety and activate the cholecystokinergic (CCK) pronociceptive system (Enck et al., 2008). One study on ischemic pain specifically demonstrated that oral administration of an inert substance accompanied by verbal suggestion of increased pain sensitivity induced not only hyperalgesia but also activity in the hypothalamic-pituitary-adrenal (HPA) axis (Benedetti, Amanzio, Vighetti, & Asteggiano, 2006). Furthermore, social context, such as

the gender of a model demonstrating the expected pain response, can influence expectation and manifestation of a hyperalgesic effect (Benedetti, 2013; Colloca & Benedetti, 2009). However, the present study did not involve a live demonstration of the pain threshold test by a research assistant, nor did the information at the start of the experiment allude to negative pain related side effects of the naltrexone pill. Indeed, the pain threshold test was referred to as a 'blood-pressure measure', and the participant information sheet only indicated the possibility of general side effects of naltrexone such as mild mood and other physiological sensations (e.g. dizziness, nausea). Although the pain threshold test was repeated three times, at no stage was there specific indication that taking the naltrexone pill would change the participant's sensitivity to pain, and it seems unlikely that a confounding expectation of pain emerged through this experimental protocol.

However, the placebo literature highlights a difference between conscious expectation due to verbal suggestions (as explored above), and behavioural conditioning as a result of e.g. the act of injecting a substance or ingestion of a pill. The latter may have a significant effect *independent* of any conscious expectation (e.g. Benedetti et al., 2003). These data suggest that conscious expectation affects perceived physiological pain, whereas behavioural conditioning appears to mediate unconscious physiological processes, such as immune function or hormone release (*ibid*). The pain threshold test included in the present study involved a self-reported subjective indication of pain threshold, which is clearly a measure of conscious physiological pain rather than a measure of an unconscious physiological response. As such it is unlikely that the behavioural conditioning associated with ingesting a pill could fully explain the fact that placebo-treated participants experienced a significantly reduced pain threshold compared with the control participants.

Nevertheless, participants in the control treatment did not take any pill, so could not have experienced any potential anxiety or expectation (positive or negative) regarding which pill they had

taken. As a consequence, it is reasonable to assume that this may have resulted in an experiential difference between the control participants and those in the other two treatment conditions. PANAS scores were used to assess positive and negative affect in the present study, and this method of identifying levels of anxiety and expectation, particularly in relation to placebo effects during pain expectation, has been validated in previous studies (e.g. Scott et al., 2007). Scott et al. (2007), reported that administration of a placebo was associated with a significant reduction in PANAS negative affect ratings, and a (non-significant) trend in higher PANAS positive affect scores compared to those that did not receive a placebo. Specifically, they noted that the PANAS measure of fear was influenced by the placebo effect. However, in a follow-up study comparing nocebo and placebo effects, the same researchers reported no significant effects of positive or negative PANAS measures in the placebo treatment, although they do highlight a correlation between positive PANAS ratings and left NAcc μ -opioid and DA activation (Scott et al., 2008). Considering that nocebo responses are associated with deactivation of DA, and opioid release (Scott et al., 2008), it is plausible that a nocebo effect may be indicated by mood as measured by the PANAS. In the present study, a shortened (10-question) version of PANAS was used, but there was no interaction between treatment and the change in either negative or positive affect scores (see Figure 5.5), and the non-significant trend suggested that those who took a pill had a higher increase in positive affect after the silent disco compared to the control. According to these measures, there were no significant anxiety effects associated with taking a pill and not knowing whether it was naltrexone or not. As a result, it is unclear precisely what has caused the strong nocebo effect in the present data, particularly in comparison to the naltrexone-treated participants who did not experience strong hyperalgesia, but merely a suppressed analgesic effect.

Naltrexone suppressing analgesia rather than causing a hyperalgesic effect

As expected, in the present study, naltrexone-treated participants did not experience a significant analgesic effect. The fact that the effect was not stronger (i.e. hyperalgesic) is possibly due to the dose of naltrexone used and the simultaneous presence of opioids (e.g. Powell et al., 2002), or the method used to induce and assess pain (e.g. Levine, Gordon, & Fields, 1979; Levine, Gordon, Jones, & Fields, 1978).

At a sufficiently high dose, antagonists block the action of all endorphins associated with analgesia, thereby causing hyperalgesia, but at lower doses the same antagonist can cause mild analgesic effects (Levine, Gordon, & Fields, 1979). In exploring this bi-directional dose response, Powell et al. (2002) identified a bimodal G protein-coupled μ -opioid receptor that responds to ultra-low doses of naltrexone (10ng/kg) and causes an analgesic effect in rats when administered in combination with morphine. Furthermore, they review evidence for several different variants of opioid receptor, some which are specific to μ - and β - opioids (George et al., 2000; Gomes, Jordan, Trapaidze, Nagy, & Devi, 2000). Their evidence illustrates that β - antagonists do not necessarily produce hyperalgesia when in the presence of μ - agonists (George et al., 2000; Gomes et al., 2000), and similar findings are reported for naltrexone (Abul-Husn, Powell, Sutak, Hong, & Jhamandas, 2007). In a keystone human study on this subject, low doses of antagonist refers to pills of 0.4 and 2mg, and high doses were 7.5 and 10mg pills (Levine, Gordon, & Fields, 1979).

In the present study, a 50mg pill acted in the presence of endogenous opioids (released during the movement task). Although this dose is high compared to those used in the study by Levine et al. (1979), the fact that the present study involved an activity designed to release endogenous opioids may be a consideration. It is possible that the dose of 50mg was not sufficient to entirely block opioid receptors and produce a hyperalgesic effect. There are, however, no extant

studies to elucidate whether this was an adequate dose for this degree of exercise (for example, Daniel et al. (1992) used 50mg of naltrexone in combination with 75 minutes of strenuous exercise, but did not measure pain threshold, merely mood).

An additional explanation for the non-hyperalgesic antagonist effects draws on the method used to induce and measure pain. Naltrexone-treated rats which are subjected to repeated painful stimulation appear to experience mild analgesic effects over time (Greeley et al., 1988). This may be relevant in the present study where participants anticipated multiple repeats of the 'blood-pressure measurement' and its associated pain. The effect of repeated measures is explained by the role of anxiety in the experience of pain. As already discussed in the section on the nocebo effect, nocebo hyperalgesia is associated with anticipatory anxiety and activation of the CCK axis (Enck et al., 2008). Indeed, CCK antagonists, not opioid antagonists (in their study naloxone was used), successfully prevented nocebo hyperalgesia, indicating that the pain associated with anxiety is not in fact mediated by opioids (Benedetti, Amanzio, Casadio, Oliaro, & Maggi, 1997; Benedetti & Amanzio, 1997). This may explain why an opioid antagonist like naltrexone might not result in a strong hyperalgesic effect, as was evident in the present study.

Although anxiety induced by repeated measurements is important, Benedetti et al. (2006) emphasise that the nature of the stressor which causes the anxiety is perhaps more central in determining whether hyperalgesia or analgesia occurs. Hyperalgesia appears to be linked to anticipatory anxiety about the pain itself (Benedetti et al., 1997; Keltner et al., 2006; Koyama, McHaffie, Laurienti, & Coghill, 2005; Sawamoto et al., 2000) whereas analgesia is caused when anxiety is about a stressor that shifts the attention away from the pain (Terman, Morgan, & Liebeskind, 1986; Willer & Albe-fessard, 1980). This suggests that there are two different pathways of HPA hyperactivity (and associated hyperalgesia). In the present study, there may have been either

form of anxiety: anxiety regarding the repeated pain measurements themselves, or anxiety about which pill was taken.

In conclusion, the naltrexone-treated participants did not experience hyperalgesia, merely suppressed analgesia, possibly due to the fact that naltrexone only antagonised part of the pain system. These results support the finding that synchronous movement causes elevated pain threshold due to EOS activation, although alternative methods of pain assessment and direct measures of the EOS should be considered for future studies (discussed in more detail in Chapter 6: ‘The need to measure EOS activation more accurately’, pg. 226).

Prosociality measures

Hypothesis 2: Self-reported social bonding following synchronisation will be significantly affected by naltrexone.

Contrary to predictions, there was no significant main effect of treatment on the prosociality index scores. As a result, it would appear that naltrexone itself did not affect the bonding as measured in the present experiment, suggesting that: a) the methods used to assess bonding were not themselves sensitive to the presence of an antagonist; b) synchrony-induced bonding (as measured here) is not directly affected by the endorphins blocked by naltrexone; c) naltrexone did not act as it was expected to, possibly due to issues with the quantity of drug administered. These possibilities are explored in the following sections.

Naltrexone and social bonding: how relevant are self-reported measures of closeness?

Despite some paradoxical evidence regarding the effect of naltrexone on social behaviours, the majority of studies suggest that opioid blockers cause individuals to engage more in social activities, in order to induce the release of endorphins (see introduction section of this chapter:

‘Opioid antagonists and social behaviour’, pg. 177). In the present study, any such change would not necessarily translate directly into self-reported measures of trust, closeness, connectedness etc., but rather the way that participants engaged in the synchronous movement task, for example how much effort was made to synchronise with the other participants. The success questions provided information about perception of success, but there was no significant main effect of treatment on either of the two success measures, and as such it is unclear precisely how the different treatments influenced social engagement during the movement task, and any subsequent bonding.

Direct measures (e.g. of eye contact, analysis of facial expressions) would provide a more robust indication of how socially engaged individuals were during the task, which would likely have implications for the types of bonding that are of interest in this study (for more discussion see Chapter 6: ‘The relevance of behavioural measures’, pg. 230). A recent study (which used the same dose of naltrexone and a similar waiting period as the present study), showed that naltrexone significantly affects both aesthetic evaluation of and motivation for viewing attractive faces of the opposite sex (Chelnokova et al., 2014). Naltrexone-treated participants showed reduced viewing time of attractive faces in a ‘wanting’ task, and rated faces as less attractive in a ‘liking’ task compared to placebo and agonist treated participants (*ibid*). These results demonstrate that the EOS mediates social motivation by controlling desire to engage with valuable social cues (in this case attractive faces)³. Accordingly, in the present study, participants treated with naltrexone may have experienced differential inter-personal judgements, and social motivation (e.g. to engage in the task and synchronise) due to different levels of attraction and attention. These variables were not directly measured in the present study but may have influenced bonding in a way that was not captured by the prosociality questions following the silent disco. Although the prosociality questions used in this

³ These data show that administration of an opioid antagonist *decreases* social motivation, rather than *increasing* engagement in social activities. This provides an example of the paradoxical evidence in the literature on this topic, as discussed in ‘Opioid antagonists and social behaviour’ pg.177).

study were drawn from other established studies, and have been applied consistently throughout this thesis (see Chapters 3, 4 and 5), the difficulties associated with measuring prosociality in a robust and reliable manner provides a significant on-going challenge for research in this field (Launay et al. in press; for more discussion see Chapter 6: 'The need to measure social bonding more comprehensively', pg. 229). The lack of differences in Prosociality Indices between the treatments in the present study suggests that either these measures are not sensitive to the changes caused by taking naltrexone, or alternatively that the bonding that develops during group synchrony is not directly linked to opioids.

Synchrony-induced bonding is not affected by endorphin blockers

Although this thesis explores a number of reasons to hypothesise that the bonding demonstrated during synchronous movement is due to activation of the EOS, and evidence from Chapters 3 and 4 do not refute this hypothesis, the results presented in this chapter suggest that the relationship between synchrony, the EOS, and bonding might not be as direct as previously suggested.

For example, it is possible that group movement synchrony does trigger the release of endorphins, but that other neurohormones (not significantly affected by naltrexone), or a combination of neurotransmitters, are critical in the bonding that forms during group synchrony. Accordingly, social bonding may still occur even in the absence of endorphins (i.e. when the EOS is under the influence of an antagonist). The likelihood that the social bonding that arises during movement synchrony may be due to synchrony-based mechanisms associated with other neurohormones is an important consideration for future research, and is discussed in more detail in Chapter 6 ('Synchrony related social bonding may happen via means other than just endorphins', pg. 223). Furthermore, although this thesis is concerned with investigating the EOS specifically, non-

hormonal mechanisms (e.g. self-other merging effects as a result of action-perception networks, discussed in more detail in ‘Self-other merging: a mechanism for synchrony-induced social bonding’, pg. 35), are also at play during movement synchrony related social bonding. It is presently unknown how hormonal mechanisms of bonding may interact (if at all) with non-hormonal mechanisms of social bonding during movement synchrony.

Future studies

It is unlikely that any one particular social bonding hormone is entirely responsible for prosocial tendencies and behaviours (e.g. Depue & Morrone-Strupinsky, 2005; Machin & Dunbar, 2011). Blocking the activity of one particular neurohormone (as we have attempted in the present study) may be insufficient to inhibit the social bonding effects that are associated with a group movement synchrony task. Indeed, there is evidence that oxytocin (widely thought to be the main bonding hormone) interacts with the EOS (Depue & Morrone-Strupinsky, 2005), and this is discussed in more detail in Chapter 6 (‘The EOS interacts with other social neurohormones’, pg. 223). It would therefore be desirable to repeat this study with oxytocin (e.g. an agonist nasal spray), or a range of other neurohormonal candidates (such as dopamine, endocannabinoids and serotonin). This would allow for a controlled and systematic comparison between the relative effects of these various interacting neuropeptides on the measurements of bonding included in the present study.

Furthermore, comparing the results from the present chapter to a non-synchrony naltrexone treatment, and an agonist manipulation, would help to determine if there are significant and interactive main effects of treatment and synchrony. It would be interesting to determine if treatment has a significant interactive effect with synchrony condition (i.e. combining the experimental designs of Chapter 4 and 5).

As a final consideration, it should be mentioned that the lack of a significant difference between control, placebo- and naltrexone-treated participants' prosociality index scores could be due to insufficient dose of naltrexone, or inadequate waiting time after taking the drug. It is worth noting that the majority of opioid intervention studies involve chronic treatment of the drug over a period of weeks, rather than a single dose as used in the present study (Jung et al., 2009; Roy et al., 2014). However, chronic administration of antagonists can reportedly result in analgesic rather than hyperalgesic effects (Bardo, Miller, & Risner, 1984; Tempel, Gardner, & Zukin, 1985; Yoburn, Nunes, Adler, Pasternak, & Inturrisi, 1986), likely due to an antagonist induced up-regulation in opioid receptors, and activation of a 'backup' analgesic system (Greeley et al., 1988). As a result, the single dose method was preferable. Although the use of a single dose administration of a 50mg pill and 1 hour waiting time (as used in the present study) has been successfully used in some previous studies (Chelnokova et al., 2014; Daniel et al., 1992), Cohen et al. (1983) highlighted that antagonist doses of approximately 2mg/kg (higher than that administered in the present study) are necessary to result in significant differences in mood and memory. It is possible that the present study was limited by the use of a moderate dose of 50mg.

In conclusion, the present study provides evidence that synchronous exertive movements are associated with endorphin release, but interpretation of results from the placebo trials is ambiguous. Although the pain threshold results for the naltrexone-treatment were in the expected direction, the causal link between this and social bonding that arises during group synchrony was not confirmed. In order to better investigate the causal link between the endorphin activation and bonding in this scenario, improvements in the experimental design could include a) adjusting the method of treatment allocation in order to avoid biasing control treatments from knowing that they did not receive an antagonist; b) changing the presentation of participant information to ensure there are no inadvertent priming effects; c) including other neurohormonal candidates and non-synchronous

Chapter 5 – Naltrexone silent disco experiment

conditions in the design; and d) increasing the dose of naltrexone. Furthermore, the results from this chapter indicate that it may be necessary to review the methods used to assess prosociality.

Additionally, the relationship between anxiety and pain, and the intrinsically subjective nature of the pain measurements used throughout this thesis, suggest that alternative methods of pain assessment may be preferable. I will discuss these possible improvements in the next chapter.

Chapter 6 – General discussion

6.1 Overview

This thesis explored the hypothesis that dance encourages social bonding amongst co-actors by stimulating the production of endorphins in the Endogenous Opioid System (EOS). As outlined in the introductory chapter (Chapter 1), investigation into possible cognitive evolutionary explanations for the appreciation and aptitude for moving to music is motivated by the fact that music based activities such as dance are ubiquitous and ancient. This thesis employed a coupled concept of music and dance, and was concerned with how movement to music increases the psychological experience of interpersonal closeness, which may be reflected in prosocial behaviours. Previous literature indicates that dance may socially bond people due to the fact that matching movements with others can lead to a merged sense of ‘other’ and ‘self’. Furthermore, across a range of species, social bonding is underpinned by neurohormonal activation, including endorphin release by the EOS. As reviewed, the EOS is also implicated in exertive synchronous activities, and consequently it was hypothesised that this neurohormonal system may mediate the social bonding that arises during synchronised movement to music. Four data chapters were presented in order to investigate this social bonding hypothesis of dance. Throughout, there was an emphasis on using an ecologically valid concept of dance, in which groups of people perform dance movements to music rather than dyadic synchrony of simple movements to a metronome.

6.1.1 Summary of findings

To begin, the exploratory first data chapter (Chapter 2, pg. 58) provided an initial, and non-laboratory investigation into participants’ self-reported closeness and generosity in an economic game before and after either a real-world dance class (exertive and synchronised) or gym session

(exertive and non-synchronised). The results showed that spending time together during a group movement activity increased social bonding (for some measures), but that this bonding was not significantly higher in the dance classes compared to the control gym sessions. Whilst naturally existing social activities (such as dance classes and gym sessions) are an ecologically valid way to test hypotheses regarding the social bonding effects of group synchrony, these activities are easily confounded by a number of factors. Specifically this study highlighted the need to standardise the movement conditions with respect to group size, the actual movements involved in each condition, and the degree of synchrony and exertion involved in the different activity conditions.

Chapter 3 (pg. 94) improved on the design of the first study by including a direct and independent manipulation of both synchrony and exertion, a proxy measure of endorphin release, and a within-subject design in which tests were administered before and after the movement session. The aim was to investigate the relative and potentially interactive effects of synchrony and exertion on endorphin release and social bonding. Given that groups of people dancing together often already know each other, this study focussed on acquaintances rather than strangers, and included a measure of in- and out-group prosociality in order to investigate whether any social bonding effects are generalised or predominantly directed towards co-actors. Furthermore, this study was conducted in Northern Brazil, thereby providing a non-UK sample, which is a useful (though not strictly cross-cultural) addition to the investigation into social bonding and dance as a general phenomenon. The results demonstrated that both synchrony and exertion had significant and independent main effects on self-reported bonding, and on pain threshold (a proxy measure of endorphin levels). This indicates that synchrony-induced social bonding (which is already well documented) is also associated with EOS activation, even in the absence of exertive movements.

Chapter 6 – General discussion

Chapter 4 (pg. 129) introduced a laboratory-based synchrony paradigm to determine which aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with endorphin release and social bonding. The silent disco technology used in this experiment allowed manipulation of the audio-visual experience of synchrony, and the addition of another asynchrony condition in which participants heard different music and performed different movements. In addition, accelerometer technology aided the measurement of exertion, which was included in analyses in order to account for any effect of exertion on social bonding and endorphin release. The results supported the findings reported in Chapter 3, and indicated that those in synchrony with one another experience elevated pain thresholds and higher levels of social bonding (according to self-report measures, but not economic games) compared to those in a partially synchronised condition. Those in the asynchrony condition did not experience significant analgesic effects, nor an increase in prosociality index scores, although the differences between this condition and the synchrony condition were not significant. The results from this initial silent disco experiment also indicated that economic games may not be a suitable tool to assess prosociality among strangers in a between- rather than within-subject design (as discussed by: Launay et al., in press). In conclusion, this experiment provided results consistent with the hypothesis that dance encourages social bonding amongst co-actors by stimulating the production of endorphins in the EOS, but a means of directly measuring or manipulating the EOS was necessary to better determine if it plays a causal and critical role.

Chapter 5 (pg. 174) used the same experimental set-up as the experiment in Chapter 4, but specifically focussed on determining if endogenous opioid (specifically endorphin) uptake mediates the social bonding effects in dance. Naltrexone was used to block endorphin uptake. Participants were allocated to a treatment condition via double-blind administration of either a placebo pill, naltrexone pill or no pill, and all participants took part in a synchronous movement condition.

Naltrexone-treated participants experienced suppressed analgesic effects, whereas the no-pill control group experienced increased pain threshold, suggesting that the EOS is activated by exertive synchronous movement. Placebo-treated participants suffered increased pain sensitivity (a ‘nocebo effect’, which is a fairly common problem in placebo trials), and the bonding measures were not significantly affected by treatment. Possibly, an adjusted experimental design was needed, in which participants a) did not know if they had received a pill or not, or b) received a higher dose of naltrexone. In conclusion, this chapter was a relevant progression from the previous experiments in that it used a drug intervention to better determine the causal link between EOS activation during synchronised dance and social bonding.

6.1.2 Contributions to the literature

The series of experiments undertaken aimed to answer the following four questions: Firstly, does dance make people feel more socially bonded?; secondly, what role does exertion play in the relationship between synchrony and social bonding?; thirdly, what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with this bonding and endorphin release during group dancing; and finally, does endogenous opioid (specifically endorphin) uptake mediate the social bonding effects in dance?

Does dance make people feel more socially bonded?

Research on synchronised tapping (Hove & Risen, 2009; Valdesolo & Desteno, 2011), walking in time with other people (Wiltermuth & Heath, 2009; Wiltermuth, 2012), and performing simple synchronised body movements to a metronome (Reddish et al., 2013) indicate that matching movements in time can lead to people feeling more socially bonded. These effects are apparent

when dyads synchronise, but there is limited research on whether synchrony to music in bigger groups, as would occur during group dancing, also results in social bonding.

The results from this thesis support the suggestion that group synchrony in dance bonds people socially. According to all the data chapters, dance, operationalized as exertive, synchronised movement to music, does make people feel more socially close, at least according to some measures of prosociality. In Chapter 2, participants rated their inclusion of other in self scale significantly higher after compared to before the dance class, and in Chapters 3 and 4, synchrony had a significant main effect on the self-reported prosociality index. According to these measures, those in the synchrony conditions experienced elevated social bonding towards fellow performers.

Notably, this effect was evident for both strangers (Chapters 2, 4 and 5) and people who already knew each other (Chapter 3). Whilst the former has been substantially investigated (e.g. Demos et al., 2012; Launay et al., 2014; Reddish et al., 2013; Wiltermuth & Heath, 2009), there is less known about the role dance may play in the *maintenance* of relationships, likely due to the challenges of accounting for variability in how well bonded people are prior to the experiment. Chapter 3 addressed this challenge through the use of multilevel linear modelling, and before and after measures of social closeness. The results indicated that synchronous movement to music increases prosociality amongst acquaintances, an important contribution to the literature given that much of our group dancing and music making occurs regularly amongst acquaintances and friends.

However, the social bonding effects demonstrated in the prosociality index questions were not evident in the various economic games (the dictator game in Chapter 2, and the weak-link coordination and trustee games in Chapter 4). The possible reasons for this are discussed in more detail in the section on limitations (Section 6.3.1, ‘The need to measure social bonding more comprehensively’, pg. 230), but in summary, given that the other measures of prosociality did

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demonstrate significant differences between conditions across the various chapters, the experiments presented in this thesis suggest that economic games may not be a suitable method for investigating prosociality when looking at the between-subject effect of synchrony on bonding between strangers.

In Chapter 3 it was demonstrated that dance does cause social bonding effects (according to the self-report measures), but only towards those who take part in the activity. This suggests that active participation in dancing is key, and supports the suggestion that synchronising together may help to establish a group identity (Wiltermuth & Heath, 2009). However, the out-group prosociality data (i.e. feelings of closeness towards the entire school class) had the same overall but non-significant trend as the in-group data in Chapter 3. This indicated that the effects of synchrony on out-group social bonding may have been present (as suggested by e.g. Reddish et al., 2014), but, at least in this experiment, were not as strong as the social bonding that occurs between co-actors.

In conclusion, the results from the various chapters indicate that dance does make people (acquaintances or strangers) feel socially bonded, if measured by self-report prosociality questions in relation to those who took part in the act of dancing. Importantly, this thesis has demonstrated that social bonding effects (previously demonstrated in studies on dyadic synchrony and in small groups performing simple (non-dance) movements to a metronome) are also evident when people are dancing to music. However, as highlighted in Chapter 2, other activities, such as a group circuit training sessions, also result in feelings of social closeness. This is probably because the gym sessions were highly exertive, therefore activating the EOS, which might be mediating the social bonding effects felt after compared to before the activities.

What role does exertion play in the relationship between synchrony, social bonding and endorphin release?

The suggestion (from the results in Chapter 2) that exertion might have an independent effect on social bonding was the main focus of Chapter 3. Although the link between movement synchrony and social bonding is well established, whether the EOS plays a role in this effect has not, prior to this thesis, been directly investigated. Non-synchronised exertive sports activate the EOS (Boecker et al., 2008), and according to the proxy measure of pain threshold, endorphins are released in response to social (versus alone) sporting activity (Cohen et al., 2010; Sullivan et al., 2011), when exercising under the condition of in-phase (versus anti-phase) synchrony (Sullivan et al., 2014), whether with friends or strangers (Sullivan & Rickers, 2013). In these studies, the relative effects of synchrony and exertion were not determined, nor were data on social bonding collected. Consequently, it was not known whether endorphins are also released in situations of low exertive synchrony, because previous studies on finger tapping, walking, rocking etc. did not measure endorphin release; nor did they investigate the hypothesis that the EOS may mediate the social bonding that occurs during these cases of interpersonal synchrony.

The results from Chapter 3 showed that exertion has a significant and independent effect on social bonding measures and pain threshold. This is a novel finding in that it demonstrates that the EOS is likely to play a role even in low-exertive synchronous activities. Due to this finding, the remaining two chapters went on to control for exertion level, in order to focus on the effect of synchrony in the social bonding and endorphin release that arises during group dancing.

What aspects of synchrony are associated with social bonding and endorphin release during group dance?

In order to determine what aspects of synchrony in dance are associated with increased social bonding, synchrony was directly manipulated in a number of ways throughout the thesis. Behavioural synchrony (matched movements and timing) is shown to result in interpersonal bonding compared to a non-movement condition (e.g. Wiltermuth & Heath, 2009), situations where participants perform the same movement, but temporally out-of-phase (e.g. Richardson et al., 2007), or sequentially (e.g. Reddish et al., 2013). However, when investigating the effect of synchrony in dance, non-movement control conditions are confounded by the fact that they also differ in terms of exertion, which is evidently problematic, as suggested by Chapter 2 and empirically demonstrated by Chapter 3. Furthermore, as this thesis was concerned with investigating group effects, it was not possible to contrast in- and anti-phase synchrony, as it involves one of two binary movement states and at least two participants would end up in-phase, and therefore synchronising with each other. In reality, people dancing together generally entrain to the same music, but do not necessarily perform identical movements, and therefore the partial synchrony condition (in which people synchronised temporally, but not in terms of the movement) was chosen to act as a control in Chapters 3 and 4.

The results from both chapters indicated that the behavioural synchrony condition was the most conducive to encouraging social bonding between individuals (in support of previous studies on synchrony and bonding), whether it was among friends (Chapter 3) or strangers (Chapter 4). Furthermore, the synchrony condition was associated with the highest pain threshold (as suggested by: Sullivan et al., 2014) in both chapters. It is important to note that in Chapter 3, partially synchronised individuals did experience an increase in prosociality scores, but only when in the high exertion condition. Those who were in the low exertion partially synchronised condition were the only participants to demonstrate no change in social bonding after the movement activity. This

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demonstrates that people (who already know each other) dancing together will feel more socially close to one another even if they are not behaviourally synchronised, but that the dancing needs to be *exertive* for this effect to arise. Overall, the results from Chapters 3 and 4 did demonstrate, however, that when performing instructed (i.e. non-improvised) exertive dance movements, matching movements and timing is associated with more interpersonal bonding, and greater elevation in endorphin release, compared to the partially synchronised conditions.

Importantly, this effect did not depend on people knowing that they were hearing the same music. In Chapter 3, the musical stimuli were played out loud and all participants shared a common audio-visual experience as a result. However, the silent disco technology used in Chapter 4 meant that participants did not know what the other participants could hear, and therefore the effect of the synchrony condition in this experiment was established by the interpersonal visual feedback matching their personal movements and audio experience. The fact that participants still experienced increased social closeness after the synchronised silent disco supports studies which have demonstrated that visual feedback is sufficient in establishing the effects of synchrony (e.g. Demos et al., 2012; Richardson & Marsh, 2005). Although it is plausible that participants in the synchrony condition in the silent disco experiments assumed that they were all listening to the same audio stimulus, it is not known how participants experienced the partial synchrony condition (i.e. whether they could tell that they should have been temporally entrained with the others due to the fact that they were hearing the same music, but with different movement instructions). Regardless, in both the silent disco and the study in Chapter 3, the partial synchrony condition resulted in significantly less bonding and endorphin release than the synchrony condition.

Interestingly, the asynchrony condition in Chapter 4 did not result in significantly lower social bonding scores and pain threshold. Although this condition did not experience as high an

increase in pain threshold or prosociality index scores compared to the synchrony condition, the difference was not statistically significant. This condition differed from other non-synchrony conditions often used in the literature in that it involved both mismatched movements and timing, rather than sequential movements or synchronised movements performed out-of-phase. To my knowledge, this is the first study to investigate full body asynchrony in this manner, likely due to the fact that the majority of studies investigating synchrony have used simple movements (e.g. tapping) for which manipulation of temporal synchrony was of greater interest and easier to manipulate than different movements and different timing. The fact that the negative effect of this condition on the social bonding and pain threshold was not as strong as it was for the partial synchrony condition will warrant further investigation. It should also be considered that control conditions which involve similar movements but at different times (e.g. sequential timing) may be particularly distracting, thereby causing *negative* bonding effects. Given this, synchrony effects reported in other studies may in fact be biased due to the control conditions producing a negative effect on bonding measures, thereby overestimating the effect of synchrony. The addition of the asynchrony condition in Chapter 4 indicates that being unsynchronised does not necessarily always contrast significantly with being in synchrony, although it is plausible that due to the fact that this movement condition involved different dance repertoires, participants were less aware of the fact that they were moving at different times.

In conclusion, in support of previous research, the results from Chapters 3 and 4 demonstrate that participants feel more socially bonded after matching both their movements and timing (in the synchrony condition) compared to a less synchronised control condition. Of the various movement conditions included in these experiments, the type of synchrony most suited to encouraging increased prosociality and endorphin release was behavioural synchrony. The matching of both movements and timing had the strongest effect, whether or not participants were explicitly

aware of the fact that they were hearing the same music or not, suggesting that shared music itself is not key in the effects of instructed synchrony in dance.

Does endogenous opioid (specifically endorphin) uptake mediate the social bonding effects in dance?

Chapters 3, 4 and 5 used pain threshold as a proxy measure of endorphin release to infer EOS activity. In these experiments the use of a blood pressure cuff to induce ischemic pain acted as a low-cost method for indexing endorphin release, as used widely in previous studies (Cogan et al., 1987; Cohen et al., 2010; Dunbar, Kaskatis, et al., 2012; Dunbar, Baron, et al., 2012; Sullivan et al., 2014; Sullivan & Rickers, 2013). Some of these studies have proposed that synchrony induced social closeness may be mediated by the EOS (Cohen et al., 2010; Sullivan et al., 2014; Sullivan & Rickers, 2013), but as yet no study has systematically measured both prosociality and pain threshold. This is a novel contribution of the present thesis.

Chapters 3 and 4 demonstrated that synchronised exertive movements were associated with both elevated pain threshold and measures of social closeness. Although there was no correlation between these data in either chapter, these results suggested that the EOS is activated during synchrony. The use of an endorphin blocker in Chapter 5 aimed to directly manipulate the EOS, rather than relying entirely on pain thresholds to infer the possible relationship between synchrony, EOS activation and social bonding. However, the results of Chapter 5 indicated that whilst naltrexone did antagonise pain threshold, social bonding measures were not significantly affected. Due to the complication of a placebo effect, and questions over whether the dose of naltrexone was sufficient to cause the expected effects, it was difficult to draw conclusions from this experiment. Nevertheless, this experiment laid the foundation for future studies which might manipulate the EOS and also synchrony in order to determine whether this system plays a causal and critical role.

In conclusion, this thesis provides important contributions to the questions of ‘does dance make people feel more socially bonded?’; ‘what role does exertion play in the relationship between synchrony and social bonding?’ and ‘what aspects of synchrony (similar movement and/or mere temporal entrainment to music) are associated with this bonding and endorphin release during group dancing?’. In terms of the final question: ‘does endogenous opioid (specifically endorphin) uptake mediate the social bonding effects in dance?’, the results from Chapters 3, 4 and 5 provided limited evidence that endogenous opioid (specifically endorphin) uptake directly mediates the social bonding effects in dance. However, the possibility that the EOS plays an indirect role is discussed in the following section.

6.2 Does the EOS mediate the social bonding that arises during synchronised group dance?

The experiments included in this thesis collectively provide a wealth of data from which the overall mediation effect of the EOS can be established by combining the data and performing a mediation analysis. Mediation modelling is a form of path analysis which has been developed specifically to test this type of hypothesis, in that it allows for inferences to be made about whether an effect is transmitted via an intermediary variable to a dependent variable of interest. In this case, activation of the EOS is hypothesised to be a causal intermediary between movement synchrony and social bonding, as measured by a prosociality index.

Data inclusion

The results from Chapters 3 and 4 were combined to create as large a sample as possible for an exploratory mediation analysis. The data from these two chapters were chosen due to the fact

that the studies both included synchrony and partial synchrony conditions, identical methods of measuring pain threshold, and a measure of prosociality through the creation of prosociality indices.

To ensure that the movement conditions were comparable between the two experiments, the asynchrony condition was dropped from the Chapter 4 silent disco dataset. Furthermore, the low exertion conditions were excluded from the Chapter 3 dataset in order to most closely match the movement conditions in Chapter 4's silent disco, in which the dancing was exertive. This resulted in a sample, $N = 213$, in which all participants danced at a comparable exertion level in both synchronous and partially synchronous conditions. A dummy variable was coded whereby partial synchrony was scored "0" and synchrony was scored "1". As such, the intended model would test whether synchrony had a positive effect on pain threshold in relation to partial synchrony, which it was hypothesised would in turn increase prosociality index scores. Given that prosociality was measured twice in Chapter 3, but only once (after the movement session) in Chapter 4, only the average prosociality index scores after the movement session were used in the mediation analysis.

It is important to note that because these data were combined across two different experiments (one conducted in Brazil, the other in the UK) and the fact that the actual prosociality indices in each were based on a non-identical set of self-report questions, the mediation model was adjusted to account for the fact that these data were sourced from two independent experiments (discussed in further detail below).

Mediation analysis

The mediation program PROCESS (Hayes, 2014) was used to conduct a simple ordinary least squares path analysis (Hayes, 2013), whereby the difference in pain threshold (end minus start) was estimated as a causal intermediary between the movement condition and the prosociality index.

In PROCESS, mediation analysis involves the regression of the mediator on the specified predictor(s) and then regressing the outcome variable on the mediator and the predictor(s), regressions 1 and 2 respectively (see Figure 6.1). By convention, the path coefficient between the predictor and mediator is referred to as a , the coefficient between the mediator and outcome is b , and the path between the predictor and outcome variable is referred to as c' . The indirect, or mediated, effect is the product of a and b , whilst controlling for c' , and the direct effect is c' , whilst controlling for ab (see Figure 6.1). PROCESS constructs a bootstrap confidence interval for ab by generating n bootstrap samples with replacement. It then estimates the beta coefficient for ab drawn from each of these n samples and creates a probability distribution for ab (Hayes, 2013). If 95% of the estimations for ab are different from zero it is possible to infer with 95% confidence that the effect is statistically significantly different from zero (i.e. if the 95% confidence interval for ab does not contain zero), the effect is considered significant. This method of inference testing is superior to standard parametric inference tests, because it avoids making potentially erroneous assumptions about the normality of the sampling distribution (Hayes, 2013). Assuming pain threshold is an acceptable proxy for EOS activity, this model would therefore test whether synchrony had an effect on prosociality index via activation of the EOS. Given that the present hypothesis was directional, a one-tailed test was conducted.

Accounting for the differences between the experiments

Due to the fact that the experiments were sampled in two different cultures, and the prosociality index data were compiled from non-identical questions, it was necessary to determine if these effects required a multilevel mediation analysis. However, it was not possible to test whether pain threshold and prosociality were statistically different between the experiments due to the fact that the data violated the assumptions of the ANOVA and appropriate non-parametric inference

tests (the data were non-normal, subject to unequal variances between groups and drawn from differently sized samples). Moreover, two groups at level 2 (i.e. only two experiments) does not constitute a rich enough data structure to allow for multilevel analysis, which could have biased the results (for review see: Bell, Morgan, Kromrey & Ferron, 2010; and for simulation study, see: Clarke & Wheaton, 2007). This would have led to convergence problems when attempting to specify a multilevel mediation model (see: Hayes, 2014).

As an alternative, ‘experiment’ (i.e. whether the data were sourced from Chapter 3 or 4) was included as a clustering variable in the analysis (i.e. included as a covariate: Hayes, 2014). Whilst this approach assumes fixed effects across experiments, it controls for any differences that arise between experiments due to operational or cultural effects (Hayes, 2014), and results in a more conservative estimate of the mediation effects (indeed, not controlling for experiment resulted in increased significance in the final results).

Mediation analysis results

The assumptions of the mediation analysis were checked and indicated that all assumptions were met except for residual normality (see Appendix 7.5.1). However, inferences drawn from bootstrap confidence intervals can be generalized despite non-normal data, as they make no assumptions about the normality of the sampling distribution (Hayes, 2013).

The synchrony condition had a significant positive effect (*a*) on pain threshold, and in turn pain threshold had a significant positive effect (*b*) on the prosociality index scores (see Figure 6.1 and Table 6.1). This indicates that those in the synchrony condition were less pain sensitive (i.e. experienced an analgesic effect which indicates activation of the EOS), which in turn resulted in increased prosociality index scores.

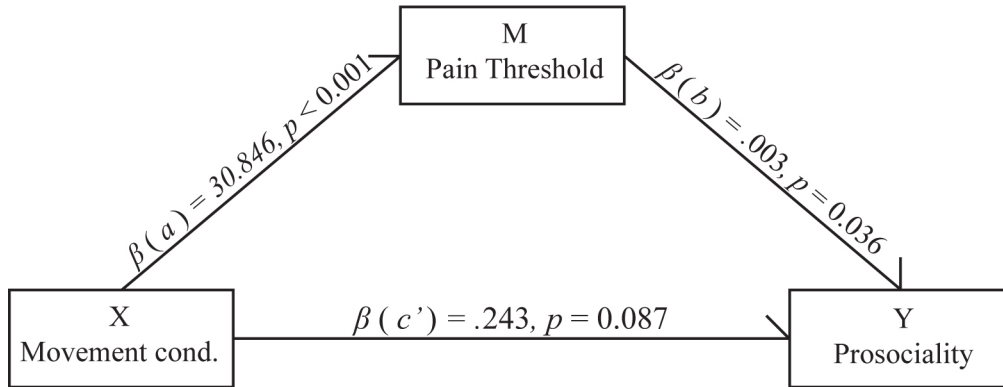


Figure 6.1 Diagram demonstrating mediation analysis and results, for which the indirect effect is significant ($ab = 0.086$, $SE = 0.044$, $95\%CI_{bs} = -0.022$ to -0.168).

Note: direct effect = c' ; the indirect effect of X on Y via $M = ab$ (one-tailed), which is significant as the confidence interval does not contain zero.

Table 6.1 Mediation model of effect of movement condition on prosociality index via pain threshold.

Antecedent	Consequent									
	M (Pain Threshold)					Y (Prosociality Index)				
		β	SE	t	p		β	SE	t	p
X (Movement Cond.)	a	30.846	7.743	3.983	<0.001	c'	-0.243	0.179	-1.361	0.087
M (Pain Threshold)	-	—	—	—	—	b	0.003	0.001	1.811	0.036
Constant	i_1	-21.607	8.456	-2.556	0.011	i_2	4.635	0.191	24.272	<0.001
Model Summary	Regression 1:					Regression 2:				
	$R^2 = 0.099$, $F(2,210) = 11.650$, $p < 0.001$					$R^2 = 0.032$, $F(3,209) = 2.322$, $p = 0.076$				

A one-tailed bias-corrected 95% bootstrap confidence interval ($n_{bs} = 10000$) for the mediated effect did not contain zero ($ab = 0.086$, $SE = 0.044$, $95\%CI_{bs} = -0.022$ to -0.168). As such, it is possible to infer with 95% confidence that, given that pain threshold is an adequate proxy for EOS, there was a significant mediated effect in which synchrony resulted in increased EOS activation compared to the partial synchrony condition, which in turn resulted in increased prosociality scores.

Moreover, the direct effect, c' , was not significant, indicating full mediation: according to this analysis, the effect of movement condition on prosociality was transmitted entirely via pain threshold. In conclusion, the mediation analysis results indicate that synchrony has a positive effect on prosociality via pain threshold, which acts as a mediator.

Synchrony related social bonding may happen via means other than just endorphins

Although the trend discussed in the preceding section is promising, it is important to consider the possibility that group movement synchrony does trigger the release of endorphins (Chapters 3, 4 and 5), but that other neurohormones or a combination of neurotransmitters are critical in the social bonds that form during group synchrony.

The EOS interacts with other social neurohormones

As discussed in Chapter 5, it is unlikely that any one particular bonding hormone is entirely responsible for prosocial tendencies and behaviours (e.g. Depue & Morrone-Strupinsky, 2005; Machin & Dunbar, 2011). Other candidates that should be considered, for example, are oxytocin and dopamine. Oxytocin is widely considered *the* bonding hormone (Bartz, Simeon, et al., 2011; Meyer-Lindenberg et al., 2011) and some have suggested that this neurohormone is responsible for the social bonding that arises during group music-making (Freeman, 2000; Grape et al., 2003; Huron, 2001). Although empirical evidence for a direct bonding role of oxytocin in synchrony based activities is lacking, oxytocin is known to interact with the EOS (Depue & Morrone-Strupinsky, 2005), and, similar to endorphins, has been implicated in social touch in humans (e.g. during hugging: Light, Grewen, & Amico, 2005) and in pain management (e.g. in music therapy: Ulrica Nilsson, 2009). However, most studies on oxytocin and bonding involve the formation of mother-infant and pair bonds (e.g. Atzil et al., 2011; Feldman, 2012) and these may behave very differently

to other non-reproductive kinds of social bonds. Nonetheless, the possibility that this hormone may play a role in the formation of social bonds during music-based activities needs to be investigated further, as do the implications of the fact that oxytocin and the EOS interact.

Dopamine is another neurohormone which is known to play some part in mother-infant and pair bonding through interaction with oxytocin and the EOS (Broad et al., 2006). Tactile stimulation during mating and birthing are associated with the release of oxytocin, arginine vasopressin (in males, during mating) and beta-endorphins which activate the mesolimbic dopamine reward system (Curley & Keverne, 2005). Consequently, it has been suggested that dopamine plays a role in social attachment (Insel, 2003). In rodents, the EOS is typically associated with pleasure states, and the dopamine system with goal-seeking behaviour (e.g. the desire to engage in an activity to trigger a pleasurable state: Carelli, 2004; Cheer et al., 2007; Salamone, Correa, Farrar, & Mingote, 2007). Dopamine neurons are activated by the prediction of and motivation for a hedonic reward (Berridge & Kringelbach, 2008; W. Schultz, 1997).

Similarly, in humans reward-seeking behaviours are associated with dopamine release (Pessiglione, Seymour, Flandin, Dolan, & Frith, 2006). Dopamine is key in reward and motivation circuits during musical activities (e.g. Salimpoor et al., 2011), which are likely to interact synergistically with the EOS in mediating the pleasure states associated with music (Chanda & Levitin, 2013). The release of dopamine during, for example, music-based activities may act as a reward and motivation for these social encounters (as speculated by: Curley & Keverne, 2005). Although there is no empirical research regarding the specific role of synchrony in activating reward circuits, in rats dopamine has been implicated in temporal processing mechanisms, such as the internal clock which is used to estimate durations and determine interval timing (for a review see:

Meck, 1996). The relationship between the EOS (pain threshold) effects demonstrated in the present thesis and dopamine is certainly an important avenue for future studies.

The EOS consists of more than just endorphins

As discussed in Chapter 1 ('What is the EOS?', pg. 21), the EOS consists of enkephalins, dynorphins and β -endorphins (Benarroch, 2012), the latter of which was the primary focus of this thesis. Although the focus on endorphins was justified by the link between this particular neurohormone and bonding and pain threshold, as discussed at length in the literature review, it is important to consider that other (linked) elements of the EOS may be involved in the social bonding effects measured in the present thesis. For example, naltrexone targets two of the three types of opioid receptors (Greeley et al., 1988), and arguably rejection of the hypothesis that EOS mediates the social bonding during synchronised dance would require the use of other opioid antagonists to knock out all aspects of this system, and would benefit too from more accurate and direct measures of the EOS, as discussed in the next section.

6.3 Critique of the studies and directions for future research

This thesis presents novel research on and partial support for the endorphin-mediated social bonding hypothesis of dance. This section explores some important considerations in the general interpretation of the data presented as well as some of the limitations of the studies. The four main limitations of this study are: 1) the methods used to assess EOS activation; 2) the methods used to determine prosociality; 3) the effects of shared goals and joint attention; and 4) a measure of the accuracy of synchronisation. After reviewing these, I will discuss the generalisability of the results in the present thesis, and the scope for future research.

6.3.1 Limitations of the studies

The need to measure EOS activation more accurately

As reviewed in Chapter 1, pain threshold is a commonly used proxy measure of endorphin release due to evidence that endorphins play a central role in the pain management system (Benedetti, 1996; Bodnar, 2008; D’Amato and Pavone, 1993; Dishman and O’Connor, 2009; Fields, 2007; Mueller et al., 2010; Zubieta et al., 2001). However, testing pain is intrinsically difficult due to its subjectivity and variability between individuals (Myles & Christelis, 2011), and it is possible that the findings of the present thesis were limited by the proxy method used to assess EOS activity. Alternative pain measurement methods might be more robust, and direct measurement of EOS activation preferable in future studies.

Alternative pain threshold measures

There are a range of different methods of assessing pain, and the length of time holding a hand in ice water (Dunbar, Kaskatis, et al., 2012; Dunbar, Baron, et al., 2012) or the ‘ski test exercise’ (maintaining a squat position with legs at right angles: Dunbar, Baron, et al., 2012) were considered for use in the present thesis. However, the former test was not pursued due to difficulties in ensuring that the ice was at the exact same temperature in all testing sessions. The ski test was considered unsuitable due to the fact that the experimental manipulations throughout this thesis involved physical exercise, and it was possible that muscle fatigue following the movement session may have biased a pain threshold measure which relied on muscle strength and endurance.

Probably the most reliable measure of pain currently available is the use of an electrocutaneous simulator for which a concentric electrode is attached to (for example) the forearm and delivers electric stimuli of increasing intensity (e.g. Jamner & Leigh, 1999). This system is

capable of delivering a wide range of intensities, is reportedly harmless, and has high consistency and reliability (*ibid*). However, the equipment is expensive, and given that this technology was not available for use in the present thesis, the blood pressure cuff method (commonly used in previous studies: Cogan et al., 1987; Cohen et al., 2010; Dunbar, Kaskatis, et al., 2012; Dunbar, Baron, et al., 2012; Sullivan et al., 2014; Sullivan & Rickers, 2013) was chosen instead.

Although the protocol followed for administering this pain threshold test was identical to a number of previous studies (e.g. Dunbar, Baron, et al., 2012; Sullivan et al., 2014), Amanzio and Benedetti (1999) highlight the need to account for variation in individual pain threshold, and suggest a modified blood pressure cuff method. In their study, participants reclined on a bed, extended their arm vertically and were subjected to the maximum pressure of 300mmHg. Participants then lowered their arm and performed a set number of hand squeezes. Pain threshold was determined by the length of time participants could sustain the pressure following the completion of the squeezes. This method was employed in order to control for variability in pain threshold between subjects (Amanzio & Benedetti, 1999), and it is worth considering that the method used in the present thesis was comparatively less robust. It would have been preferable to have participants all reach a certain pre-determined pressure, and to use the length of time as the measure of pain tolerance. However, the necessity of testing four participants simultaneously and the research space available for the experiments did not allow for participants to lie down in the manner described by Amanzio and Benedetti (1999). Instead, the simple blood pressure cuff method was used, and repeated measures (before and after the movement sessions) and multilevel modelling were used to account for individual variation in pain threshold.

It is important to not overlook the fact that although pain threshold is a widely used and validated proxy measure for EOS activation (Sprenger et al., 2006; Zubieta et al., 2001), the

relationship between the EOS and pain control is complex (Leknes & Tracey, 2008). Whilst endorphin release (due to for example exercise or synchrony) may induce analgesia, painful stimuli (e.g. during testing of pain) also result in opioid activation (Zubieta et al., 2001), causing a feedback loop that means that any measurement of pain is intrinsically confounded by the fact that it is necessary to induce pain in order to measure it. Consequently, far more preferable methods involve the direct measure of activation in brain areas known to have a high concentration of EOS receptors.

Direct measures of EOS activation

As reviewed in Chapter 1 ('Evidence that the EOS is important in music-based activities', pg. 47), some of the evidence supporting the link between music listening and EOS activation relies on PET (e.g. Blood & Zatorre, 2001) and fMRI data (e.g. Menon & Levitin, 2005). fMRI can provide high resolution information about the areas of the brain activated during music processing. PET scanning provides a quantitative measure of receptor and transporter binding sites (e.g. Sprenger et al., 2006; Zubieta et al., 2001). When used in combination with radioisotopic and ligand labelling techniques, PET can provide in vivo imaging of opioid receptor availability, thereby providing a measure of, for example, endorphin uptake (e.g. Mueller et al., 2010).

A challenge with these methods is that they require participants to lie within the scanner, without moving their head. Consequently, it is much easier to research the effect of music on the brain, than it is the effect of dance. While PET studies investigating dance have been devised (e.g. Brown et al., 2006b), by necessity these involved very limited movement of the legs only. Consequently, this method would not be appropriate for an investigation into the effects of dance as it naturally occurs in an exertive full-bodied form, and the relative effects of synchrony and exertion could not be determined. Furthermore, although 'two-persons neuroscience' techniques allow the

simultaneously scanning of two participants facing each other and interacting (Hari, Himberg, Nummenmaa, & Ha, 2013; Yun, Watanabe, & Shimojo, 2012), it is not yet possible to measure larger groups, as was the focus of the present research.

Consequently, these scanning methods were not suitable for an investigation into how group movement synchrony in dance induces social bonding via EOS activation. If, however, it were possible to place participants in scanners before and immediately after a synchronised movement session, then future studies would be able to apply these direct measures of the EOS to the hypothesis investigated here.

The need to measure social bonding more comprehensively

The present thesis included a range of behavioural measures (economic games) and self-report measures of social closeness, which were broadly referred to as indices of ‘prosociality’. This term has been used across a range of different academic fields to describe a variety of behavioural tendencies toward a stranger (e.g. Meier, 2006; Van Baaren, Holland, Kawakami, & Knippenberg, 2004; Winking & Mizer, 2013) and groups (e.g. George & Bettenhausen, 1990; Wheelless, Wheelless, & Dickson-Markman, 1982), as well as describing a general personality type (e.g. Penner & Fritzsche, 1995; Saroglou, Pichon, Trompette, Vershueren, & Dernelle, 2005; van Lange, Otten, De Bruin, & Joireman, 1997).

The methods used to assess prosociality include economic games (Berg et al., 1995; Johnson & Mislin, 2011; Kurzban, 2001; Meier, 2006; Rigdon et al., 2009), behavioural tasks to measure helpfulness (e.g. Jacob, Guéguen, Martin, & Boulbry, 2011; Kirschner & Tomasello, 2010; Kokal et al., 2011; Macrae & Johnston, 1998; Valdesolo & Desteno, 2011), direct explicit questions of closeness (e.g. Aron et al., 1992; Lakin & Chartrand, 2003; Miles et al., 2011), and interpersonal

coordination (e.g. Miles et al., 2010; Valdesolo et al., 2010). Oftentimes the selection of what prosociality scales to include in a study appear somewhat unstandardized, and published results are biased towards those which found significant effects, rather than measures which did not. In the present thesis, the averaging of all self-report measures to create prosociality indices meant that there was no selection bias in what measures were reported. Nevertheless, research on social bonding and prosociality in humans would benefit greatly from a set of coherent, standardised measurements.

As discussed in each data chapter, the measures included in the present study were chosen on the basis of their use in other similar studies in the field of psychology. However, it is important to note that there was incongruence between the behavioural and self-report prosociality data, and that evidence of the reliability and accuracy of these measures in the literature is mixed.

The relevance of behavioural measures

Economic games are a popular method of measuring prosocial behaviour in which a generous monetary decision is not predicted by economic theory, and is therefore interpreted as cooperation and an indication of how socially bonded participants feel (e.g. Launay et al., 2013; Wiltermuth & Heath, 2009). Although some studies have found these economic games successful indicators of prosociality following synchronisation (e.g. trust: Launay et al., 2013; e.g. weak-link: Wiltermuth & Heath, 2009) in this thesis it is possible that no such effect occurred due to too low a payoff (in the dictator and trustee games), the absence of experimenter bias (which is argued by Schachner and Garvin (2010) to have driven the results of Wiltermuth and Heath (2009)), or the fact that these measures are not generally suitable for determining prosociality in a between-subject manipulation of synchrony among strangers (Launay et al., in press). Whilst these games are generally taken to reflect social preferences (Von Neumann & Morgenstern, 1944), they are more

likely to reflect societal norms (Henrich et al., 2005) than affiliative intentions towards others (Winking & Mizer, 2013). Consequently, in the present thesis, the decisions in the economic games were likely subject to large between-subject variation, rather than condition-driven differences.

A limitation of these behavioural measures is that they assume a baseline level of interest in engagement with a group level or dyadic economic interaction in the first place, and the measure of prosociality is inferred from the decisions made during the economic game. In reality, the more relevant point at which to determine prosociality is before the game even starts, i.e. are participants even willing to engage in the game at all, or would they rather just receive their money and avoid any further interaction with the group? One way of determining this at a behavioural level is to test participants' willingness to cooperate without them consciously realising that the test is taking place (Launay et al., in press).

For example, some studies have had a confederate 'accidentally' drop a box of pencils or pens, and whether or not the participant helped to pick up the dropped items, and how many they retrieved, were used as measures of prosociality (Kokal et al., 2011; Macrae & Johnston, 1998; van Baaren et al., 2004). However, this test requires the confederate to be double-blind to the condition, and for the dropping of the objects to appear accidental. This was achieved in a study on pairs of young children, in which they were told to collect a tube of marbles, one of which had a faulty bottom which caused the marbles to drop upon the child lifting the tube (Kirschner & Tomasello, 2010). In this instance, the prosociality measure was whether the other child would delay their own progress in the task in order to help the victim of the marble dropping. Generally speaking, the use of an implicit measure such as this is argued to be preferable when interested in complex human behaviours (such as prosociality) because it avoids biases associated with demand characteristics (Eisenberg & Fabes, 1990).

However, these methods were not suitable in the present thesis due to the logistics of the experiment, namely three to four participants taking part at once. It would have been necessary for different research assistants to each execute the pencil drop test (for example) on their assigned participant, and this would have introduced a large amount of variation. It is worth noting anecdotal evidence from the silent disco experiment in Chapter 4 that participants tended to leave the experiment chatting to one another after the synchrony condition, but appeared more intent on leaving alone, without conversing with the other participants, following the non-synchronised conditions. It would be beneficial to formulate a measure of these post-experiment behaviours.

The reliability and suitability of self-report prosociality measures

As discussed in each data chapter, self-report prosociality questions were included on the basis of their use in similar studies. For example, the IOS scale (included in all four data chapters in the present thesis) is reported to have a high test-retest reliability and relevance for measuring closeness between individuals (Dibble et al., 2011; Hornsey et al., 2011). Explicit self-report measures are suitable when independent of subconscious attitudes (Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005), but given that the experiments included in the present thesis specifically aimed to investigate people's feelings towards other participants, it was not possible to completely control for differences in personal attitudes. Generally, however, such variability becomes less intrusive with large sample sizes and random allocation to experimental conditions. In the present set of studies, the use of multilevel modelling afforded some control over the nested nature of these data, and was able to account statistically for the lack of independence of testing group membership. Furthermore, in Chapters 2, 4 and 5, attempts were made to ensure that participants were rating strangers, and in Chapter 3 where participants knew each other they rated

the explicit measures before and after the experiment to adjust for their baseline feelings of affiliation.

Nevertheless, as previously discussed, implicit measures are a useful addition to a measure of prosociality due to the avoidance of subject bias. Implicit self-report questions, such as willingness to donate a kidney or blood to another individual, have been used in some studies (e.g. Schwartz, 1973). However, probably the best way to implicitly measure intention to engage prosocially is analysis of eye contact (Kleinke, 1986; LaFrance, 1979), or facial expressions and physiological measures (Eisenberg & Fabes, 1990). For example, eye contact acts as a signalling technique (Kleinke, 1986) that almost always indicates a keenness to engage further (Emery, 2000; Hietanen, Leppänen, Peltola, Linna-Aho, & Ruuhiala, 2008). In combination with measures of other positive social cues, eye gaze is argued to demonstrate affiliative intentions (Dunbar & Shultz, 2010).

In conclusion, the best method for measuring prosociality remains a contested subject, but future studies would probably benefit from the inclusion of one or more implicit measures.

The effect of shared intentionality and joint attention

Recent research has highlighted that the effects of synchronisation on prosociality are more pronounced when participants share the goal to intentionally synchronise (Reddish et al., 2013), and that some of the effects previously attributed to synchrony (e.g. social memory) may be due to differential levels of attention between synchrony conditions (Hadley et al., 2012). As a result, the studies in the present thesis may have been limited due to the fact that they did not directly account for these factors.

Intentional synchrony and shared goals

When individuals share the explicit goal of synchronising, this is termed intentional synchrony (Knoblich and Sebanz 2008). This form of synchrony generally involves shared intentionality (Tomasello et al 2005), which means the participants share a goal, and a plan on how to achieve that goal (Reddish, 2012). Shared intentionality improves social closeness, particularly when in combination with synchrony (e.g. Knoblich & Sebanz, 2008; Reddish et al., 2013) because it leads to enhanced self-other merging and inter-dependent self-construal (Kirschner & Tomasello, 2010). In the present thesis, joint goals were not purposefully manipulated in the experimental designs. In Chapter 3, participants in both synchrony and partial synchrony conditions received identical instructions, and consequently the conditions should not have differed in terms of shared goal. However, in Chapter 4's silent disco, participants in the synchrony condition were explicitly told to synchronise their movements with the other participants. This instruction was included in an effort to ensure that the synchrony condition was in fact synchronous, even though participants could not hear what other music or instructions fellow dancers were receiving through their headphones. Reddish et al. (2013) highlighted that the effects of synchrony are strongest when participants are explicitly told to synchronise, and this may have influenced the findings in the silent disco experiments. However, in reality, when people actively dance together they arguably share the intention to synchronise, if not with each other then at least with the music. It has been argued that dance is by definition a situation of shared intentionality, as it involves “getting people to experience each other as coactive, similar and cooperative members of a group” (Kirschner & Tomasello, 2010, p. 362). When individuals synchronise during music and dance activities, the synchrony does not occur by accident, but rather as a result of deliberate modification by each participant of their timing and movement (Reddish et al., 2013). As this thesis was concerned with testing dance in as ecologically valid a manner as possible, manipulation of shared goals was not considered important.

The effect of joint attention

Simultaneous co-attention with other group members can increase emotional intensity (Shteynberg et al., 2014) and when in combination with interpersonal entrainment leads to an “attentional union” (Macrae et al., 2008). This facilitates self-other merging, and synchrony induced cooperation (Kirschner & Tomasello, 2010). Joint attention is expected to have been present in all conditions as a by-product of the design of the experiments in the present thesis. For example, in Chapter 3, in both synchrony and partial synchrony conditions, participants were quickly aware of whether they had the same sequence of movements or a unique sequence. Mutual and self-correction occurred as a result, indicating that joint attention is likely to have been similar across the movement conditions. In the silent disco chapters, however, it is less clear whether joint attention differs between conditions.

Synchrony is known to lead to enhanced person-perception (Woolhouse & Tidhar, 2010) and social memory (e.g. Macrae et al., 2008; Miles et al., 2009). In an experiment using silent disco equipment, Woolhouse & Tidhar found that in-tempo improvised dancing (i.e. being on the same music channel) encourages people to “expend greater attentional resources” on each other (2010, p. 608), and that this is an important prerequisite for subsequent interpersonal bonding. This is broadly supported by evidence that joint attention during synchronous tasks facilitates bonding (e.g. Kirschner & Tomasello, 2010), and it is likely that mutual attention and gaze direction would underpin the fact that individuals remember more about others when they were synchronised, rather than when they were not synchronised (e.g. Hadley et al., 2012). Consequently, eye-tracking technology would be a valuable addition in future studies of this kind.

Accuracy of synchronisation

Whilst this thesis provides a novel investigation into the effects of synchrony during dance on social bonding, a direct quantification of synchrony was lacking from these studies. This would form an important part of future research, and would have been particularly useful in, for example, the first study (Chapter 2), where the degree of synchronisation likely formed a notable confound when comparing the various real-world dance classes.

Quantification of synchronisation is easiest when measuring auditory indices (e.g. drumming; Kirschner & Tomasello, 2009; e.g. Launay et al., 2013). For example Kirschner and Tomasello (2009) video taped each experiment session, and isolated the content of audio channels on the left and right side of the experimental set up in order to distinguish the participants' drumming from the stimulus beat. This method is relatively simple when there is only one participant synchronising with a metronome. In the present thesis, however, participants were moving to music, and dance movements did not manifest in audio signals suitable for extraction by the recording technology widely used in tapping or drumming studies.

Furthermore, the interest in the present thesis was behavioural synchrony, not just temporal synchrony, and consequently analysis of visual data would have been more important.

Quantification of behavioural synchrony can either be achieved by the secondary analysis of video material (either by humans or software), or by measuring movement directly. For the former, movement sessions are normally filmed and subsequently coded according to the degree of synchrony. Possibilities for this include direct coding of video files by someone who is blind to the (intended) experimental conditions and hypotheses (e.g. Zivotofsky & Hausdorff, 2007). However, as this method is susceptible to human error and bias (the possibility that the coder guesses the

hypothesis and this influences their coding), it is often necessary to have multiple coders, which is costly and time consuming.

An alternative is Motion Energy Analysis (MEA) software, which compares the amount of movement pixel by pixel and according to varying degrees of time epochs. This method allows for a continuous objective quantification of, for example, body positions and nonverbal behaviour (e.g. Ramseyer & Tschacher, 2011). Unfortunately, as each testing session in the experiments included in the present thesis involved three to four participants facing each other, it was difficult to film the sessions in such a way as to provide equal perspective on all participants' movements (e.g. when there were four participants, one of the individuals likely had their back to the camera, or was masking full view of another participant from the perspective of the camera). This poses a challenge for the software which simply compares images and body shapes in general areas of the video frame. Furthermore, the program cannot distinguish between different types of behaviours, only whether action has occurred in the specific pre-defined regions of the video. As such, the MEA is unlikely to accurately determine the degree of synchrony in the types of experiments included in this thesis.

Motion capture systems are arguably more reliable than the MEA software described above because motion data are recorded directly, whilst the movement occurs, rather than being generated secondarily during video processing (Sevdalis & Keller, 2009). Body sensors (similar to the Actiwatches used in the Chapters 4 and 5 in the present thesis) can aid in the identification of temporal synchrony, if used with a low enough time epoch (e.g. Phillips-Silver et al., 2011). Unfortunately the Actiwatches used in the present study could only store data every 15 seconds, which was not accurate enough for cross reference with the musical stimuli in order to determine whether participants were hitting the musical beats with their movements. Other motion capture technologies useful in the quantification of behavioural synchrony involve participants wearing

reflector patches on various body parts, usually in combination with multiple cameras placed at different angles. This method has been used in gait analysis, and in studies of more complex and variable movement such as dance (Brown et al., 2005; Neave et al., 2011; Phillips-Silver et al., 2011; Sevdalis & Keller, 2009), but require a large amount of technology. Although the studies in the present thesis were limited by the lack of a quantification of synchrony, of principal concern was the social closeness experienced by participants following the movement activities, for which participants' perceptions of synchrony was more important. Consequently, asking participants how successful they had been at synchronising was considered an important feature of the design. However, future studies would benefit from the use of synchrony quantification software, MEA, or other technologies. This would aid an understanding of how perception of synchrony relates to an objective measure of synchrony in real-world situations of dance, which is discussed in more detail in the following sections.

6.3.2 Generalisability of the results and outstanding research questions

This thesis aimed to extend the findings of previous studies on the social bonding hypothesis of dance (Kirschner & Tomasello, 2010; Reddish, 2012; Wiltermuth & Heath, 2009) by using a more ecologically valid definition of dance. Previous studies were limited due to the use of metronome or nationalistic musical stimuli, and elementary movements that arguably do not constitute dance at all. Although the present thesis made important improvements on these experimental designs by including popular music rather than a metronome or drum beat, and movements that are recognisable as dance, the operationalisation of dance still required some constraints. In order to investigate, for example, the relative effects of synchrony and exertion, it was necessary for dance movements to be standardised, and therefore instructed prior to the movement session. Dance often takes this instructed form, and indeed in order for sustained synchrony rather than mimicry to

occur, it is necessary for participants to have prior knowledge of the dance movements, and for the musical stimuli to provide a predictable beat. However, much of dance in the real world is not instructed or rehearsed, but rather improvised. On these occasions, people express themselves personally in an unplanned, yet coordinated manner, as couples (in a partner dance) and in larger groups as well. In reality dance does not often involve matching of both movements and timing, but rather some form of coordination that may vary in the degree of behavioural and temporal synchrony.

Given this variation, a number of possible questions should be considered in future studies:

- 1) would social bonding and endorphin release be greater when participants are improvising, and synchrony arises spontaneously?
- 2) Does instructed (and rehearsed) synchrony act as a signalling mechanism, with in- and out-groups delineated according to who knows the dance and music?
- 3) How much synchrony, and of what body parts, is critical in the social bonding effects of dance?
- 4) What are the group size limits to the synchrony effects established in this thesis?

Spontaneous synchrony and improvisation

Human synchrony and coordination can be delineated as either planned or emergent (Knoblich, Butterfill, & Sebanz, 2011). Dance as researched in the present thesis involved instructed movements (on occasion synchronised), which is very different from situations where uninstructed or improvised dancing occurs, during which the emergence of spontaneous synchrony may happen unintentionally. As already discussed, the social bonding effects of synchrony are affected by joint attention and shared goals and whether synchrony was achieved intentionally (e.g. Reddish et al., 2013). Consequently, spontaneous synchrony in dance, for example during improvisation, warrants empirical attention.

In natural dance settings (e.g. night clubs), groups of friends dancing in small groups or circles often end up coordinating and mimicking each others' movements for short periods of time. Under these circumstances instances of synchrony are emergent, although a lack of empirical research means it is not known how intentional or directional this spontaneous synchrony might be, or what particular role such synchrony might serve. One study which involved observation of dancing in nightclubs concluded that it is an example of courtship behaviour, with mostly males approaching females (Hendrie, Mannion, & Godfrey, 2009). Although the amount of spontaneous synchrony was not specifically the focus of their study, observations of synchrony were interpreted as an indicator of intimacy. This is based on evidence that people are more likely to coordinate with others whom they already like (van Baaren et al., 2004). Consequently, spontaneous synchrony is more likely to occur between friends, or as a signal of interest in pursuing a social connection with the other person, as assumed by Hendrie et al. (2009).

The present thesis has demonstrated that instructed dance synchrony increases feelings of social closeness, and it is plausible that this effect would be evident in cases of spontaneous synchrony, for example during improvisation. Given that improvised dancing is such a common occurrence in the real world, empirical investigation into the social bonding effects in these spontaneous circumstances would be a valuable addition to an understanding of the social bonding hypothesis of dance.

Improvisation

Performers (of music and dance) report a strong feeling of 'togetherness' during certain instances of improvisation, moments which reportedly involve synchrony (Berliner, 1994). These moments have been likened to concepts of 'flow' (e.g. Dietrich, 2004) and 'being in the zone', described by Seham (2001) as "a state of unselfconscious awareness in which every individual action

seems to be the right one and the group works with apparently perfect synchronicity” (p. 64).

Despite this strong group effect in both dance and musical activities, much empirical research on improvisation has focussed on a single improviser, and on musical improvisation specifically (e.g. Bengtsson, Csíkszentmihályi, & Ullén, 2007; Brown et al., 2006a; Limb & Braun, 2008). For example, specific cortical regions are involved in the improvisation rather than recall of music (Bengtsson et al., 2007), suggesting that spontaneous creativity is neurologically distinct from non-improvised musical performance, at least when improvising alone.

Woolhouse and Tidar (2010) are the only researchers to date to specifically test the effects of synchrony during *group* improvised dance, but importantly, in their study ‘synchrony’ referred to temporal frequency locked synchrony, not the behavioural synchrony as researched in the present thesis. Participants heard one of two different tracks of music, and it was assumed that visually it would be apparent to each participant whether they were moving in time to the same or different track of music as other participants. It was found that participants remembered more about others who had happened to be on the same music channel (i.e. with whom they had (temporally) synchronised), but as this study did not include a quantification of spontaneous synchrony, it is not known what part this may have played in influencing the social perception scores. Importantly, these results are likely due to differences in eye gaze, indicating the importance of joint attention in the discussion of the social bonding effects of synchrony (Hadley et al., 2012).

The improvisation hypothesis of dance

In addition to the social bonding hypothesis, it has been proposed that the composition and improvisation (of music, but arguably also dance) can be considered preparatory activities that train cognitive flexibility (Levitin & Tirovolas, 2009). These activities involve complex sensory-motor processing skills (Brown et al., 2006b), and arguably signal mental, emotional and physical flexibility

and fitness (Cross, Woodruff, & Road, 2008; Miller, 2000). There is some evidence that musical expertise is an ‘honest signal’ of genetic quality, at least in men (e.g. Sluming & Manning, 2000), which supports the sexual selection hypothesis of musicality. Levitin and Trivoloas (2009) argue that dance acts as a ‘cognitive display’, signalling the ability of the participants to be physically capable as well as creatively competent. Creative abilities and lateral thinking in general may well have been essential in early human development (Tooby & Cosmides, 2001).

Although empirical evidence regarding the causal links between improvisation in music-based activities and evolutionary benefits are lacking, it is important to consider that dance often (if not mainly) manifests as improvised movements, rather than instructed dance, and the difference between these situations remains a potential avenue for future research.

Does instructed dance act as a signalling mechanism?

The experimental designs in the present thesis resorted to instructed synchrony in order to ensure that synchrony occurred. The results suggest that these occasions are associated with increased social bonding between co-actors, but not a group of individuals who were not part of the synchronised experiment (Chapter 3). As discussed in the previous section on improvisation, synchronising with others as investigated in this thesis requires the learning and practising of movements. If participants learn certain moves (even if this occurs in isolation, as in Chapters 4 and 5), and then perform these movements with others who have learnt the same movements, the experience of then matching movements in time likely signals that they have all been through the same process, and by definition have a shared common experience. This would likely positively affect the bonds felt between the participants. As their ‘belonging’ to the group is visually confirmed through the act of synchronising, if the activity takes place in the presence of others not in the ‘know’ (i.e. not taking part in the synchronising), the synchronised co-actors may experience an

additional boost in social closeness as they reinforce their identity as an ‘in-group’ (as predicted by: Hewstone et al., 2002). An excellent real world example of this is a popular form of public dance called ‘flash mobs’.

Flash mob dances are a form of public performance, often comprised of complete strangers who have used online communication to learn a dance sequence and coordinate the particular time and place to perform the dance (Gore, 2010; Molnar, 2013). The result is large number of people (often in the hundreds, and on occasion in the thousands) appearing to spontaneously begin a coordinated performance in a public space such as a train station, airport or town square (for examples, there are a wealth of YouTube videos documenting these events). People in the public space include a mix of participants and those who did not know about the event. Those in the latter category appear to feel ‘left out’, and often attempt to join in and learn the movements as the performance is underway (Gore, 2010). In doing so they initiate a move from the category of an ‘out-group’ member to ‘in-group’ member. The fact that this occurs when flash mobs happen, and also to a lesser extent in club-dancing where people begin to mimic each other, illustrates the fact that the desire to ‘belong’ to a group and be included is relevant, and suggests the importance of synchronising in the signalling and display theory of dance (reviewed in Chapter 1: ‘Dance/music as a mechanism for signalling coalition’, pg. 31).

How much synchrony, and of what body parts, is critical in the bonding effects during dance?

As already described, synchronisation in dance is not merely limited to behavioural synchrony, and indeed it is not known what part of the body is likely to be most important when it comes to perceiving (and also measuring) synchrony. A valuable avenue for future research would be determining what (and if) specific body parts need to be in synchrony for co-actors to perceive the synchrony, and for the feelings of social closeness to subsequently arise. Motion capture systems

(discussed earlier) would help investigate this question, and the results would have important implications for dance movement therapies. The present thesis has provided a valuable contribution to this topic by identifying behavioural synchrony as more conducive than temporal synchrony when it comes to social bonds (discussed in more detail in ‘General implications of findings’, pg. 245). However, in situations where full body synchrony is not possible, an understanding of what type of synchrony is sufficient to have a positive effect would be useful.

Group size limit on effects

As discussed in Chapter 1 (‘The importance of source, context and agency’, pg. 39), the majority of studies investigating synchrony and social bonding have focussed on dyadic synchronisation (e.g. Hove & Risen, 2009; Launay et al., 2013; Valdesolo et al., 2010). Although the present thesis has demonstrated that similar effects are evident in groups of three and four, it is not known whether these effects will occur similarly in larger groups. Pairs of people, and even small groups, may be more capable of achieving synchronisation with relative ease, as there are fewer people to keep track of. However, in large groups, self-other merging is less likely to occur, since a larger number of individuals within a group will lead to greater inaccuracies in synchrony and greater difficulties for action perception networks to track the timed movements of others. Future studies should investigate the group size limits associated with the social bonding effects of dance, and of different types of synchrony and coordination. It is plausible that with larger groups, bigger movements and an externalised rhythmic scaffolding (as provided by music) may be needed to facilitate synchronisation and the activation of the EOS. There may also be an optimal group size limit for the effects of behavioural synchrony as researched in the present thesis, and other types of coordination and synchrony in dance may have different optimal group sizes. Research in this area would benefit from conducting studies on flash mobs, as discussed in ‘Does instructed dance act as

a signalling mechanism?’ (pg. 242). As reviewed in Chapter 1 (‘Human social bonds: “grooming at a distance”, pg. 28), dance has been proposed as a mechanism by which individuals can effectively bond socially with more than one person at a time, thereby facilitating the development of larger social networks than supported by dyadic bonding strategies such as grooming (Dunbar, 2004). How many people can simultaneously benefit from this social bonding technique is yet to be determined.

6.4 General implications of findings

Although dance is not limited to behaviourally synchronised movement, as discussed in the previous sections, research on this form of synchrony is of particular relevance when it comes to possible advances in pain management and social rehabilitation therapies.

Music has long been used as a method of pain management therapy (for a review see: Cepeda et al., 2006). The present thesis has demonstrated that synchronous movement to music has analgesic effects, and consequently active engagement with music and behavioural synchronised dance may be a useful additional tool in the relief of pain (in circumstances where movement is possible of course). In addition to its role in pain management, music and movement therapy are successfully used to improve well-being (e.g. for those with dementia: Hokkanen et al., 2008; Alzheimer’s Disease: Ledger & Baker, 2007; post-violence trauma: Teague, Hahna, & McKinney, 2006; and Schizophrenia: Ulrich, Houtmans, & Gold, 2007) and physical rehabilitation (e.g. in treatment of Parkinson’s disease: Earhart, 2009; Hackney & Earhart, 2009).

However, the results from the present thesis are of more relevance for therapies aimed at improving social empathy (Behrends, Müller, & Dziobek, 2012; McGarry & Russo, 2011), interpersonal relationships (e.g. Choi, Lee, & Lim, 2008; Ramseyer & Tschacher, 2011) and general

social and communication skills (e.g. Moukheiber et al., 2010; Silverman, 2007; Ulrich et al., 2007), particularly for those suffering from autism (e.g. Kim, Wigram, & Gold, 2008; Orr, Myles, & Carlson, 1999). Historically, many therapy interventions have drawn on psychodynamic theory (Mikulincer, 2003) in which, for example, a therapist improves their relationship with a patient by mirroring their nonverbal behaviours (see: Ramseyer & Tschacher, 2011). Additionally, passive music listening is a popular tool for inducing relaxed states (e.g. Krout, 2007; Lepage et al., 2001), and has been used successfully in autism therapy to help manage socially disruptive behaviours usually indicative of anxiety and distress (e.g. Orr et al., 1999). Autism is characterised by social withdrawal and limited expression of empathy (e.g. R. T. Schultz, 2005) and these challenges are believed to be due at least in part to a dysregulated EOS (Leboyer et al., 1992; Jaak Panksepp, 1979; Shattock & Whiteley, 2002; Willemsen-Swinkels et al., 1996). Consequently, opioid antagonist treatments are often successfully used to improve socialisation (Roy et al., 2014; Willemsen-Swinkels et al., 1996).

According to the results from the present thesis, behavioural movement synchrony to music is a promising future avenue for autism therapy, due to the fact that it involves synchrony and exertion, both of which have significant effects on interpersonal social measures and EOS activation. Such a method has been proposed (Ramachandran & Seckel, 2011), but whether the type of movement activities used in the present thesis would have significant effects on those with Autism remains to be empirically tested. Based on the findings presented here, behaviourally synchronised dance between a therapist or parent and autistic individual, perhaps in combination with multiple mirror reflections of the patient (to enhance perception of synchrony by providing images of complete synchrony in real time), would help to increase social closeness.

6.5 Final conclusions

This thesis has provided novel research on and preliminary support for the hypothesis that dance encourages social bonding amongst co-actors by stimulating the production of endorphins in the Endogenous Opioid System. The data presented has demonstrated that dance, an exertive and synchronised group activity to music, leads to people feeling more socially close, as measured by explicit self-report prosociality questions. This bonding effect is directed towards co-dancers, whether strangers or acquaintances, and is significantly and independently affected by both exertion and synchrony. Similarly, pain threshold is elevated when participants engage in behaviourally synchronised dance, and this analgesic effect is suppressed when participants are treated with naltrexone, an endorphin blocker. The fact that synchrony and exertion have significant and independent effects on pain threshold reveals that EOS activation occurs even during instances of low exertion synchronisation, which may explain previous results showing that even activities like tapping can lead to social bonding. Furthermore, these studies highlighted that visual cues of synchrony were sufficient in the effects associated with behavioural synchrony, but that across the experiments, partial synchrony (temporal synchrony but with different movements) was the least conducive movement condition for elevating pain threshold and inducing social bonding.

Although the naltrexone treated participants did not experience differential social bonding as expected, a mediation analysis comparing the relevant data from Chapters 3 and 4 indicated that the EOS (as measured by pain threshold) does appear to mediate the effect of movement condition on prosociality index scores. Future studies should investigate these effects in cases of improvised dance, and in varying group sizes. Furthermore, the interactive role of the EOS with other neurotransmitter systems, and the use of behavioural synchrony in dance movement therapy are profitable avenues for future research.

Chapter 6 – General discussion

In conclusion, this thesis utilised an ecologically valid operationalisation of dance to contribute to our understanding of the role of synchrony and the EOS in the social bonding that arises when we move to music.

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Chapter 7 – Appendices

7.1 Chapter 2 Appendices

7.1.1 Dictator game instructions

“Dear participant,

You have been provided with two white envelopes. The large white envelope contains £5 in 50p coins. You can choose to keep as much of this money as you wish. You can place a quantity of this money, of your choice, inside the smaller white envelope.

Money placed in the small envelope will be randomly allocated to an individual who is not taking part in this study, but who is participating in the (circuit/ dance) session (starting shortly/you have just finished). The randomly selected individual will receive this money within one day, after being notified by email. Neither the researcher, nor the recipient, will know who the money comes from.

Please make your decision now. Place the money that will be given anonymously to someone else in the session inside the small envelope.”

7.1.2 Questionnaire

- Age, Gender, ‘Current status’ (Student, unemployed, employed, other).
- Number of friends/acquaintances in the activity session: *“Do you know anyone else (who will be/ who was) in this (circuit training session/ dance class)? (People who you recognise and know by name, excluding the instructor).*
- Positive and Negative Affect Scale (PANAS): *“Please indicate how you are feeling in this moment”,* for distressed, excited, upset, scared, enthusiastic, alert, inspired, nervous, determined, and afraid.
- Prosociality questions (1 – 5 Likert scale where 1 = very slightly or not at all and 5 = extremely: *“Please answer the following questions about the person sitting on your left. You should not*

know this person. 1) How connected do you feel with this person; 2) How much do you trust this person?; 3) To what extent do you think you would turn to this person for advice if you had a problem?.

- Inclusion of Other in Self (IOS): "...please choose the picture that best describes your relationship now." (1 – 7 pictorial scale with labelled circles of increasing overlap to indicate relationship between 'self' and 'group').

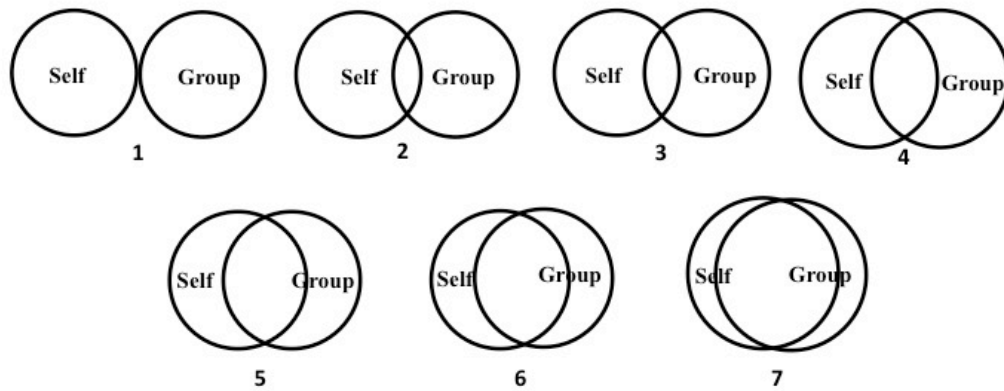


Figure 7.1 Adapted Inclusion of Other in Self (IOS) scale.

- Altruism Scale (1 - 4: Likert scale where 1 = never, 2 = 1-2 times, 3 = often, 3 – 5 times, 4 = very often, more than 5 times) *"In the past month...I have given directions or money to a stranger; I have helped a stranger (e.g. delayed an elevator, held a door open, carried their belongings); I have donated money, clothes or my time to work for a charity; I have pointed out a clerk's error in undercharging me for an item; I have donated blood; I have allowed someone to go ahead of me in a lineup or queue"* (adapted from (Eckel & Grossman, 2000).
- The role of the activity in personal identity (Likert scale 1 – 5, where 1 = strongly disagree, 5 = strongly agree): *"Working out/ dance is an important part of my identity"*;
- Gym activity: Music and enjoyment of activity (Likert scale 1 – 5): *"I enjoy a work out session more if I listen to a personal music system (e.g. ipod) than if I don't have one; I enjoy a work out session more if there is music playing in the room than if there is no music"*; Perception of social nature of activity (Likert scale 1 – 5): *"A circuit training session is a social activity"*.
- Dance activity: Familiarity with genre of dance: (Yes/no): *"Is today the first time you will be taking a class in this style of dance?"*

7.1.3 Description of dance sessions

Dance classes

The dance classes included Butoh, Contemporary, Flamenco, Ceroc, Salsa/Merengue/Bachata, Tap Rhythm, Breakdancing and Hip Hop. Table 7.1 outlines the differences between the dance classes in terms of the number of participants, the amount of time spent moving to music/ rhythmic clapping, and whether the dance class involved partner work or physical contact with other participants at any stage. These data were obtained as estimates during the observation of the sessions. The setup of the class and style of dance is described in more detail below.

Table 7.1 Outline of the number of participants in each dance class, and details of the nature of each class.

	Number of participants	% of class which included active synchrony to music/rhythmic clapping	Partner work/physical contact
Butoh	5	22.22%	Yes
Contemporary	9	66.67%	Yes
Flamenco	12	100.00%	No
Lindy Hop	11	20.00%	Yes
Salsa/Merengue/Bachata	3	33.33%	Yes
Tap Rhythm	9	77.78%	No
Breakdancing	1	15.50%	Yes
Hip Hop	10	66.67%	No

Table 7.2 Overall trends (p-values) for the dance classes with respect to the change in various dependent variables (after - before) according to whether the classes involved physical contact or no contact, and whether there was music >50% or <50% of the time.

	Physical contact	No contact	Moving to music >50%	Moving to music <50%
IOS	$p = 0.029$	$p = 0.241$	$p = 0.038$	$p = 0.242$
Dictator donation	$p = 0.044$	$p = 0.007$	$p = 0.106$	$p = 0.063$
Prosociality Index	$p = 0.343$	$p = 0.681$	$p = 0.495$	$p = 0.701$
Positive affect	$p = 0.683$	$p = 0.388$	$p = 0.976$	$p = 0.820$
Negative affect	$p = 0.247$	$P = 0.300$	$p = 0.287$	$p = 0.153$

Flamenco

Flamenco dance is highly rhythmic and involves energetic foot stamping, clapping and various stylised arm movements. The class began in a circle with a unison clapping exercise. The instructor taught a clapping sequence (with stamping) for 15 minutes then went into lines facing a mirror and kept rotating lines while in this formation. During this section of the class there was no music, but the instructor taught by singing, counting and clapping. The sequence built up from just clapping and stamping to moving left and right and including upper body (mostly shoulder movements). The next section of the class involved rhythmic music (drum and clapping sound, no singing or melody). The dancers formed two lines facing each other and moved forward and back, performing the taught sequence. The penultimate exercise had the dancers in a circle once again, where they learnt a more complex rhythmic sequence to music. The finishing exercise was in lines facing the mirror to music. It involved a cool down upper body slow and controlled movement to a solo singer with no beat.

Butoh

Butoh is a Japanese form of dance which involves slow, meditative movements which are closely related to imagery and interpersonal contact (physical and imagined). The dance class was mostly instructed in a small intimate circle. The class began with someone volunteering to find the centre of the room and mark it with a circular roll of tape. The dancers were invited to form a 'beautiful' circle around the centre, large at first, and then getting smaller and smaller until the participants were touching shoulders. There was no music during this time. Next dancers passed through the middle of the circle, all at the same time, which resulted in a large amount of body contact. The instructor spoke almost constantly, describing the movements in a slow and thoughtful manner. It was very intimate and close. After 20 minutes the class paired up and did a trust game (in partners with one person's eyes closed, touching their partner's fingertips and being led around the room). In the same pairs, the dancers did a thread imagery exercise, where the controlling partner pretends there is a thread attached to any part of the other's body, and pulls the imaginary thread to cause the other to move. When working in partners, many of the dancers introduced themselves and laughed. The final exercise involved participants moving from one side of the room to another whilst in a straight line. The exercise also involved imagery and the dancers were instructed to picture themselves bearing a gift for a loved one on the opposite end of the room. They imagined a rod/thread going through their body, pulling them slowly through time and space to their loved one. The class ended with the dancers in a circle.

Contemporary

Contemporary dance (as taught in this class) focuses on the concepts of space, weight, momentum, and informing movement with breath. Prior to the class the dancers sat in a circle, introduced themselves and commented on their experience with contemporary dance. The first exercise involved participants improvising movements which emphasised direction changes (without music). Following this, the dancers formed lines facing the instructor and learned a simple contemporary sequence involving basic body movement, arm swinging. This was repeated multiple times with increasing momentum, to music. Next dancers were taught a floor sequence in unison.

Lindy Hop

Lindy Hop is a 1920's American partner dance, which involves both partners facing the same direction and performing energetic (mostly leg) movements. The class started with dancers learning the basic step in a line, after which the dancers practised the step with partners to music. Partners were rotated regularly, and the total time dancing in partners was 35 minutes.

Salsa/Merengue/Bachata

The basic movements of these three Latin partner dances were taught in a line, initially without music, and then to a slow, clear rhythmic music track. Following this, dancers were randomly partnered, and performed a basic leading exercise involving mostly arm/upper body contact and learnt the principle of leading and steering and following. This was then repeated with the footwork and music, and partners were rotated regularly. The class covered the basics of all three Latin dancers, and simple partner moves for each.

Tap and rhythm

The class began with music and teaching of basic moves, facing mirror in lines (3 minutes). The instructor then talked through the steps, demonstrating and having the group join her. There was music for approximately 10 minutes of the class, but the movements involved stamping (and tapping) throughout.

Breakdancing

Breakdancing involves a number of strength based floor movements, often which demand balancing on one part of one's body. During this class music was playing throughout, but mostly as background sound rather than a musical cue for rhythmic movement. The dancers learned a series of basic stunts and after some time were split into pairs, and were encouraged to introduce themselves. The pairs practised a simple sequence, and partners were rotated. Towards the end of the class dancers returned to lines and practiced the routine in unison with music (in half time, and eventually full time). The class ended in a circle, with each individual performing something that they had learned that day, everyone clapping after each.

Hip Hop

The Hip Hop class started with warm up stretches to music, led by the instructor and performed in unison by the dancers (10 minutes). Next the instructor demonstrated a sequence to music and then taught the dancers a sequence step by step. The participants performed the sequence to music in unison for the majority of the class (35 minutes).

7.1.4 Normality and homogeneity of variance

The distribution of dictator game donations was significantly different from normal for both activities, before and after the activity session. Furthermore, baseline group familiarity, negative affect, IOS and the Prosociality Index data were non-normal in their distributions. Natural log transformation resulted in normal distributions only for the data sampled before the dance activity. The measure of altruism was normally distributed when measured after the dance condition, and before the gym session, but otherwise was significantly different from a normal distribution. Natural log transformation resulted in normal distributions of altruism scores for all conditions except for after the gym activity. The positive affect data were normally distributed for all conditions except for after the gym session, which was significantly non-normal. Natural log transformation resulted in normality of positive affect data, except for before the gym activity. The distribution of negative affect scores was significantly different from normal, and tog transformation did not result in normality. All measures had homogenous variance.

7.1.5 MLM results for various baseline measures

Table 7.3 Results for MLM for the effect of activity (gym and dance), and timing (before and after), and interaction effects.

		Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>P</i>
Activity	Altruism	0.368	1	17.89	1.663	0.214
	Familiarity	0.001	1	0.001	0.078	0.783
	Identity	0.036	1	0.036	2.084	0.151
Timing	Altruism	0.168	1	0.168	0.778	0.379
	Familiarity	0.037	1	0.037	4.421	0.037
	Identity	1.771	1	1.771	0.936	0.335
Activity*Timing	Altruism	0.000	1	0.000	0.001	0.970
	Familiarity	0.016	1	0.016	1.524	0.219
	Identity	2.315	1	2.315	2.724	0.101

MLM includes testing group as a level.

7.2 Chapter 3 Appendices

7.2.1 Pre- and post- activity questions

In-group prosociality (where each question began with the words: “*Thinking about all the pupils in this room now...*”); and out-group prosociality (where each question began with the words:

“*Thinking about all the pupils in the whole class ...*”): questions:

- Inclusion of Other in Self (IOS): “...*please choose the picture that best describes your relationship now.*” (1 – 7 pictorial scale with labelled circles of increasing overlap to indicate relationship between ‘self’ and ‘group’).
- Trust: “...*How much do you trust the other pupils?*” (1 – 7 Likert scale where 1 = very slightly or not at all and 7 = extremely).

- Connection: “...*How connected do you feel to the other pupils?*” (1 – 7 Likert scale where 1 = very slightly or not at all and 7 = extremely).
- Likeability: “...*How likeable are the other pupils?*”; and “...*How much do you like the other pupils overall?*” (1 – 7 Likert scale where 1 = very slightly or not at all and 7 = extremely).
- Similarity: “...*Do you feel similar in personality to the other pupils?*” (1 – 7 Likert scale where 1 = very slightly or not at all and 7 = extremely).

Pre- and post- questionnaires also included questions from the Positive and Negative Affect Scale (PANAS): “*Please indicate how you are feeling in this moment*”, for distressed, excited, upset, scared, enthusiastic, alert, inspired, nervous, determined, and afraid.

7.2.2 Post- activity additional questions

Assessment of participants’ experience of the music task included the following questions:

“*Now think about the movement session you just did and please answer the questions*” (all a 5 – point Likert scale where 1 = very slightly or not at all and 5 = extremely):

- Fun: “...*Was the movement session fun?*”
- Discomfort and embarrassment: “...*How uncomfortable or embarrassed did you feel during the movement session?*”
- Difficulty: “...*How difficult was the movement session for you?*”
- Enjoyment: “...*Did you enjoy the movement session?*”
- Boredom: “...*Were you bored during the movement session?*”
- Success: “...*In your opinion, were you good at doing the movements?*”, “...*In your opinion were the other pupils good at doing the movements?*”; “...*In your opinion, were you in time with the music?*”; and “*In your opinion, were the other pupils in time with the music?*”

“*Did this physical activity remind you of anything in everyday life?*” (space for a short written answer)

- Musicality and inclusion of music in everyday life: “*Is music a part of your weekly life?*” (7 – point Likert scale where 1 = very slightly or not at all and 7 = extremely).
- Dance experience and inclusion of dance in everyday life: “*Is dancing a part of your weekly life?*” (7 – point Likert scale where 1 = very slightly or not at all and 7 = extremely).
- Hypothesis check: “*What do you think this study is about? Write down your best guess*”.

7.2.3 Details of the high and low exertive movements

High exertion movements

These movements were all performed standing. They included:

- ‘Palmas’ (translation: “clapping”): participants lifted their arms up and clapped their hands together (level with their face/ above their head), then bent their knees and hit their hands on their thighs.
- ‘Peão’ (rough translation: “buffalo cowboy”): participants had their left arm placed across their chest and the right arm bent at the elbow, arm pointing upwards. They rotated their right upper arm (as if swinging a lasso), and moved their feet as if imitating a galloping horse. This movement was based on a similar *Carimbo*⁴ dance move.
- ‘Cruzar’ (translation: “cross”): participants bent and straightened their knees on alternate beats while simultaneously crossing bent arms in front of their chest, and then opening the arms out.

Low exertion movements

These movements were named similarly as the high exertion movements, but were adapted to be performed while seated (without any lower body movement) in order to reduce the physical exertion load.

⁴ Carimbo is a traditional dance of Marajós. It combines African beats with traditional Indian melody (performed by flute and song). ‘Peão’ refers to a man who rides horses to herd Buffalo (which are farmed in the area as working animals and for meat/leather products).

- 'Palmas': participants clapped their hands together (in line with their lower torso), and then hit their thighs.
- 'Peão': participants placed their arms in an identical position to that of the high exertion 'Peão', but they were instructed to point upwards with their right-hand index finger and make small rotations at the wrist (rather than rotate the whole upper arm).
- 'Cruzar': participants straightened their hands and crossed them in front of their lower abdomen, and then face, alternating which hand was on top.

7.2.4 Prosociality index and success index reliability statistics

Table 7.4 Cronbach's alpha statistics indicating how the overall reliability statistics change with removal of each individual measure prosociality (N=1056).

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IOS	22.330	36.978	0.466	0.226	0.712
Trust	23.250	37.959	0.499	0.259	0.707
Connectedness	22.680	37.141	0.563	0.323	0.686
Likeability1	22.370	37.687	0.485	0.254	0.706
Similarity in personality	23.940	37.336	0.408	0.181	0.703
Likeability2	21.490	39.780	0.493	0.269	0.706

The large N value is as a consequence of the fact that each prosociality question was measured four times per participant: at the start and end, and for the in- and out-group.

Table 7.5 Cronbach's alpha statistics indicating how the overall reliability statistics change with removal of each individual measure success (N=264).

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Personal movement success	12.120	4.989	0.462	0.234	0.652
Other participants movement success	12.000	5.198	0.435	0.233	0.667
Personal musicality success	12.222	4.752	0.501	0.330	0.627
Other participants musicality success	12.250	4.861	0.546	0.351	0.600

7.2.5 Normality and homogeneity of variance

All PTT start data were normally distributed with the exception of low exertion synchrony condition. PTT end data were normal for the low exertion synchrony and partial synchrony conditions, and the change in PTT was normal for the synchrony conditions, but not the partial synchrony conditions. All pain threshold data had homogenous variance, except for the PTT end data.

Prosociality index data (in- and out-group) were normally distributed at the start for all conditions except high exertion synchrony. The end data (in- and out-group) were normal for all conditions except high exertion partial synchrony. The change in in-group prosociality scores were normal for the high exertion conditions, but significantly non-normally distributed for the low exertion conditions, and all were non-normal for the change in out-group prosociality index scores. All prosociality data had homogenous variance.

Positive affect data had homogenous variance and were normally distributed for the low exertion conditions, but non-normally distributed in the high exertion conditions. Negative affect data were non-normally distributed throughout, with non-homogenous variance. The measures of success, embarrassment and boredom were also non-normally distributed with homogenous variance. The measure of fun, difficulty and enjoyment were non-normal and had non-homogenous variance between synchrony and partial synchrony conditions. Log transformations did not result in normality, and caused non-homogeneity for most of the variables.

7.2.6 Results for miscellaneous questions

Table 7.6 Mean (SD) of participants' musical and dance experience and expertise, and various measures of participants' experience of the experiment.

	High exertion synchrony	High exertion partial synchrony	Low exertion synchrony	Low exertion partial synchrony
Musicality	4.38 (2.232)	3.85 (2.306)	4.28 (2.193)	4.70 (2.134)
Ability to dance	4.28 (2.194)	3.19 (2.140)	3.70 (2.230)	3.68 (2.369)
Music activities	5.70 (1.967)	5.46 (2.173)	6.08 (1.494)	5.87 (1.535)
Dance activities	4.14 (2.251)	4.62 (2.275)	4.59 (2.216)	4.13 (2.296)
Fun	4.78 (0.565)	4.62 (0.837)	4.63 (0.809)	4.48 (1.013)
Embarrassment	2.06 (1.305)	2.36 (1.343)	2.19 (1.378)	2.14 (1.277)
Difficulty	1.75 (1.090)	2.05 (1.318)	1.78 (1.170)	2.21 (1.281)
Enjoyment	4.57 (0.700)	4.61 (0.909)	4.78 (0.608)	4.27 (0.995)
Boredom	1.77 (1.285)	1.78 (1.373)	1.94 (1.330)	2.19 (1.382)

Table 7.7 MLM results for self-reported measures of musical and dance experience and expertise.

		Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Synchrony	Musicality	0.344	1	0.344	0.039	0.844
	Ability to dance	5.131	1	5.131	0.935	0.334
	Music activities	3.003	1	3.003	0.941	0.335
	Dance activities	0.053	1	0.053	0.001	0.980
Exertion	Musicality	7.551	1	7.551	1.744	0.190
	Ability to dance	5.738	1	5.738	1.079	0.300
	Music activities	8.883	1	8.883	2.763	0.100
	Dance activities	0.001	1	0.001	0.003	0.959
Interaction	Musicality	13.501	1	13.501	2.825	0.097
	Ability to dance	3.993	1	3.993	0.802	0.371
	Music activities	0.016	1	0.016	2.763	0.100
	Dance activities	14.154	1	14.154	2.774	0.097

MLM includes testing group as a level.

Table 7.8 MLM results of participants' experience of the experiment.

		Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Synchrony	Fun	1.602	1	1.602	2.657	0.107
	Embarrassed	1.393	1	1.393	0.845	0.361
	Difficulty	5.086	1	5.086	3.504	0.065
	Enjoyment	0.593	1	0.593	1.373	0.245
	Bored	3.991	1	3.991	2.484	0.119
	Success Index	0.000	1	0.000	0.004	0.952
Exertion	Fun	1.106	1	1.106	1.813	0.182
	Embarrassed	0.058	1	0.058	0.056	0.814
	Difficulty	1.023	1	1.023	0.698	0.406
	Enjoyment	0.033	1	0.033	0.081	0.774
	Bored	0.693	1	0.693	0.433	0.513
	Success Index	0.465	1	0.465	1.117	0.294
Interaction	Fun	0.006	1	0.006	0.010	0.921
	Embarrassed	1.297	1	1.297	0.860	0.357
	Difficulty	0.010	1	0.010	0.007	0.935
	Enjoyment	0.016	1	0.016	0.036	0.850
	Bored	0.018	1	0.018	0.011	0.916
	Success Index	0.283	1	0.283	0.638	0.427

MLM includes testing group as a level.

7.2.7 Pain threshold results with all data included

Table 7.9 Results of Pain threshold multi-level repeated measures MLM.

PTT	Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Time point	16773.80	1	16773.80	9.273	0.003
Time point *Synchrony	21384.40	1	21384.40	13.978	<0.001
Time point *Exertion	17443.40	1	17443.40	11.310	<0.001
3-way Interaction	3991.60	1	3991.60	2.711	0.101

MLM includes testing group as a level.

7.3 Chapter 4 Appendices

7.3.1 Silent disco questionnaires

Pre-disco questionnaire:

- Age, Gender
- Positive and Negative Affect Scale (PANAS): “Please indicate how you are feeling in this moment”, for distressed, excited, upset, scared, enthusiastic, alert, inspired, nervous, determined, and afraid.
- Mini-IPIP Personality scale (1 – 5 Likert Scale): Extraversion: “Am the life of the party; Do not talk a lot (R); Talk to a lot of different people at parties; Keep in the background (R)”; Agreeableness: “Sympathize with others’ feelings; Am not interested in other people’s problems (R); Feel others’ emotions; Am not really interested in others (R)”; Conscientiousness: “Get chores done right away; Often forget to put things back in their proper place (R); Like order; Make a mess of things (R)”; Neuroticism: “Have frequent mood swings; Am relaxed most of the time (R); Get upset easily; Seldom feel blue (R)”; Intellect: “Have a vivid imagination; Am not interested in abstract ideas (R); Have difficulty understanding abstract ideas; Do not have a good imagination (R)”

Post-training, before silent disco

- Confidence: “*How confident are you that you can remember these four dance moves and do them on demand?*” (1 – 5 Likert scale, 1 = very slightly or not at all, 5 = extremely).

Post-disco questionnaire

- Inclusion of Other in Self (IOS): “*...please choose the picture that best describes your relationship now.*” (1 – 7 pictorial scale with labelled circles of increasing overlap to indicate relationship between ‘self’ and ‘group’).
- Connectedness: “*...How connected do you feel to the other participants?*” (1 – 7 Likert scale where 1 = not at all and 7 = very much).
- Likeability: “*How likeable were the other participants?*” (1 – 7 Likert scale, as above).
- Similarity in personality: “*To what extent do you feel similar in personality to the other participants?*” (1 – 7 Likert scale, as above).
- Success: “*In your opinion, how successful were you at: following the audio instructions* (‘Instructions Success’ - all movement conditions); *synchronising your movements with the other participants and to the musical beat* (‘Overall Synchrony Success’ - synchrony condition); *synchronising your movements to the musical beat* (‘Music Synchrony Success’ - partial synchrony and asynchrony conditions). (1 – 7 Likert scale, as above).
- Fun: “*How much fun did you have during the silent disco?*” (1 – 7 Likert scale, as above).
- Embarrassment: “*How uncomfortable or embarrassed did you feel during the silent disco?*” (1 – 7 Likert scale, as above).
- Difficulty: “*How difficult was the silent disco task?*” (1 – 7 Likert scale, as above).
- Enjoyment: “*How enjoyable was the silent disco task?*” (1 – 7 Likert scale, as above).
- PANAS “*Please indicate how you are feeling in this moment*”, for distressed, excited, upset, scared, enthusiastic, alert, inspired, nervous, determined, and afraid (1 – 5 Likert scale, 1 = very slightly or not at all, 5 = extremely).

- Hypothesis check: *“What do you think this study is about? Write down your best guess”*

7.3.2 Economic games instructions

Now you will take part in two decision-making experiments. In these experiments you can earn real money. How much you earn depends on your decisions and the decisions of other participants. During these two experiments your earnings will be counted in tokens. At the end of the experiment the tokens you have earned will be converted into pounds and paid out privately and confidentially

Weak link coordination game (referred to as ‘Decision making experiment 1’)

The first experiment consists of 5 independent rounds. Every round each participant is given a fresh endowment of 20 tokens. In each round you can also earn tokens. How much you earn depends on your decisions and the decisions of other participants. Each participant must decide how many of these tokens (between 0 and 20) to have private, and how many to contribute to a public pot. Tokens kept private keep a constant value. But tokens in the public pot have a different value. The tokens you receive from the public pot depend on your contribution and the contributions of the other participants in that round. How much money you receive back from the pot is calculated as follows: Each round, you receive double the lowest contribution to the public pot in that round (including zero). The lowest contribution will be the minimum contribution of the four participants including yours. At the end of each round, you will be presented with a summary showing how much you decided to contribute (between 0 - 20), how much the lowest contribution was in that round, your earnings back from the pot, and your accumulated final total token count.

At the end of the experiment, the total amount of cash you have earned is the cumulative sum of all your public pot earnings and your private tokens after all 5 rounds. We will exchange your tokens for cash before you leave at the end of the experiment. In this experiment, you will receive cash according to the exchange rate of 30 tokens = £1. Once you have read the instructions carefully and understand, please press OK to start.

You have an Endowment of 20 tokens. How many would you like to donate to the pot?

Your Decision was: ‘x’

The minimum decision in your group has been: 'y'

Your profit this round is: $(20-x) + y$

Trustee game (referred to as 'Decision making experiment 2')

In this experiment you will be randomly paired with one of the other participants taking part in your testing session. This game has two stages. In the first stage, you will be given a quantity of money (£5) and decide how much of it to give to a randomly assigned partner (Player 2). Any money given to Player 2 will be doubled before they receive that money. Player 2 will then decide how much of the doubled quantity to keep, and how much to return to you.

In the second stage of the game, you will act as the receiver (Player 2), and will indicate how much of different amounts you would be willing to return to the other individual. At the end of the experiment, you will receive your money.

First stage: You have £5, how much of it would you like to send to Player 2?

Second stage: You are acting as Player 2, how much of the following amounts would you return to Player 1?

Amount received:	£2	£4	£6	£8	£10
Amount you want to return:					

7.3.3 Prosociality index and success index reliability statistics

Table 7.10 Cronbach's alpha statistics indicating how the overall reliability statistics change with removal of each individual measure prosociality (N=206 participants).

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
IOS	14.171	9.211	0.494	0.323	0.742
Connectedness	13.483	8.976	0.716	0.539	0.600
Likeability1	12.493	11.428	0.548	0.388	0.707
Similarity in personality	14.146	10.439	0.493	0.264	0.727

N = 206 includes all the prosociality data from both Chapter 4 and Chapter 5 silent disco experiments.

7.3.4 Normality and homogeneity of variance

The distribution of the change in PTT (end – start) data were not significantly different from normal for the partial synchrony and asynchrony conditions, but not the synchrony condition. PTT start and end data were all normally distributed for the synchrony and partial synchrony conditions, but distribution of the PTT start data in the asynchrony condition was significantly different from normal. PTT start data had homogenous variance between conditions, but PTT end data had heterogeneous variance. Removal of individuals who reached 300mmHg at either the start or finish also resulted in normal distributions for all PTT data (except for the change in PTT for the synchrony condition), but resulted in heterogeneous variance at both the start and end.

The Actiwatch data during the silent disco section of the experiment were normally distributed for all the movement conditions, but during the training session, these exertion data were significantly different from normal distributions for the synchrony and asynchrony conditions. These data did not have homogenous variance.

The prosociality index data was normally distributed, as was positive affect at the start, but negative affect at the start was non-normal for all conditions. The change in positive was only normally distributed for the synchrony condition, and the change in negative was non-normal throughout. Both success measures and the measures of confidence, fun, difficulty, embarrassment

and enjoyment were all non-normally distributed. The weak link coordination game data had homogenous variance for each round, however the data were non-normal for all movement conditions in round 1, and in rounds 2 and 3 the data were only normally distributed for the synchrony condition, but not the partial synchrony and asynchrony conditions. In round 4, the data were only normally distributed for the asynchrony condition, and in round 5, the partial synchrony data were normally distributed. The trustee game data (player 1 and 2) had homogenous variance but were non-normally distributed. Log transformation did not result in normality for all variables.

The measure of neuroticism on the personality scale was normally distributed for all conditions. Agreeableness, extraversion, intellectual and conscientiousness data were normally distributed for partial synchrony and asynchrony conditions, but not the synchrony condition. All these measures had homogenous variance except for the measure of extraversion.

7.3.5 MLM results for baseline measures and participants' experience of the silent disco

Table 7.11 MLM results for the effect of movement condition on various personality measures and the ability of participants to remember the movements.

	Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Extraversion	72.783	2	36.391	2.758	0.084
Agreeableness	1.564	2	0.782	0.091	0.913
Conscientiousness	81.417	2	40.708	3.654	0.029
Neuroticism	9.027	2	4.513	0.344	0.709
Intellect	6.771	2	3.385	0.831	0.448
Confidence in ability to perform movements	5.789	2	2.895	4.305	0.016

MLM includes testing group as a level.

Table 7.12 MLM results for the effect of movement condition on various measures of participants' experience of the experiment.

	Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>P</i>
Fun	1.272	2	0.636	0.476	0.627
Difficulty	1.625	2	0.813	0.581	0.561
Embarrassment	0.717	2	0.358	0.186	0.832
Enjoyment	2.019	2	1.009	0.881	0.427
Instruction Success	2.609	2	1.304	1.363	0.261
Music Synchrony Success	0.970	2	0.970	0.009	0.925

MLM includes testing group as a level.

7.3.6 MLM analyses of the differences between dance repertoires

In the original design of the experiment, the synchrony and partial synchrony condition involved all participants performing repertoire 'A'. In the final months of experimenting, those allocated the synchrony condition were assigned to repertoire 'B' or 'C' instead in order to increase the sample size of these dance repertoires. Within the synchrony condition, when the different repertoires were compared, there was a significant main effect of repertoire on activity score during the silent disco ($F(2) = 10.755, p = 0.002$), and posthoc analysis indicated that repertoire A had a significantly higher activity score compared to repertoire B ($t = -4.632, p = 0.001$) and C ($t = -2.454, p = 0.030$; see Figure 7.2).

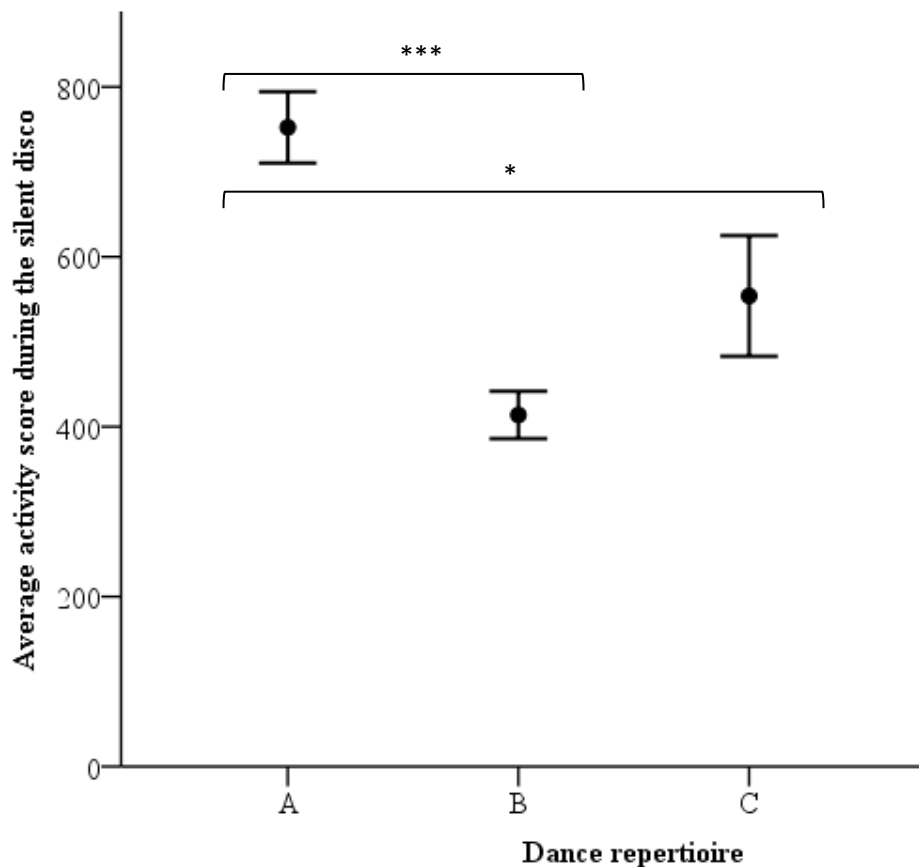


Figure 7.2 Average activity scores for dance repertoires A, B, and C, for those in the synchrony condition (± 1 SE).

*Synchrony participants only (N = 55); *** indicates significance of $p \leq 0.001$ and * a significance of $p \leq 0.05$ in MLM analysis with testing group included as a level.*

A MLM was conducted on the activity scores during the silent disco, with dance repertoire as a fixed effect, for the asynchrony condition (in which all four dance repertoires featured; see Figure 7.3). This analysis indicated that there was a significant main effect of repertoire on activity index ($F(3) = 10.969, p < 0.001$), and post hoc analysis indicated that repertoire A was significantly higher than repertoire B ($t = -4.911, p < 0.001$), and repertoire C ($t = -4.599, p < 0.001$) and almost significantly higher than repertoire D ($t = -1.836, p = 0.081$). Repertoire D was itself significantly different from B ($t = 3.074, p = 0.006$) and C ($t = -2.762, p = 0.012$).

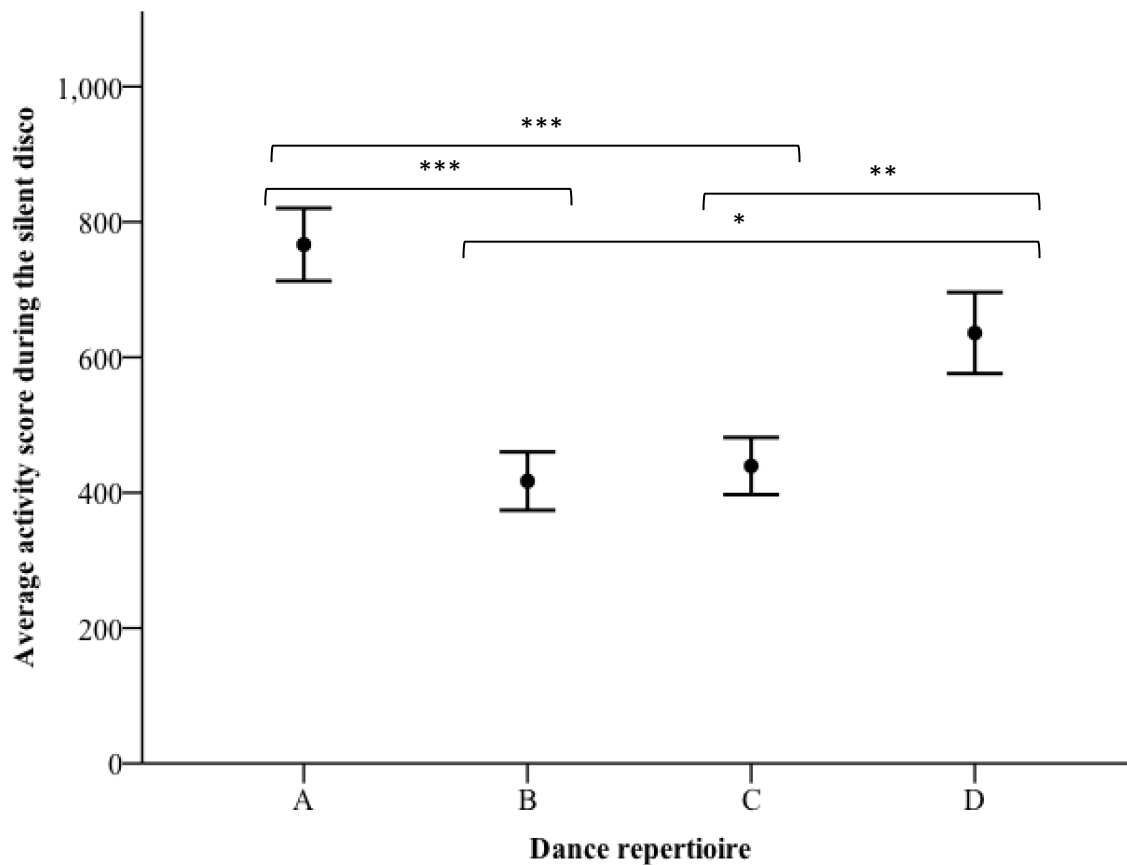


Figure 7.3 Average activity scores during the silent disco for dance repertoires A, B, C and D, for those in the asynchrony condition ($\pm 1SE$).

*Asynchrony participants only (N = 24); *** indicates significance of $p \leq 0.001$ in MLM analysis with testing group included as a level.*

7.4 Chapter 5 Appendices

7.4.1 Normality testing and homogeneity of variance

With the exclusion of those who reached 300 mmHg, all PTT data were normally distributed for all treatments and had homogeneous variance. However, when all data were included PTT start data were significantly different from normal in the naltrexone treatment, and the change in PTT was significantly non-normally distributed for the placebo and naltrexone treatments. All prosociality index data were normally distributed with homogenous variance, and the distribution of the success index was significantly different from normal for all treatments, but with homogenous variance. The measures of confidence, fun, embarrassment, difficulty and enjoyment all had distributions significantly different from normal, with homogenous variance. Extraversion and neuroticism data were normally distributed for all treatments. Agreeableness was normally distributed for the control treatment, but not for placebo and naltrexone treatments, and measure of intellect was only normally distributed for the placebo treatment. The placebo and naltrexone treatments were normally distributed with regards to conscientiousness, with significantly non-normal control data. The change in positive affect was normally distributed for the control and placebo treatments, but not the naltrexone, and all treatments had non-normally distributed data for the change in negative affect. All personality measures had homogenous variance. Log transformation did not correct for the lack of normality for any variables.

7.4.2 MLM results for baseline differences in variables

Table 7.13 MLM results for start measures of various baseline variables compared between control, placebo and naltrexone treatments.

	Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Extraversion	0.269	2	0.134	0.010	0.999
Agreeableness	4.966	2	2.483	0.371	0.671
Conscientiousness	20.888	2	10.444	0.800	0.452
Neuroticism	16.662	2	8.331	0.654	0.530
Intellect	3.191	2	1.595	0.395	0.675
Confidence in ability to perform movements	0.532	2	0.266	0.580	0.568

MLM includes testing group as a level. N = 103.

7.4.3 MLM analysis of various measures of participants experience of the silent disco

Table 7.14 MLM results for the effect of movement condition on various measures of participants' experience of the experiment.

	Sum of Squares	<i>d.f</i>	Mean Square	<i>F</i>	<i>p</i>
Fun	1.031	2	0.515	0.441	0.649
Difficulty	2.323	2	1.162	1.227	0.312
Embarrassment	3.390	2	1.695	0.886	0.415
Enjoyment	0.131	2	0.065	0.022	0.979
Instruction Success	0.635	2	0.318	0.408	0.670
Overall Synchrony Success	0.451	1	0.451	2.573	0.098

MLM includes testing group as a level. N = 103.

Table 7.15 Mean (SD) of various measures of participants' experience of the experiment.

	Control	Placebo	Naltrexone
Fun	5.300 (1.208)	5.571 (1.037)	5.382 (1.155)
Embarrassment	2.371 (1.478)	2.371 (1.308)	2.735 (1.544)
Difficulty	1.800 (0.961)	2.229 (1.190)	1.765 (0.923)
Enjoyment	5.567 (1.04)	5.457 (1.039)	5.500 (1.441)
Instruction Success	5.967 (1.066)	6.029 (0.666)	6.176 (0.797)
Overall Synchrony Success	5.033 (0.999)	5.029 (1.124)	5.647 (0.917)

7.4.4 Differences between start, mid and end pain threshold measurements

Table 7.16 Results for the one sample T-test for each treatment between the three PTT measurements.

		<i>t</i>	<i>d.f</i>	<i>p</i>	<i>N</i>
PTT mid – PTT start	Control	0.663	31	0.512	32
	Placebo	-0.761	35	0.452	36
	Naltrexone	-0.692	34	0.494	35
PTT end – PTT mid	Control	2.931	31	0.006	32
	Placebo	-0.424	35	0.675	36
	Naltrexone	3.123	34	0.004	35
PTT end – PTT start	Control	2.375	31	0.024	32
	Placebo	-0.665	35	0.510	36
	Naltrexone	1.060	34	0.297	35

7.5 Chapter 6 Appendix

7.5.1 Assumption checks for mediation analysis

The data were checked for violation of the relevant assumptions. Because PROCESS conducts path analysis using a series of regressions, the standard regression assumptions apply to each of Regression 1 ($R1$) and Regression 2 ($R2$) (Hayes, 2013). Indeed, the Variance Inflation Factor (VIF) in regression 2, $VIF = 1.05$, indicated multicollinearity was not likely present in the model (Field, 2009). No tolerance level was < 0.9 , well above unacceptable cut-offs of < 0.1 (Field, 2009), and variance proportion weightings indicated discrete variance elements of the prosociality index were being explained by the pain threshold and the direct effect of movement condition. Consequently it was concluded that the assumption of no multicollinearity had been met.

An inspection of the residual plots indicated no structure in the residuals that might hint at heteroscedasticity or a non-linear model. Moreover, Levene's test for homogeneity of variance in $R1$, with only one dichotomous predictor, was not significant, $F(1, 211) = 2.041, p = 0.155$, indicating equally distributed variances between the two movement conditions. The Durbin-Watson statistics were $R1 = 1.9$; $R2 = 1.977$, indicating that the assumption of independence of observations had been met (Field, 2009). Inspection of the Q-Q plots did not appear to indicate residual non-normality; however, both regressions yielded a significant result on the Shapiro-Wilk test, $R1 W(213) = 0.982, p = 0.008$; $R2 W(213) = 0.96, p < 0.001$, indicating that neither set of residuals was normally distributed.

In both regressions, less than 5% of standardized residuals were > 1.96 standard deviations away from the mean and no Cook's distance was > 0.1 , well below the unacceptable level of > 1 (Field, 2009), indicating no data points were likely to be exerting undue influence on the model. Finally, path analysis additionally assumes a causal relationship between X and Y via M . This assumption can at least be theoretically justified—uncertainty about the appropriateness of the pain threshold as a proxy for activation of the EOS notwithstanding—by the fact that X is an experimentally manipulated set of conditions and therefore temporally precedes resultant changes in Y (Hayes, 2013). It was concluded that the data met the assumptions of the model.

7.6 Audio/visual Appendix and DVD guide

7.6.1 Chapter 3: Supplementary material

Training tracks

The training tracks used for this experiment were composed in Garage Band (MacOS) to create a simple drum beat song to which the participants could practice the movements prior to the movement session (See folder ‘3.1 Movement training tracks’). Both movement tracks were used in the teaching of the dance moves across all conditions.

Movement session

Instructions

A translation of the audio instructions (see folder 3.2 Movement session tracks, file: ‘Pre-session instructions (Portuguese)’) is included below.

“Pay attention! When the music begins, start with the first movement on your card. When you hear ‘change’ do the next movement on your card. When you get to the last movement, return to the first one again. Pay attention! Only change your movement when you hear ‘change’. Look at your cards and the other pupils!”

Also included were two practice sessions, where the researchers (one per participant) joined in to demonstrate what to do in terms of following the instructions and knowing when to change to the next movement. At the end of the instructions, the researcher asked the students *“Lets repeat, I will play the music. How will you know which movement to do?”*, *“How will you know when to change to the next movement?”*, and *“When you get to the last movement on your card, and you hear ‘change’, what should you do?”*.

The participants proceeded to the movement session only when all three questions had been answered by all the participants, and the final instructions were *“OK now we start. Remember: Look at your cards and the other pupils!”*

Movement session tracks

The same stimulus track was used for all movement conditions (folder 3.2 Movement session tracks, file ‘Movement session stimulus’). The music used in the movement session were adapted versions of various tracks from ‘Brazilian beats’ (Artist: Sarr Band; Album: Brazil Electric). The original songs were edited to include only sections of the songs with no lyrics, and these sections were used to create a loop (i.e. a coherent unit of the song which can be repeated as many times as necessary).

Video samples

Short snippets are included to illustrate the four movement conditions (folder 3.3 Movement session video samples).

7.6.2 Chapter 4: Supplementary material

Training videos

Each participant watched the training videos in a private cubicle. Each participant was assigned a training video according to what movement session they had been assigned. In the synchrony and partial condition, all participants watched the same training video, for example dance repertoire A (folder 4.1 Silent Disco training videos, file ‘Dance repertoire A’). In the asynchrony condition, each participant watched a different dance repertoire (Dance repertoire A, B, C or D).

Silent disco movement session

Instructions

All conditions had the same audio instructions, with one difference. Those in the synchrony condition were instructed to synchronise with each other (underlined in the quote below). In the synchrony condition, the participants had the following instructions (for the audio file see folder 4.2.1 Synchrony condition, file ‘Synchrony instructions’):

“Welcome to the silent disco part of the experiment... we are going to play you a series of musical tracks and your goal is to synchronise your movements with each other, and to the musical beat. Follow your musical instructions

as much as possible, and try to do each movement fully. Use your own style but always try and hit each beat. If you make a mistake don't worry, just pick up the next move when it is announced. Remember to relax and enjoy yourself. Keep your eyes open and make eye contact with the other participants...

In the partial synchrony and asynchrony conditions (where participants were not doing the same movement at the same time), the participants had the following instructions (for the audio file see folder 4.2.2 Partial synchrony/4.2.3 Asynchrony condition):

“Welcome to the silent disco part of the experiment... we are going to play you a series of different tracks and your goal is to follow your own musical instructions and synchronise your movements to the musical beat you hear. Follow your musical instructions as much as possible, and try to do each movement fully. Use your own style but always try and hit each beat. If you make a mistake don't worry, just pick up the next move when it is announced. Remember to relax and enjoy yourself. Keep your eyes open and make eye contact with the other participants...”

Silent disco audio tracks

The stimulus material for each movement conditions are included in folder 4.2 Silent Disco movement session tracks. In the synchrony condition, participants heard the same audio track (folder 4.2.1 Synchrony condition, file ‘Dance repertoire A’). In the partial synchrony condition, the participants had learnt the same dance moves, but the order that they were instructed to do the moves was different for each participant (folder 4.2.2 Partial synchrony condition, files ‘Dance repertoire A1, A2, A3 and A4’). In the asynchrony condition, the audio tracks corresponded to the dance repertoire assigned to each participant (folder 4.2.3 Asynchrony, files ‘Dance repertoire A, B, C and D’).

Video samples

Short snippets are included to illustrate the four movement conditions (folder 4.3 Silent Disco movement session video samples).