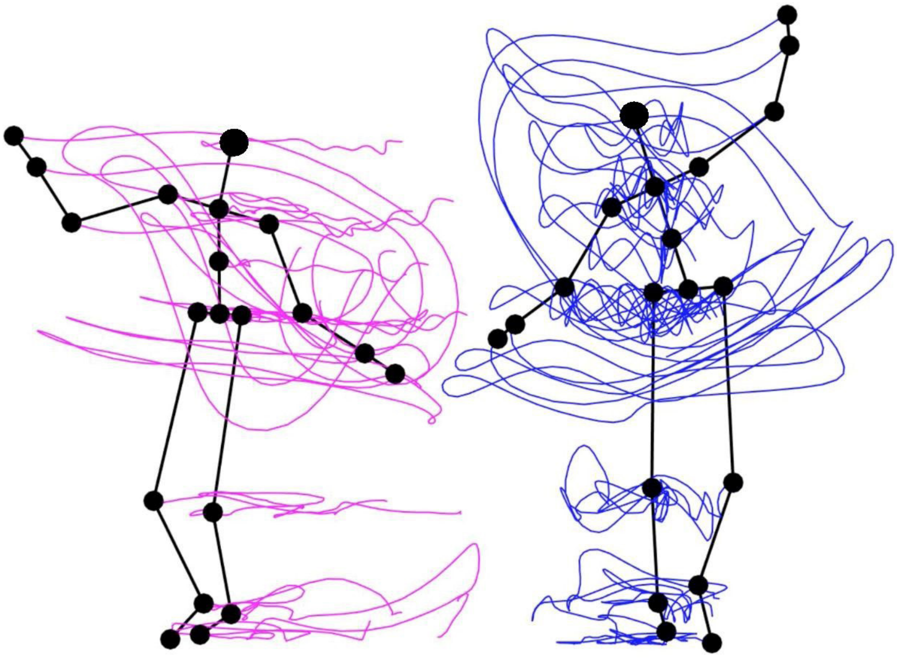
JYU DISSERTATIONS 33

Emily Carlson

Me, You and the Dance

Effects of Individual Differences and Social Context on Music-induced Movement



UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF HUMANITIES AND SOCIAL SCIENCES

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Emily Carlson

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Effects of Individual Differences and Social Context on Music-induced Movement

Esitetään Jyväskylän yliopiston humanistis-yhteiskuntatieteellisen tiedekunnan suostumuksella julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa S212 marraskuun 3. päivänä 2018 kello 12.

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Spatial depths of being survive
The birth to death recurrences
Of feet dancing on earth of sand;
Vibrations of the dance survive
The sand; the sand, elect, survives
The dancer. He can find no source
Of magic adequate to bind
The sand upon his feet, his feet
Upon his dance, his dance upon
The diamond body of his being.

-- Jean Toomer (1894 – 1967)

ABSTRACT

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To dance is usually to dance with someone else. Dance often takes place in social contexts such as a club or party, where individuals' movements not only reflect their own traits and feelings but can the movements of others in many ways. The aim of this thesis is to study some of the factors that may affect music-induced movement in social contexts, particularly trait empathy. The thesis also aims to investigate the influence of inherently dyadic features, such as similarity between dance partners, and to explore how entrainment and interaction can be quantified in a free dance movement context using a variety of analytic approaches. A first analysis of individual dance data from 30 participants found correlations between Big Five personality traits and responsiveness to small changes musical tempo but failed to find a relationship between dispositional empathy and participants' adjustment to musical tempo. This suggested that, in dance, empathy may more readily manifest interpersonally than individually. To explore this further, a motion capture study was conducted in which 73 participants were recorded dancing alone and with several partners to music excerpts from eight different genres, which were selected using a novel, data-driven approach to identifying naturalistic stimuli. Kinematic movement features were extracted from these data for comparison with self-report measures of empathy and personality traits. Subsequent analysis using the Social Relations Model found that partners with greater trait empathy altered their movements more in responses to different partners than those with less empathy, while agreeableness was linked to head movements. A perceptual experiment was then carried out using animations created from data of dyads whose members' empathy scores were either both high, both low, or high and low respectively, with 33 participants rating dyads' level of interaction and similarity. Analysis showed that dyads combining high- and low-empathy members were rated as interacting more than others. Finally, rated stimuli were analyzed using computational methods, with an aim to develop quantitative descriptions of entrainment. It was found that dyads who were rated as highly interactive moved at more similar periodicities, tended to orient their heads towards each other, and to use their hands significantly more during dance. Taken together, these results paint a multi-dimensional picture of motoric entrainment and engagement in the dyadic dance setting, providing direction and motivation for further investigation into free dyadic dance movement.

Keywords: dance, empathy, personality, social interaction, motion capture

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FIGURES

FIGURE 1 Location of markers and joints in typical motion capture data ... 46
FIGURE 2 Motion capture space and marker configuration as modified for Study III, including identifying markers placed on the calves. ... 48

CONTENTS

ABSTRACT
ACKNOWLEDGEMENTS
FIGURES AND TABLES
CONTENTS
LIST OF PUBLICATIONS AND AUTHOR'S CONTRIBUTIONS

1 INTRODUCTION 13

2 BACKGROUND 16
2.1 Definition of dance 16
2.2 Evolutionary origins of music and dance 17
2.3 Embodied cognition 21
2.4 Embodied music cognition 23

3 INDIVIDUAL DIFFERENCES 26
3.1 Personality 26
3.1.1 Definition and background 26
3.1.2 Personality, music and movement 28
3.2 Empathy 30
3.2.1 Definition and background 30
3.2.2 Empathy and music 33
3.3 Individual differences and social functioning 36
3.4 Social functioning, movement and music 38
3.5 Summary and conclusion of introduction 39

4 AIMS AND OVERVIEW OF THE THESIS 40

5 METHODOLOGIES 42
5.1 Self-report measures 42
5.1.1 Measures of The Big Five: TIPI and BFI 42
5.1.2 Measures of dispositional empathy: IRI, EQ and SQ 42
5.2 Motion capture 44
5.2.1 History and theoretical overview 44
5.2.2 Motion capture apparatus 45
5.2.3 Adjustments to apparatus for dyadic capture 47
5.2.4 Data preprocessing 48
5.3 Statistical analysis of dyadic data 50
5.4 Perceptual measures 53

6 METHODS 54
6.1 Study I: Participants 54
6.2 Study I: Stimuli 54

6.3 Study I: Procedure 54
6.4 Studies II and III: Data-driven stimuli selection 55
6.5 Study II: Survey Participants 56
6.6 Studies II, III and IV: Survey data collection 56
6.7 Study III and IV: Motion capture data collection 57
6.7.1 Participants and groups 57
6.7.2 Procedures 57
6.8 Study IV: Perceptual study 58
6.8.1 Data-driven stimuli selection 58
6.8.2 Participants 59
6.8.3 Procedures 59

7 MAIN RESULTS AND DISCUSSION 60
7.1 Study I: Results and Discussion 60
7.2 Study II: Results and Discussion 62
7.3 Study III: Results and Discussion 63
7.4 Study IV: Results and Discussion 65

8 CONCLUSION 67
8.1 General discussion of results 67
8.2 Limitations and future work 70
8.3 Concluding remarks 72

YHTEENVETO (FINNISH SUMMARY) 73

REFERENCES 74

ORIGINAL PUBLICATIONS

LIST OF PUBLICATIONS INCLUDED IN THE THESIS

I Carlson, E., Burger, B., London, J., Thompson, M. R., & Toiviainen, P. (2016). Conscientiousness and Extraversion relate to responsiveness to tempo in dance. *Human movement science*, *49*, 315-325.

II Carlson, E., Saari, P., Burger, B., & Toiviainen, P. (2017). Personality and musical preference using social-tagging in excerpt-selection. *Psychomusicology: Music, Mind, and Brain*, *27*(3), 203-212.

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AUTHOR'S CONTRIBUTION TO PUBLICATIONS

I The author was responsible for the preprocessing of personality data and principally responsible for the relevant analysis of personality and motion capture data and writing of the paper.

II The author contributed to the planning of the experimental design and stimuli selection, was responsible for data collection and analysis and was principally responsible for the writing of the paper.

III The author contributed to the planning of the experimental design and was principally responsible for data collection, preprocessing, analysis and writing of the paper.

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1 INTRODUCTION

Imagine a person. She consists on one level of a brain and body which sense and respond to the world, on another of a unique set of traits, experiences, preferences, and abilities. Play this person some music. It consists of a regular beat, various rhythms, harmonies, and timbres, may belong to a certain genre, may be one of her favorite songs or something she has never heard. After a few moments, she is likely to start to move (Lesaffre et al., 2008), especially if the song has the right groove or beat (Janata, Tomic, & Haberman, 2012; Repp, 2005). She may tap her feet or nod her head in synchrony with the drum or sway from side to side, and even begin to dance. If she is quite extraverted, she may fling her arms wide and move around the floor, or if she is rather neurotic she may keep her arms more closely to her side and make small, quick movements (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010). Her movements may reflect a variety of different qualities of the song she hears—its rhythm, the genre to which it belongs, the emotion it expresses, and even qualities of the sound and timbre that she herself does not perceive consciously (Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2013). Some may even argue that she is imitating the music, even empathizing with it, using her body to translate sound into human movement (Godøy, 2003; Leman, 2008).

Now, imagine that a second person has entered the space, bringing along her own unique senses, qualities and experiences. She, too, may begin to move to the music. If she is an introvert while the first is an extravert, the two dancers' movements may be quite different from one another. What will happen as these two people continue to move to the same music? Will they continue to move on their own or will they interact in some way? Will their contrasting personalities help or hinder their engagement (Cuperman & Ickes, 2009; Isbister & Nass, 2000)? Will they imitate each other along with or rather than the music (Chartrand & Bargh, 1999; Stel & Vonk, 2010)? If is strongly empathic, will she imitate her partner, the music, or both? Will they become entrained, each timing their movements in relation to the other? Will their interaction be obvious to all or too subtle to detect with the naked eye?

People dance—and dance with others—every day and in many settings all over the world. Bodily movement is a near-universal response to hearing music (Lesaffre et al., 2008), and it is indeed so natural to entrain rhythmically to a steady beat that this behavior can be difficult to do otherwise (Repp, 2005; M. J. Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007). Research has shown that a multitude of factors can affect qualities of dance movements, including personality, musical genre, timbral features, groove, the emotion expressed by the music, or the emotion felt by the dancers (Burger, 2013; Repp & Su, 2013). Nevertheless, the majority research on music-induced movement, or dance, has focused on individual dancers, leaving out aspects of dance that relate to social functioning. This is a particularly notable gap in light of theories that dance and music evolved as human behaviors to serve social purposes (Laland, Wilkins, & Clayton, 2016; Richter & Ostovar, 2016). Although music perception has been linked to empathic processes (Leman, 2008; Miu & Balteş, 2012; Vuoskoski & Thompson, 2012), which in turn have been linked to physical imitation, mimicry and entrainment (Iacoboni, 2009; Sonnby–Borgström & Sonnby-Borgstrom, 2002; Svenja Maren Köhne, 2015), there has been little empirical study of how empathic functioning relates to motoric engagement with music (Bamford & Davidson, 2017).

This thesis aims to fill some of the gaps in our understanding of dance by explicitly addressing the social nature of this phenomenon. The role of individuals and their unique traits are considered in the context of social functioning, including individual differences in dispositional empathy and the effect of a dyadic context on dance movement. The thesis consists of four interrelated studies; the first analyzing motion capture and personality data from individuals, the second using a novel, data-driven approach to naturalistic stimuli selection for use in the other studies, the third analyzing motion capture and personality of dyads, and the last combining the analysis of motion capture and perceptual data. The research presented here was carried out using technology and resources available at the Department of Music, Arts, and Culture at the University of Jyväskylä, specifically its laboratory featuring a high-quality optical motion capture system. Two motion capture experiments, one involving individual dancers and the other involving dyads, were carried out in this laboratory, providing rich data from which various movement features were computationally extracted and compared with measures of individual difference and perceptual measures.

This thesis summary provides an overview of the empirical and theoretical background for this work, information on the methodologies employed, and of the methods and main results from each of the four studies. The summary is organized into eight chapters. Chapter 2 provides a theoretical background regarding dance and embodied cognition, and Chapter 3 provides theoretical and empirical information regarding individual differences of personality and empathy. The aims of the thesis are considered in Chapter 4. Chapter 5 provides an overview of methodologies employed in the thesis, including motion capture and analysis of dyadic data. In Chapter 6, the methods of data collection for the studies are given, and the main results are given and discussed in Chapter 7. Chapter 8 provides a general discussion as well as a section on limitations and directions for future work.

2 BACKGROUND

2.1 Definition of dance

Dance is defined by the *Oxford English Dictionary* as a verb meaning, "to move rhythmically to music, typically following a set sequence of steps" ('Dance,' n.d.). For the current thesis, which concerns free and spontaneous movements in the presence of musical stimuli, only the first part of the definition is needed: to move rhythmically to music. It can be further specified that, in this case, the object moved is oneself (i.e., one's own body rather than a puppet or a ribbon). Various movements outside of dance, such as gait, may be rhythmic in that they are organized in an isochronous way (Merker, Madison, & Eckerdal, 2009; Phillips-Silver, Aktipis, & Bryant, 2010) and may be done in the presence of music. Therefore, a second clarification is that the rhythmic movement in question should be in response to and to (some degree) synchronized with heard music and specifically heard rhythm. Rhythm is comprised of an isochronous pulse (the *tactus)* which can be hierarchically grouped or subdivided into various divisions of the period (Repp, 2005; Richter & Ostovar, 2016). Synchronization is the timed coordination of an action with another stimulus such as a musical beat, such as two metronomes clicking simultaneously (Repp, 2005). As synchronization with a heard rhythm could also include other behaviors, such as marching to a beat, which are highly repetitive and generally afford motoric synchronization to a single level of a rhythmic hierarchy, a further specification is that dance requires varied motoric responsiveness to hierarchical levels of a rhythm (Richter & Ostovar, 2016; Toiviainen, Luck, & Thompson, 2010). Thus, for this thesis, to dance is defined as: *to move oneself rhythmically in a varied, hierarchical way in response to and in synchrony with music.*

2.2 Evolutionary origins of music and dance

Why do humans dance? There is evidence that dance has existed in human society for as many as 70,000 years. Cave paintings which are believed to depict dance show groups of humans spaced at regular intervals, invoking isochronous rhythms, and in identical postures, for example with hands raised, invoking synchronous coordination among group members (Christensen, Cela-Conde, & Gomila, 2017). However, the origin, and in some senses, the purpose, of human music and dance is still an open question (Huron, 2001). It has been suggested that melodic aspects of music may have evolved in tandem with language, sharing the function of communicating emotions and possibly sharing a common protolanguage origin (Mithen, Morley, Wray, Tallerman, & Gamble, 2006; Patel, 2006). Gesture, too, many have preceded spoken language in the evolution of communication (S. Brown, 2000). Many argue, however, that this does not adequately explain why humans dance, as dancing is an energetically expensive activity that seems to have no purpose, at least none directly related to survival needs of sustenance, safety and procreation (Christensen et al., 2017; Ravignani & Cook, 2016; Richter & Ostovar, 2016). For this reason, even Darwin cited dance as one of the most mysterious of human behaviors. Despite of its apparent purposelessness, however, all known human cultures have music with a regular, periodic beat that affords synchronization (Cross, 2006; Nettl, 2000) and all cultures appear to synchronize to music through dance (Kaeppler, 2000). Music and dance have long been and continue to be important, pervasive elements of social settings across many cultures (Giurchescu, 2001; Laland et al., 2016; Phillips-Silver & Keller, 2012). There is evidence that children spontaneously move in synchrony to an external beat at a very young age across cultures (Eerola, Luck, & Toiviainen, 2006; Ostovar, 2016), leading some researchers to suggest that, despite its mysteriousness, the propensity and ability to dance may even be innate (Christensen et al., 2017; Cross, 2006; Laland et al., 2016; Richter & Ostovar, 2016), a part of our human makeup derived from evolutionary forces.

As a possible explanation for how and why dance may have evolved as a human behavior, some (including Darwin) have favored the idea that, similr to non-human animals, humans' vocal and physical displays are strategies linked to attracting and selecting a mate. This would lead to the propagation of the species and, as a result, the propagation of genes associated with skill in music and dance (Miller, 2000). There is indeed some experimental evidence for this; McCarty, Hönekopp, Neave, Caplan, and Fink (2013), for example, found that females rated point-light animations of physically stronger males' dance movements as more attractive than those of males with less strength. Weege, Pham, Shackelford, and Fink, (2015) replicated this finding, while Luck, Saarikallio, Thompson, Burger, and Toiviainen (2012) showed a close relationship between both males' and females' ratings of dance skill and 'datability' based on dance movements. Others have expressed skepticism that sexual selection adequately explains the origins of music and dance; Brown (2000) argues against this explanation, pointing out that music is not sexually dimorphic, that it plays only an indirect role in courtship, and that romantic love songs are not common features of smaller, tribal cultures. Christensen et al. (2017) suggest that dance plays an indirect role in mate selection by affording access to biochemical markers of fitness and genetic compatibility found in saliva and sweat, and, in the case of spontaneous, free dance movement, may provide information about another's psychological and psychosocial qualities, such as personality (p. 23). Such functions of music and dance, according to both authors, are likely to have arisen after these behaviors had already evolved for other reasons.

Underlying our ability to dance is our ability to entrain motorically to an external stimulus, leading some to suggest that such entrainment may be the key to understanding this behavior. Clayton (2012) defines entrainment as "the process by which independent rhythmical systems interact with each other" (p. 49), which can happen mechanically, as when multiple metronomes placed on a moveable surface become synchronized, but entrainment also happens biologically. An example of biological entrainment familiar to most is the influence of cycles of sunlight and darkness on circadian cycles of sleep and wakefulness. Many are also familiar with the experience of falling into step with a friend while out for a walk together, or, of course, tapping along to the beat of some heard music.

Although often used interchangeably with synchronization, entrainment implies not only the timing of an action to coincide with an external event (which can, in theory, happen by mere coincidence), but that at least one signal adjusts to the other to maintain coordination, thus implying a more stable and, in the case of biological systems, an arguably more purposeful relationship over time. Phillips-Silver, Aktipis, and Bryant (2010) define three necessary abilities that allow organisms to spatiotemporally entrain: the ability to perceive rhythmic information, to produce rhythmic output, and to transmit rhythmic information between sensory and motor systems.

The first of these, perception of rhythmic information has broad survival relevance across species, from the ability to adjust behavior to seasonal changes to the detection of the sound of potential predator or prey; the production of rhythmic output is similarly widespread across species through locomotion or for social signaling (Phillips-Silver et al., 2010). Despite this, there is limited evidence that non-human species are able to motorically entrain to an external signal, although there are exceptions, and it is notable that these exceptions tend to appear in species that are social or have some ability in vocal mimicry (Large & Gray, 2015; Merchant & Honing, 2014; Patel, Iversen, Bregman, & Schulz, 2009). Non-human species, such as fiddler crabs, also sometimes engage in synchronous chorusing; that is, the use of repetitive, precisely timed signaling by a group, allowing a signal to be amplified beyond what could be created by an individual group member. Rhythmic entrainment to a pulse is not necessarily implicated in this behavior, although some speculate rhythmic entrainment could have arisen from synchronous chorusing at some point in human evolution (Bispham, 2006; Merker et al., 2009). Ravignani and Cook (2016) suggest a broader view of the evolution of dance as a species-general ability to coordinate movements both cooperatively and antagonistically, although this too, does not necessarily account for the rhythmicity of dance behaviors. Although the raw materials of our ability to dance seem to be shared with other species, dance itself still appears to be a particularly human phenomenon.

The ability for spatiotemporal entrainment between group members, or social entrainment (Phillips-Silver et al., 2010), could serve many uses for group survival. The ability of group members to closely synchronize has been shown to signal strong coalition (Hagen & Bryant, 2003), and to increase feelings of cohesion and affiliation among group members, in both children and adults (Hove & Risen, 2009; Launay, Tarr, & Dunbar, 2016; Rabinowitch et al., 2015; von Zimmermann, Vicary, Sperling, Orgs, & Richardson, 2018). Richter and Ostovar (2016) have noted the cross-cultural prevalence of soothing infants by rocking them and its possible connection to fetal exposure to periodic stimuli arising from maternal physiological functioning (e.g., heartbeat, breathing), suggesting that dance might, therefore, be related to human neoteny and the development of self-soothing mechanisms. Phillips-Silver and Keller (2012) similarly suggest that entrainment behaviors are related to early childhood interactions such as turn-taking and mimicry with adults. Testing the influence of entrainment on early behavior, Rabinowitch and Meltzoff (2017) found that preschool children passively swung in synchrony next to a peer displayed better social cooperation in subsequent tasks (such as hitting a button at the same time as a partner) than children who were swung out of sync with a peer. The authors suggest that this effect could be due to increased feelings of likeness and affiliation between children who experienced synchrony (as per Rabinowitch et al., 2015) or because the coordination of movement increased children's awareness of temporal processes. Although these results concerned entrainment at a single beat level and not dance per se, they support the idea that dance may have evolved to support pro-social behavior and group cohesion that is necessary for human survival.

Leaving aside the debate as to whether music and dance evolved out of necessity to meet the survival needs of early humans—a question which will be difficult to settle conclusively (Phillips-Silver, 2009)—it is evident that music and dance serve many psychological and psychosocial functions. Christensen et al. (2017) consider dance in terms of its potential benefits and suggest that the role of dance in human society is "an external system of autoregulation that aids in the maintenance of psychobiological and mental health" (p. 9). They relate dance to six 'biobehavioral' functions: 1) experience of flow and attentional focus, which they claim benefits an overstimulated brain, 2) to produce or eliminate basic biochemical agents related to various emotion experiences (i.e., analogous to sweat and tears eliminating stress-related hormones from the body), 3) to experience imagery, 4) to communicate emotional states or tell stories, 5) to increase awareness and realization of the self or to experience *catharsis*, and 6) to increase social cohesion. In a similar vein, (Monteiro & Wall, 2011) note that “rituals incorporating dance can make use of its ability to serve as a healthy psychological defense mechanism, which allows psychologically or socially unacceptable impulses to be expressed and worked through in sublimated forms” (p. 239); that is, dance strengthens a society by providing an outlet for emotions such as anger that could damage the group as a whole. Although not specifically discussing dance, Watson-Jones and Legare's (2016) description of the functions of group rituals, which often feature music and dance, include facilitating cooperation among group members and increasing group social cohesion, functions which have been attributed to dance in multiple studies (Reddish, Fischer, & Bulbulia, 2013; Solberg & Jensenius, 2017; von Zimmermann et al., 2018).

A variety of experimental evidence corroborates the idea that dance serves biological, psychological, and social functions. Quiroga Murcia, Kreutz, Clift, and Bongard, (2010) surveyed non-professional dancers about their perceptions regarding the benefits of engaging in dance, and found strong agreement with many statements in line with Christensen et al.,'s (2017) biobehavioral functions, including ‘improve balance and body awareness,’ ‘improve mood,’ ‘important for my mind’, ‘help to express feelings’, and ‘gives me a great feeling of togetherness’ (p. 155-156). Maraz, Király, Urbán, Griffiths, and Demetrovics (2015) developed an inventory for assessing dance motivation and found that factors including fitness, mood enhancement, and intimacy motivated their participants to dance. These benefits do not appear to be merely placeboes; Lobo and Winsler (2006) showed that young children involved in dance improved their social competence over children in another activity, while Horwitz, Lennartsson, Theorell, and Ullén (2015) showed an association between engagement with dance and increased abilities in emotional communication. Tarr, Launay, and Dunbar (2016) have shown evidence that moving in synchrony through dance with a group facilitates endorphin release. In further study, it was shown that, while blocking endorphin release decreased enjoyment of dance, it did not decrease the association between dance and feelings of social closeness (Tarr, Launay, Benson, & Dunbar, 2017). Not only does this finding support the idea that one of the primary functions of dance is to benefit social function, it suggests that there may be multiple reasons we engage in dance that can be dissociated from one another. The dissociation between experienced pleasure and increased social closeness of these results also emphasizes motoric synchronization as an element underlying the social benefits of dance.

These and indeed many of the results described above implicate bodily movement as being influential on and reflective of human cognition, particularly social cognition. These ideas are in line with an increasingly popular research paradigm known as *embodied cognition*, which is defined and discussed in the following sections.

2.3 Embodied cognition

Popular science bookshelves in recent years are overflowing with titles like *The Brain that Changes Itself*, or *The Tell-Tale Brain*, or *Incognito: The Secret Life of the Brain*, or *This is Your Brain on Music: The Science of a Human Obsession*. Technological developments in the second half of the twentieth century have created an unprecedented ability to examine the functioning of the most complex organ in the human body, using electroencephalogram (EEG) to observe electrical activity and functional magnetic resonance imagery (fMRI) to record patterns of blood flow. A popular webcomic depicts a doctoral student as a brain on a stick (Cham, 2009), gently highlighting how easy it can be to forget that to be human is to be far more than a brain. Still, despite the new wealth of neuro-imaging studies, the problem of how an organ that is "locked away inside our heads with only impoverished, probabilistic perceptual access to the world" is able to control "rapid, function and successful behavior in a dynamic physical and social environment," (A. D. Wilson & Golonka, 2013, p. 2) remains open. Traditional views of cognition, most famously associated with philosopher and scientist René Descartes (1596-1650), consider the mind and body to be wholly distinct from one another; that is, there is an abstract mental reality related to but beyond our physical reality that accounts for human consciousness, thought and feeling. Cognitivism is the view that that intelligent behavior can best be explained as arising from internal thought, with the brain acting as a computer that determines behavior by completing computations on symbolic representations of the real world according to a set of rules. The body passively provides information and responds to commands arising from rational thought (Anderson, 2003; Haugeland, 1978).

Embodied cognition is a paradigm for understanding human cognition that sets itself in contrast to this traditional model. Embodied cognition theorists posit that the perceptions and actions of the body are directly, rather than passively, involved with cognition (M. Wilson, 2002). Rather than a linear process of perceive-compute-respond, action and perception are inherently and immediately linked and able to affect one another. The body and its movements are not merely a vehicle that is controlled by efferent signals arising from the brain or from an abstract mind. Instead, afferent sensorimotor signals from the body are considered to be part of a dynamic system of cognition in which perception, action, and understanding arise from bodily interaction with a dynamic environment. A. D. Wilson and Golonka (2013) describe embodied cognition as "the surprisingly radical hypothesis that the brain is not the sole cognitive resource we have available to us to solve problems" (p. 1). That is, an isolated brain, as in the comic mentioned above, would not be fully capable of human cognition in the absence of a body.

There has been a sharp rise in the number of research articles with the title 'embodied' or 'embodied cognition' appearing in the title or keywords since 1980 (see Mahon, 2015, p. 421). Even a cursory look through this literature obviates that embodied cognition is a particularly broad church, including many disciplines such as philosophy, psychology, sociology, linguistics, and artificial intelligence, and existing on a spectrum of parallel and competing views and varied degrees of radicalism. Some researchers have attempted to define embodied cognition in terms of a wide and interconnected set of principles. Margaret Wilson (2002), for example, articulated six claims arising from diverse accounts of embodied cognition; these included the idea that cognition must be understood in the context of the environment in which it takes place, that cognitive work is off-loaded onto the environment, and that cognition is based on representations of the body (M. Wilson, 2002). Shapiro (2007) defines embodied cognition not as a theory at all but as a 'research program' with three main goals: 1) to understand cognitive processes in terms of bodily properties rather than abstract mental symbolism, 2) to understand what role the body plays in cognition and 3) to understand how aspects of the environment play a role in cognition. Other researchers have expressed skepticism and advised restraint regarding claims that cognition is embodied or that this claim is incompatible with cognitivism (Goldinger, Papesh, Barnhart, Hansen, & Hout, 2016; Goldman & de Vignemont, 2009; Markman & Brendl, 2005). Still, others have argued that most embodied theorists do not go far enough in their claims, asserting that true embodied cognition precludes all cognitive representation in favor of bodily task response model (Chemero, 2011; A. D. Wilson & Golonka, 2013).

Amid such theoretical cacophony, it is necessary for research dealing with human movement to define precisely which aspects of embodied cognition are relevant and of interest. For the purpose of the current thesis, therefore, *embodied cognition* is considered to be: *the assumption that bodily states and movements can both influence and directly convey information about feelings, thoughts, and dispositions.* The body is considered to be an important element of human psychological and social functioning, specifically in the context of music and dance, and that studying bodily movement can, therefore, be considered a valid and useful means of gaining understanding of human psychology.

Research in a variety of domains provides evidence for the influence of the body on cognition. An early example comes from Strack, Martin, and Stepper (1988), who manipulated participants' facial expressions by having them hold a pen in their mouths either lengthwise to, simulate smiling, or by the end, to simulate frowning. Participants who held the pen lengthwise to simulate smiling reported perceiving more humor in cartoons presented to them during the manipulation than those who simulated frowning, showing that facial expression associated with positive- or negative-affect are not only responses to affect but play a role in creating it. Dijkstra, Kaschak, and Zwaan (2007) asked participants to recall autobiographical memories while sitting in congruent postures (e.g., reclined in a chair while recalling a dentist visit) or incongruent postures and found that better recall was associated with congruent postures, suggesting these primed the memory. Our bodies may also influence our self-perceptions; Schubert and Koole (2009) showed increases in males' self-reported assertiveness and social esteem, while Nair, Sagar, Sollers, Consedine, and Broadbent (2014) showed that slumped postures were associated with lower self-esteem and higher stress responses.

The influence of the body on cognition even extends to processes over which we have no conscious control; Gray et al. (2012) showed that manipulation of participants' cardiac cycles influenced both self-reported intensity of emotion and activity in the frontal cortex measured using fMRI. Research analyzing human gait has found that depression (Michalak et al., 2009), emotion (Roether, Omlor, Christensen, & Giese, 2009) and personality traits and aggressiveness (Satchell et al., 2017) are manifested in this basic movement. Knowledge about how personality is embodied has influenced the development of computational virtual agents as well as robotics aimed at human interaction (Neff, Wang, Abbott, & Walker, 2010). Our bodies also affect our understanding of other humans; Chartrand and Bargh (1999) showed evidence for a human tendency to subconsciously mimic those with whom they are socially engaged, and furthermore that such mimicry was associated with increased positive perceptions of social interactions. Neal and Chartrand (2011) showed decreased ability to recognize emotion in others' faces in participants who had undergone procedures that minimize facial movement. Even our verbal communication is difficult to disentangle from bodily processes; Goldin-Meadow, Ferris, and Palenik (1998) showed both that blind participants spontaneously gestured while speaking and that seeing participants gestured while speaking to blind participants, suggesting that gesture is an intrinsic part of spoken language.

This brief overview shows that embodied processes are involved in a wide range of human functions. The next section explores the relationship between embodied cognition and musical functioning.

2.4 Embodied music cognition

It is fairly self-evident that the body plays an important role in human experience and understanding of music. Moving in response to heard music, typically in an organized and synchronous way, is so common and natural a behavior that it can actually be difficult *not* to do (Lesaffre et al., 2008; Repp, 2005; Repp & Su, 2013). Although it is less obvious in the current age of easy access to recorded music, for most of human history hearing music required it to be made live, which requires movement. Drawing a bow across a string; hitting a drum; even vibrating the vocal chords; not to mention the expressive gestures that typically accompany such sound-producing actions—all manifest the fundamental inseparability of movement and music (Davidson, 2001; Eerola, Jakubowski, Moran, Keller, & Clayton, 2018; Thompson & Luck, 2012).

There is indeed evidence that a close relationship between sound and movement exists in the brain. For example, that when trained pianists listen to piano music, fMRI studies have shown activation in areas of their cortexes associated not only with auditory processing but also with motor control (Bangert et al., 2006). To show this phenomenon is not limited to experts, Lahav, Saltzman, and Schlaug, (2007) taught non-musicians to play a short melody on the piano and found that participants' pre-motor areas were activated when listening to the melody while lying still, but significantly less so when hearing a different melody. Such findings support broader theories that the brain responds to perceived actions of others by simulating the action internally through activation of motor networks (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). In this vein, Godøy (2003) suggests that music is a "fundamentally cross-modal phenomenon" (p. 317), and that sound can be decomposed into the action or 'excitation' that creates it (e.g., hitting a piano key or drawing a bow across a string) and the resulting auditory resonance. From this separation, we are able to build internal images of sound-producing movements, which can be understood as simulations of the sounds we are hearing. This close link between movement, imagery, and sound is illustrated by the emerging possibility of using the visually recorded motion of musical instruments to recreate sound (Godøy & Song, 2016). Research has suggested that there are many levels to the relationship between music performance and bodily movement; Davidson, for example, has shown that gestures in music performance can convey expressive intention separately from the sound of a performance (Davidson, 1993, 2001). Thompson and Luck (2012) showed that when pianists were asked to perform with more expression, they used more movement in their playing, and listeners judged that performances with more movement were more expressive regardless of sound.

In Leman's (2008) proposed a theory of embodied music cognition, music is conceived of as 'moving sonic forms' with which listeners engage through corporeal articulations; that is, mentally simulated as well as actual bodily movements. Leman characterizes such corporeal articulations as direct involvement with music, in contrast to indirect involvement via linguistic or symbolic descriptors of music. In support of this view, Godøy, Song, Nymoen, Haugen, and Jensenius (2016) provide a comprehensive review of literature relating to similarity between movement and musical sounds in a variety of domains, including the use of sound-tracing paradigms, in which participants are asked to 'trace' heard sounds as drawings or as movements, which has shown notable similarity between different listeners' embodiment of similar sounds. The authors also discuss remarkable similarities between multiple musical performances of expert players and show a relationship between the movements of a samba dancer at the accompanying foot-taps of a drummer using motion capture.

From the paradigm of embodied cognition, we can view dance as not merely a response to heard music but as an integral part of the way we process and understand music on conscious and unconscious levels. This idea has been supported by research showing relationships between dance movements and timbral and rhythmic features of music; for example, greater pulse clarity relates to increased overall body movement, while the head and upper body relate to flux within various spectral bands of sound (Burger et al., 2013). There is also evidence that hierarchical aspects of rhythm tend to be embodied through distinguishable movement patterns, with lateral way of the body associated with rhythm at the four-beat level (typically one full cycle of a metric pattern) while the upper body is more typically used to entrain with a rhythm at the tactus (single beat) level (Toiviainen et al., 2010).

Further experimental evidence suggests that our bodily movements can even affect how music is perceived. Phillips-Silver and Trainor (2005) exposed infants to metrically ambiguous rhythmic stimuli while they were bounced to embody either a two- or three-beat meter and found that infants later showed preference for the meter to which they were bounced. These authors repeated the study with adults and found similar results, furthermore showing, through tests involving blindfolded movement and unmoving observation of others, that the results depended on bodily sensation rather than visual information (Phillips-Silver & Trainor, 2007). From this, we can speculate that the embodiment of rhythm shown by Toiviainen et al., (2010) may not only be a response to a heard hierarchical pattern but directly involved in parsing it. Maes and Leman (2013) showed that children's perception of emotion in ambiguous heard music was influenced by whether they had been taught dance movements to that music that embodied positive or negative emotion. This finding aligns with other work showing that participants who had been induced into positive or negative mood states displayed different movement patterns (Dyck, Maes, Hargreaves, Lesaffre, & Leman, 2013) and that observers are able to recognize emotion from point-light displays of dance movement (Camurri, Lagerlöf, & Volpe, 2003).

The framework of embodied cognition is particularly useful when considering the influence of individual differences on dance movements, as it is natural to assume that unique individuals will respond physically to music in unique ways. This idea harkens back to Christensen et al.'s (2017) supposition that dance, particularly spontaneously improvised dance, is useful in mate selection because it reflects psychological or dispositional qualities of the dancer, as well as the suggestion that dance functions for self-intimation. Research has shown that individual differences can influence multiple aspects of dance movements (Burger, 2013; Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010). The he following chapter introduces and discusses individual differences as described by personality and dispositional empathy before exploring their relationships with music, dance, and embodied cognition.

3 INDIVIDUAL DIFFERENCES

3.1 Personality

3.1.1 Definition and background

The term *Personality* originates from the Latin *personalis,* meaning "of a person." Influential British psychologist and early personality theorist Raymond Cattell (1905-1998) defined personality in terms of consistency in a person's behaviors (Cloninger, 2009), while a more nuanced approach considers personality in terms of consistency of behavior across similar situations (Wagerman & Funder, 2009). In the Oxford English Dictionary, it is defined as "The combination of characteristics or qualities that form an individual's distinctive character" ('Personality,' n.d.) and, importantly, is categorized as a mass noun; that is, a person's behavior manifests multiple predicting factors. Although the characterization of personality as a set of facets or traits has a long history, an important early example in the development of modern psychology is provided by Carl Jung (1875-1961), who posited the existence of eight different psychological types and popularized the terms *extraversion* and *introversion*. Early attempts to systematize the nomenclature of personality began in the early twentieth century with the work of German psychologist Ludwig Klages (1872-1956), who suggested that examination of language could lead to insights about different personality types, and Swiss psychologist Franziska Baumgarten (1883-1970), whose study of applied psychology lead her to believe that multiple traits and qualities should be examined rather than a single intellectual or personality factor (Digman, 1990; Goldstein, 2018). The first factor-based system was developed in the 1940s by Cattell, consisting of sixteen bipolar scales; over the next decades, multiple researchers independently found evidence that five factors were necessary and sufficient to describe human personality traits. Over time these have become standardized and are commonly referred to as the Big Five (Digman, 1990). The Big Five consists of the five following dimensions:

Extraversion

Historically conceptualized as 'social adaptability' or 'power,' extraversion describes a drive towards social interaction, the tendency to be talkative, assertive, to experience positive affect and to engage in sensation seeking (Ashton, Lee, & Paunonen, 2002; Digman, 1990; J. A. Gray, 1970). Eysenck (1967) theorized that differences in physiological arousal and inhibition underpin difference between extraverted and introverted individuals, and research has indeed shown that extraverted participants have smaller peaks in brain activity in response to stimuli than introverts (Stelmack, Achorn, & Michaud, 1977). Research has also shown that extraversion is related to faster stimulus habituation and slower preparation of movement in response to stimuli (Blumenthal, 2001; Stahl & Rammsayer, 2004), and may be related to goal orientation (Ashton et al., 2002).

Neuroticism

As the only dimension of the Big Five that is habitually referred to by its As the only dimension of the Big Five that is habitually referred to by its negative pole, Neuroticism is conceptualized in some studies as 'Emotional Stability,' switching the polarity of the scale. Neuroticism is characterized by the tendency to be anxious, easily upset, emotional and insecure (Goldberg, 1990), and is associated with increases in negative affect (Costa & McCrae, 1980). Meta-analysis has shown that high levels of neuroticism to be broadly associated with vulnerability to a variety of psychiatric disorders, including depression, anxiety, and personality disorders (Kotov, Gamez, Schmidt, & Watson, 2010; Schirmbeck et al., 2015; Schroeder, Wormworth, & Livesley, 1992).

Openness

Also called 'Openness to Experience,' this trait is associated with intelligence, curiosity, and enjoyment of arts and culture, and a tendency towards abstract thought (Goldberg, 1990; John & Srivastava, 1999). Openness predicts political and social liberalism (McCrae, 2009) and modestly predicts achievement in task performance (Barrick & Mount, 1991), adaptability to changing task requirements (LePine, Colquitt, & Erez, 2000), and is associated with creativity and divergent thinking (McCrae, 1987).

Conscientiousness

Variously labeled 'will to achieve,' 'prudence,' and 'self-control,' the dimension commonly referred to now as Conscientiousness is associated more than any other dimension with task performance in a variety of domains (Erez & Judge, 2001; Roberts, Chernyshenko, Stark, & Goldberg, 2005; Witt, Burke, Barrick, & Mount, 2002). Conscientiousness is positively correlated with emotion regulation abilities in high school students and related to academic success (Ivcevic & Brackett, 2014), and it has been argued that self-regulation in childhood is an essential component of the development of adult conscientiousness (Eisenberg, Duckworth, Spinrad, & Valiente, 2012).

Agreeableness

In a meta-analysis of studies regarding the language used to describe personality, Digman and Takemoto-Chogk (1981) labeled this factor 'friendly compliance vs. hostile non-compliance.' Agreeableness is defined by a tendency to conform and comply, and to be tactful, kind and warm. It is related to pro-social behavior and overall advantages in social functioning (Graziano & Eisenberg, 1997; Graziano & Tobin, 2002), and has been associated with better peer relationships in adolescence (Jensen-Campbell et al., 2002).

3.1.2 Personality, music and movement

Studies have explored relationships between Big Five traits and how people engage with music in a variety of domains, perhaps none more than musical preference. Cattell himself suggested that music preferences might serve as a Rorschach test that could provide information about participants subconscious emotional tendencies (Cattell & Anderson, 1953), followed eventually by several studies attempting to link Big Five traits to music preference (Dollinger, 1993; Rawlings & Ciancarelli, 1997). A seminal study by Rentfrow and Gosling (2003) employed a factor-based model for measuring music preference, wherein genre preferences were found to fit into four higher order factors: Reflective and Complex (including Classical, Jazz, Blues and Folk), Intense and Rebellious (including Alternative, Rock and Heavy Metal), Upbeat and Conventional (including Country, Pop Religious and Soundtracks) and Energetic and Rhythmic (including Rap/Hip-Hop, Soul/Funk, Electronica/Dance) (see Rentfrow and Gosling, Figure 6, p. 1245). The authors found that Openness was positively correlated with liking for Reflective and Complex music and Intense and Rebellious music, that Extraversion, Agreeableness, and Conscientiousness correlated positively (while Neuroticism correlated negatively) with liking for Upbeat and Conventional music, that Neuroticism correlated negatively with liking for Reflective and Complex music, and that Extraversion correlated positively with liking for Energetic and Rhythmic music.

Research following this has found similar small to moderate relationships between Big Five traits and various measures of musical preference, to varying degrees of consistency. For example, the relationship between Openness and liking for genres such as Classical and Jazz has been supported by multiple studies (R. A. Brown, 2012; Delsing et al., 2008; George, Stickle, Rachid, & Wopnford, 2007; Zweigenhaft, 2008), while Zweigenhaft (2008) found that Extraversion related to liking for Upbeat and Conventional genres as well as Energetic and Rhythmic genres, but failed to find a relationship between liking for Intense and Rebellious music and Openness. Regardless of the support of research findings or lack thereof, there is evidence that it is commonly assumed that judgments can be made about other individuals based on their musical preferences (Boer et al., 2011; Rentfrow & Gosling, 2007), and music preference is a common topic used by participants when getting acquainted (Rentfrow & Gosling, 2006).

Other research has focused on musical behaviors rather than preferences. Openness has been shown to predict the duration of musical training in children and adults beyond socioeconomic factors (Corrigall, Schellenberg, & Misura, 2013), as well as a tendency to listen to music for cognitive engagement, such as analysis of musical structures or performance quality. The same study showed a relationship between Neuroticism and a tendency to listen to music for emotion regulation (Chamorro-Premuzic & Furnham, 2007). Openness has additionally been linked to a tendency to experience chills from listening to music (McCrae, 2007).

There is also evidence from various studies that personality is manifested in physical movement. Both biomechanical analysis of and perceptual judgements based on gait are able to provide somewhat accurate prediction of a walker's personality traits (Satchell et al., 2017; Thoresen, Vuong, & Atkinson, 2012), while non-verbal cues are used in the judgment of traits including extraversion and conscientiousness in job interviews (DeGroot & Gooty, 2009). The importance of individual movement quality is also highlighted by the finding that, presented with point-light animations of figures performing various movements, participants could accurately identify themselves and somewhat accurately identify their friends, suggesting there is something particularly personal about the way we move (Little & Boyd, 1998; Loula, Prasad, Harber, & Shiffrar, 2005). In social interaction, visual attention to a partner and open postures have been positively related to agreeableness and openness, suggesting personality plays a role in how we physically respond to others (Berry & Hansen, 2000).

Given the hypothesized origin of dance as a means of social signaling (Christensen et al., 2017; Laland et al., 2016), it is reasonable to except that individual trait qualities can be signaled through dance. Using a sample of participants who scored particularly high or low in Big Five traits, Luck, Saarikallio, Burger, Thompson, and Toiviainen (2010) showed that various components of dance movements such as amounts of local and global movement, hand movement and head movement were significantly affected by whether dancers scored high or low in particular traits. Extraversion, for example, was related to greater levels of local and global movement, hand and head speed, while Agreeableness related only to global movement and head speed. This study furthermore showed differences in participants' use of movement components varied dependent on particular genres, suggesting that both personality and musical genre affect dance movements interactively. In addition to personality, preference for musical excerpts has also been related to movement features, with more movement associated with particular liking or particular disliking for various stimuli (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2014). These studies suggest that dance may be a broad signaler of individual differences. Indeed, observers seem able to judge affect and sensation-seeking propensity from dance movements, providing some support for the idea that dance may be implicated in sexual selection (Dittrich, Troscianko, Lea, & Morgan, 1996; Hugill, Fink, Neave, Besson, & Bunse, 2011).

Dance typically occurs in more complex social settings than that of an individual dancing alone, or of one individual passively observing another.

Although some research suggests that personality traits influence the quality of verbal, social interactions (Berry & Hansen, 2000; Cuperman & Ickes, 2009), whether or how interaction with another individual affects dance movement remains largely unexplored. Before questioning how two persons with different traits might relate to each other in dance, however, it is important to consider the fundamental ability of one person to understand something about the mind of the other—that is, to empathize with them. This ability is explored in the following section.

3.2 Empathy

3.2.1 Definition and background

As its precise definition, structure, and underlying mechanisms are still the subject of some debate (e.g., Baron-Cohen, 2009; Davis, 1983; Gerdes, 2011; Goldman & de Vignemont, 2009; Jahoda, 2005; Leslie, Johnson-Frey, & Grafton, 2004; Smith, 2006; Zahavi, 2001), it is first necessary to come to a working definition of empathy for the purpose of the current thesis. The term *empathy* has a considerably shorter etymological history than *personality,* emerging as a translation of the German *Einfühlung* (literally "feeling oneself into). Aesthetic philosopher Robert Vischer (1807-1887) was among the first to use the term to apply the term, employing it along with *Mitfühlung* ("feeling with," usually translated as "sympathy") and various other *-fühlungs* to describe psychological responses to art. The concept of *Einfühlung* was taken up by Theodor Lipps (1851-1914), who described aesthetic imitation as the projection of one's sense of self into an object as a mechanism for appreciating and understanding art (Jahoda, 2005). Lipps expanded this idea to the understanding of other living creatures, arguing that we can understand another's emotions through their gestures and facial expressions not because these are definitively associated with that emotion, but because we instinctively tend to reproduce the gesture or expression and identify the feelings associated with it in our own behavior. This feeling is then projected into the actions of the other (Zahavi, 2010). The Oxford English Dictionary now defines empathy as "the ability to understand and share the feelings of another," and adds a usage note that it should not be confused with *sympathy*, which is considered a feeling of pity because of another's suffering ('Empathy,' n.d.).

Even without the ambiguities and overlap in the historical uses of these terms (Gerdes, 2011), the concept of being able to understand and even share the feelings of another is more problematic than it may seem at first blush. The mind and mental experiences of another are, after all, literally unseeable and arguably unknowable; we can see someone smiling but we cannot see happiness, nor can we directly measure another's mental state as we can measure heart-rate or temperature or even brain activity. Still, the absence of the ability to infer such information with some degree of accuracy is an unappealing prospect. How, without being able to infer his mental state, could I feel relatively certain that my nearby co-worker is not about to angrily throw me and my laptop out the window at any moment? Although it seems obvious that we are, in fact, able to infer at least some information about each other's unseeable inner states of being, the problem of exactly how we do this has not yet been definitively solved, scientifically or philosophically.

The ability to understand others is often referred to as having a 'Theory of Mind' (ToM) for which there is usually listed two major possible explanations. The first, sometimes called 'Theory-Theory' is that, based on memory and experience, we build an internal statistical model of what others' behaviors mean about their mental states. That is, if my co-worker is quietly staring intermittently at his laptop and out the window with a furrowed brow, a wealth of previous experience of peoples' furrowed brows tells me that he is probably thinking hard about something. The second explanation, called 'Stimulation-Theory,' argues that ToM arises from internally mimicking another's actions and discovering what we ourselves would feel when doing those actions. That is, if I am able to imagine the actions of staring out the window and furrowing the brow as my own, I feel as I do when I'm mentally trying to solve some problem, so I can presume that my co-worker is also trying to mentally solve some problem rather than being on the cusp of causing my doom (Gallese & Goldman, 1998; Zahavi, 2008, 2010).

Lipps' original idea of mimicry and projection of the self into the object arguably bears more resemblance to Simulation-Theory, but more impressively it aligns exceptionally well with a much-talked-about neuroscientific discovery that came nearly a century after him; in 1996, Rizzolatti, Fadiga, Gallese, and Fogassi showed the existence of neurons in macaque monkeys' premotor cortexes that activate identically whether observing or completing an action. These 'mirror neurons' quickly came to play a major role in theories of social cognition. Gallese and Goldman (1998) argued that mirror neurons lend credence to Simulation-Theory over Theory-Theory, additionally citing clinical evidence that patients with pre-frontal lesions seem unable to stop themselves from imitating gestures and actions of others, suggesting that, in typically functioning humans, observed actions are mentally imitated but motoric output is suppressed; this sometimes called internal mimicry (e.g., Leman, 2008). Iacoboni (2009) further argues for the evolutionary selection of mirror neurons for empathic understanding, while others have developed theories of dysfunctional mirror neuron systems to explain autism, a disorder characterized by impairments in social functioning (Oberman et al., 2005; Rizzolatti & Fabbri-Destro, 2010; Williams, Whiten, Suddendorf, & Perrett, 2001).

There is ample behavioral evidence that mimicry plays a role in social functioning. Chartrand and Bargh (1999) had participants interact with a confederate who either rubbed his face or shook his leg during interactions and found that participants were more likely to unconsciously engage in face-rubbing or leg shaking when the confederate engaged in these mannerisms, a phenomenon they call the chameleon effect. They also found that participants reported higher levels of liking for confederates who mimicked their own behaviors, and furthermore that those who reported higher levels of empathy were more likely to mimic others during interactions. The association between mimicry and interpersonal bonding has also been shown by Stel and Vonk (2010), focusing specifically on the imitation of facial expressions. Van Baaren, Holland, Kawakami, and Knippenberg (2004) showed that participants who had been mimicked were more likely to engage in helping, pro-social behaviors, while Cummins, Piek, and Dyck (2005) show a relationship between children's motor coordination and their ability to read facial expressions. Iacoboni (2009) reviewed and discussed literature regarding humans' social imitation and distinguished between 'low' and 'high' mimicry, the former being exact motor imitation of an observed movement, and the latter being more general responses to social priming, as demonstrated memorably by an experiment in which participants read words associated with old age (e.g., "Bingo" or "Florida") and subsequently walked more slowly from the examining room than participants who read neutral words. Lakin, Jefferis, Cheng, and Chartrand (2003) argue that mimicry was initially favored by natural selection by allowing for human communication and imitative learning but has developed to serve the function of increasing group affiliation and supporting social bonds.

Taking all of this into account, for the purpose of the current thesis *empathy* is defined as: *a complex psychological process that allows the inference of others' emotions and perceptions, for which bodily mimicry is an important mechanism*.

A few points should still be made about this definition. First, it is acknowledged that other psychological and physiological mechanisms may also be involved in empathic understanding, although they are not the principal focus of this thesis. As Zahavi (2010) points out, it is possible to understand that a dog is wagging its tail because it is happy, even without having a tail of one's own to wag. It should also be noted that empathy is not identical to its close cousin, emotional contagion. Preston and de Waal, (2002) suggest that, by comparison to emotional contagion, empathy involves a distinction between self and other and state matching at a uniquely representational level such that the other's emotion is recognized but not fully induced and may result in helping behaviors depending on contextual factors like familiarity (Preston & de Waal, 2002, p.4). Others suggest that there is room to separate cognitive empathy and emotional empathy as separate processes (Davis 1983; Smith, 2006), and there is indeed some evidence of this from neuroimaging studies (Nummenmaa, Hirvonen, Parkkola, & Hietanen, 2008; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009), although it is also then somewhat difficult to draw a line between emotional contagion and emotional empathy. However, this thesis is focused on bodily responses in naturalistic social contexts, where we assume that both cognitive and emotional aspects of empathy may play a role in guiding behavior, and therefore it is considered sufficient to include both aspects under a single definition.

There is evidence that, like personality, the tendency or even ability to use empathy varies between individuals (Banissy, Kanai, Walsh, & Rees, 2012; Baron-Cohen, 2009). Differences in dispositional empathy have been related to differences in neural structures (Banissy, Kanai, Walsh, & Rees, 2012), to decreased likelihood of engaging in aggressive or criminal behaviors (Jolliffe & Farrington, 2004; D. R. Richardson, Hammock, Smith, Gardner, & Signo, 1994), advantages in maintaining friendships (De Wied, Branje, & Meeus, 2007) and more secure attachment styles (Joireman, Needham, & Cummings, 2001). Deficits in dispositional empathy are widely related to psychological disorders (Benedetti et al., 2009; Dziobek et al., 2011; Hermans, Putman, & van Honk, 2006; Ritter et al., 2011) and particularly to Autism Spectrum Disorders (ASD) (Baron-Cohen, 2009; Minio-Paluello, Baron-Cohen, Avenanti, Walsh, & Aglioti, 2009; Schulte-Rüther et al., 2011). Dispositional empathy has also been studied in relation to various types of musical engagement; this literature is discussed in the following section.

3.2.2 Empathy and music

Many inquiries regarding music and empathy have dealt with music's capacity to induce emotional responses in listeners. As early as 1985, Funahashi and Carterette used a plethysmograph (an instrument for measuring changes in blood pressure and flow) in conjunction with self-reported feelings of empathy in response to music to create a model of physiological and sensory feedback circuits to explain how heard music could elicit emotion and empathy. Juslin and Västfjäll's (2008) model of mechanisms by which music could elicit emotions in listeners included the suggestion that empathic processes may underlie some emotional responses to music, specifically suggesting that listeners may internally mimic and thus acquire the affective state expressed by heard music almost as though music itself were a person with whom we could empathize. In line with this, Livingstone and Thompson, (2009) suggested that music may even have developed in conjunction with the development of Theory of Mind, while Trost and Vuilleumier (2013) suggest internal rhythmic entrainment as a mechanism of musical emotion induction. Egermann and McAdams (2013) showed an empirical link between dispositional empathy and participants' tendency to rate their own emotional responses to music as similar to the emotion they thought was conveyed by the music. Miu and Balteş (2012) also showed that when participants were instructed to try to feel the emotions expressed by heard music and to imagine the feelings of the performer, they reported greater feelings of induced sadness, nostalgia and power compared to those who were not explicitly instructed to engage so empathically with the music. Greater dispositional empathy is associated with increased enjoyment of sad music (Vuoskoski & Thompson, 2012).

Leman (2008) describes a model of empathic involvement with music in terms of embodied cognition, defining empathy as "an imitation of the music's emotional intentionality" (p. 122). The model consists of three layers of engagement. First, 'observation of affect,' which is defined as the sensory perception of the sonic qualities of heard music, via a mechanism of internal imitation of the music's movements (Leman's ‘moving sonic forms'). The listener identifies the affective or emotional content of the music through this mental imitation through a process of matching the simulated motion to familiar, affect-associated movements; this is, in essence, an extension of Simulation Theory in that sound is mentally translated into the form of human motion. Leman's second level of involvement is ‘imitation of affect,' in which the listener mimics the music's motion corporeally as well as internally, leading to physical sensations that may, again, remind the listener of previous experiences of a given emotion. The final step in the model is that of ‘feeling of affect,' in which the listener's physical movements have an impact on her emotions. Leman further speculates that empathy for music is likely to be moderated by social context and to support positive social feelings such as connectedness and intimacy. The idea that corporeal mimicry is an essential part of music perception is supported by research showing that bodily movement can influence music perception of rhythmic and affective characteristics (Maes & Leman, 2013; Phillips-Silver & Trainor, 2007).

Recently, Clarke, DeNora, and Vuoskoski (2015) investigated the potential for music listening to support cross-cultural empathy and affiliation by having participants listen to either music that was Indian or West African in origin followed by an Implicit Association Test which measured unconscious associations between the categories ‘Indian’ and ‘West Africa’ and ‘good’ or ‘bad.’ Participants showed stronger positive associations with pictures related to whichever type of music they heard, an effect which was strengthened by dispositional empathy; this result recalls suggestions that music and dance may ease social functioning between as well as within groups (Clayton, 2012; Hagen & Bryant, 2003). Indeed, Clarke et al., (2015) suggest that empathy may have supported affiliation through internal entrainment with the heard music, in line with Trost and Vuilleumier, (2013)’s proposals. On a dyadic level, this recalls a quite different study conducted by Rabinowitch et al., (2015), who showed that children who tapped their fingers in synchrony reported higher levels of perceived similarity and closeness than children who tapped together asynchronously.

Returning to the relationship between empathy and particular styles of music, there is some evidence linking empathy with increased liking for music that can be described as reflective, complex or mellow such as soft rock or R&B (Clark & Giacomantonio, 2013; Greenberg, Baron-Cohen, et al., 2015), leading Greenberg, Rentfrow, and Baron-Cohen (2015) to suggest that such music may be specifically used to increase empathic functioning, particularly in those suffering from a deficit of dispositional empathy, such as persons with Autism Spectrum Disorders (ASD). Other, while agreeing that engagement with music may indeed increase empathy, have suggested that the specific type of music may matter less than active engagement with music and mechanisms involving entrainment (Rabinowitch, 2015; Vuoskoski, 2015). Active engagement with music, and particularly social engagement, has been shown to increase instances of pro-social behavior in children after a single musical interaction (Kirschner & Tomasello, 2010), as well as to increase empathy in children after longer-term participation in a music-making group (Rabinowitch, Cross, & Burnard, 2013). Kirschner and Tomasello (2009) have additionally shown that young children are better able to synchronize while playing a drum along with an adult—that is, in a social context—compared to playing with a drumming robot. These results highlight the close relationship between social engagement, entrainment, empathy and physical engagement with rhythmic aspects of music, and further recall relationships between empathy and motoric imitation. Rabinowitch (2015) describes human interaction in musical contexts as requiring a hierarchy of proficiencies, such as motor control, imitation, and synchronization, and hypothesizes that "through transfer of learning, what is learned through music participation may be translated into an increased capacity for empathy" (p. 97). The particular importance of entrainment to social interaction is highlighted by the finding that swinging young children in synchrony with each other increased pro-social behavior (Rabinowitch & Meltzoff, 2017).

The above literature shows that the relationship between music and empathy has been examined from several notably different angles. On the one hand, music is considered primarily in terms of its emotional content, conceived of as itself an entity with one can empathize, or an expression of the performer’s emotions with which one can empathize (Juslin & Västfjäll, 2008; Leman, 2008; Miu & Balteş, 2012). Dispositional empathy is shown to be a moderator of the degree to which music increases positive feelings towards others (Clarke et al., 2015), but it is also suggested that listening to or engaging with music can itself increase empathy (Greenberg, Rentfrow, et al., 2015; Rabinowitch, 2015). Thus, empathy has been conceived of as an integral mechanism in engagement with music, an additional causal element contributing to the effects of musical engagement, and itself an effect of musical engagement.

In the dance-movement context of the current thesis, Leman’s (2008) model of empathic engagement with music through corporeal articulation is particularly relevant, as is the suggestion that dispositional empathy may affect music-induced behavior. Given the evidence for differences between individuals in levels of dispositional empathy (e.g., Baron-Cohen & Wheelwright, 2004), Leman’s model can lead to several interesting questions regarding the influence of such empathy on music-induced movement. For example, we might expect a person with higher dispositional empathy to move more in response to music than a less empathic person. As there is a theoretical link between empathy and mimicry, we might also expect that a person with higher empathy to have advantages in the process of imitating music. Bamford and Davidson (2017) explored this possibility in a free, spontaneous dance setting by using a stimulus that included several rapid changes between tracks with differing tempos, thus necessitating participants to adjust their movements to regain entrainment with the music. Participants who reported higher levels of empathy and agreeableness were found to adjust more quickly to new tempos, suggesting that empathy provides an advantage in entrainment to an auditory stimulus. In addition to individual contexts, the current thesis explores whether this advantage can be detected in other contexts and whether it might further relate to advantages in motoric entrainment to a dance partner. Therefore, the relationship between personality, empathy and social functioning are described in the following section.

3.3 Individual differences and social functioning

As emphasized by Leman (2008), social context may play an important role in determining our ultimate responses, including our physical responses, to music. Although individual traits like personality and empathy tell us about consistency of behavior across similar situations, our sense of our own and other's temperamental consistency may be inflated. Someone who shows a tendency towards aggression in various group social situations may behave quite differently in professional or intimate settings, or a child may be anxious and withdrawn at school but not at home (Wagerman & Funder, 2009). Similarly, a person who does not usually enjoy dancing may engage in dancing with close friends or in the presence of particularly preferred musical stimuli.

Asendorpf (2009) describes the relative contributions of temperament and situation to determining a person's behavior as reflecting research focus of the fields of personality and social psychology respectively. Although these influences have been treated as competing explanations, Asendorpf argues that there is no dichotomy between the two; that is, the evidence does not suggest that as the influence of a situation on behavior increases, the influence of disposition proportionally decreases and vice versa. In 1936, Lewin expressed the relationship of person and situation to determining behavior as a formula: $B = f(P,S)$, or, behavior is a function of the interaction of person and situation (Burnes & Cooke, 2013). Later writers have suggested that this relationship can be extended into two other formulas comprising a 'personality triad': $S = f(P,B)$ and $P = f(S,B)$; that is, if any two elements among person, behavior, and situation are adequately understood, the third element can be accurately predicted (Wagerman & Funder, 2009). Taking both person and situation into account in measuring behavior is considered an interactional approach to personality theory (Malloy & Kenny, 1986).

While a situation can be defined on many scales ("living in Finland" compared to "eating a chocolate") and may have conceptually and temporally unclear boundaries, a rich and defined source of variation for the study of cross-situational consistency lies in variation of dyadic social interactions dependent upon who the social interaction partner is (Asendorpf, 2009; Malloy & Kenny, 1986; Wagerman & Funder, 2009). Asendorpf writes "This question […] is obviously of great importance for personality psychology because many of our daily situations are dyadic interactions" (Asendorpf, 2009, p. 49). It is easy to imagine how this might apply in the context of dance; for example, an introvert who is generally shy on the dance floor may be brought out of his shell by the presence of an extraverted friend and begin to move more like an extravert.

When considering what happens when two individuals interact, a first thought may be that those who share similar traits are more likely to get along well. This is in line with common aphorisms such as, "birds of a feather flock together," but one does not have to think too far to remember another common aphorism: "opposites attract" (Ickes, 2009). Research about this has shown some conflicting results; Cuperman and Ickes (2009) found that interactions were rated by participants and perceived by observers as more positive when the dyad members shared similar traits among the Big Five, except, not surprisingly, in the case that both partners were low in Agreeability. Isbister and Nass (2000), however, found that participants reported preference for interacting with a personality type opposite to their own in the domain of Extraversion; that is, introverts preferred extraverts and vice versa. When participants were asked to evaluate dyadic interactions based solely on non-verbal behavior, more favorable ratings were garnered by dyads who were high in Agreeableness and Extraversion. These two traits have been previously labeled as interpersonal, compared to the other three Big Five traits which are considered intrapsychic, so it is reasonable to guess that they are related to better social functioning overall (Ansell & Pincus, 2004).

The ability to understand and share in another's feelings and thoughts would seem, by definition, support positive outcomes of social functioning. It may be a bit surprising, therefore, that the relationship between empathy and prosocial behaviors is arguably less straightforward than that of personality. Underwood and Moore (1982) reviewed the literature and found no relationship between empathy and altruism. Eisenberg and Miller (1987) re-analyzed this literature and found small relationships between empathy and prosocial behavior, depending on the method for measuring empathy; the strongest relationships were found when empathy was measured by self-report. Winczewski, Bowen, and Collins (2016) found that the ability to empathically understand another's emotion did not predict interpersonal responsiveness unless paired with empathic concern. That these two aspects of empathy were dissociable serves as a reminder that correctly inferring another person's feelings does not necessarily imply a desire to help, although empathy may increase helping behaviors in conjunction with context and familiarity (Preston & de Waal, 2002). These findings can be contrasted with, for example, the previously mentioned finding by Kirschner and Tomasello (2010) that children who engaged in a joint drumming situation showed greater prosocial behavior, with Tschacher, Rees, and Ramseyer (2014)'s finding that nonverbal synchrony in dyadic interactions predicted positive affect, and with Reddish et al. (2013)'s finding that cooperative behavior in adults was greatest when they were asked to actively work together in rhythmic synchrony. Indeed, it is arguable that the link between entrainment and synchrony and social functioning is noticeably stronger than links between empathy and social functioning (Hove & Risen, 2009; Miles, Nind, & Macrae, 2009; Rabinowitch et al., 2015; Rabinowitch & Meltzoff, 2017; von Zimmermann et al., 2018)

However, there is notable evidence for the importance of empathy in social functioning arising from studies showing its impairment or absence in pathological cases. One prominent theory of Autism Spectrum Disorder (ASD), a disorder defined in part by marked difficulty with or disinterest in social interaction, is that empathic functioning is impaired, possibly through impairment of the mirror neuron system (Baron-Cohen, 2009; Oberman et al., 2005; Williams et al., 2001). Impairments in empathic functioning have also been related to narcissistic (Ritter et al., 2011) and borderline personality disorders (Decety & Moriguchi, 2007; Dziobek et al., 2011), alexithymia (Grynberg, Luminet, Corneille, Grèzes, & Berthoz, 2010) and schizophrenia (Benedetti et al., 2009). People with ASD have been shown to have fewer automatic mimicry responses to social stimuli and to struggle to accurately identify the emotions of others compared to typical controls (Hamilton, 2013; Minio-Paluello et al., 2009). There is also evidence that imitation and entrainment behaviors are also impaired in the case of ASD (e.g., Amos, 2013; Minio-Paluello et al., 2009; Trevarthen & Daniel, 2005; Zachor, Ilanit, & Itzchak, 2010), pointing to the complexity of the relationships between empathy, social functioning, and physical entrainment with others. It is clear that these relationships require further research to disentangle. This thesis aims to address some of these relationships in the domain of music-induced movement. Therefore, the following section explores what is already known about movement and music in social contexts.

3.4 Social functioning, movement and music

The finely-tuned, intricate movements involved in a musical performance require that musicians be able to closely synchronize their movements to one another. Goebl and Palmer (2009) have shown that, as musicians' access to auditory feedback of their own dyadic performance was decreased, they engaged in more movements in an effort to remain synchronized. Exploring pianists' ability to distinguish between themselves and a co-performer, Novembre et al. (2012) had pianists perform familiar and unfamiliar duets wherein participants played a short right-hand melody and were told in some conditions that their partner would play the left hand, hidden behind a screen. Although the left-hand 'co-performer' was pre-recorded, when pianists believed they acted with another player, motor-evoked potentials were higher in their left hand than when they played alone; this effect was increased in participants with greater empathy. When Novembre, Ticini, Schütz-Bosbach, and Keller (2014) used double-pulse transcranial magnetic stimulation to inhibit pianists' motor simulations, pianists with greater empathy experienced more difficulty in adaptation and tempo matching with a recorded 'co-performer,' indicating that empathic participants relied more on internal motor simulations than others.

This relationship between dance and social functioning has also been explored by several recent studies that involve the direct recording of dance movements. Solberg and Jensenius (2017) used motion capture to track the head movements of a small group of dancers moving to Electronic Dance Music (EDM) using motion capture and found a relationship between participants' reported experiences of pleasure and the overall amount that the group moved as a whole. Van Dyck, Moelants, et al., (2013) found evidence for group synchrony in that there were greater correlations in dancers' activity levels within than between groups. Von Zimmermann et al. (2018) investigated synchrony and group affiliation by teaching a set of simple choreographed movements to groups and asking groups to perform them either together as a whole group or individually (that is, in the group but not necessarily in time with the group). They found, against their expectations, that the group synchrony condition did not predict greater group affiliation or the average amount that group members rated their liking of each other. Instead, they found evidence for what they called *distributed synchrony*, synchrony arising between pairs of participants within a group, was positively associated with group affiliation and liking for group members. This finding suggests that using a dyadic context to explore the influence of social factors in music-induced movement may be particularly useful.

Although, as previously discussed, dance and music may be part of the human experience because they support social functioning, many things remain unknown about how social factors affect dance movement. Research has not yet explored non-choreographed, full body movements when multiple dancers are moving at once. The influence of individual differences in personality and empathy on dance movement in social contexts has also not yet been explored.

3.5 Summary and conclusion of introduction

The findings discussed above have highlighted that there are relationships between entrainment, dispositional empathy, and social interaction, but also that these relationships still need to be disentangled and clarified. It has also been shown that individual differences of personality influence bodily movement, and may also affect the quality of social interaction, but this has not yet been explored in a dance movement setting. There is strong evidence that dance behavior is widespread and provides significant social and individual benefits, suggesting that dance is a valid context in which to study embodied individual and social processes. This is the basis for the current thesis, the specific aims of which are discussed in the following section.

4 AIMS AND OVERVIEW OF THE THESIS

The main aim of this thesis is to investigate how individual differences are embodied in free, spontaneous dance movement with a specific emphasis on empathy and social functioning. Four studies have been conducted employing a variety of methodologies to explore this question. Study I expands on previous findings regarding the manifestation of individual differences in dance movement by investigating differences in responsiveness to a slight manipulation of tempo between otherwise identical stimuli. In line with Leman's (2008) model of empathy in embodied music cognition, this study examines whether dispositional empathy would relate to increased responsiveness to music elements through the mechanism of empathic mimicry. Studies II, III, and IV involve three interconnected and overlapping data collections, driven in part by the results of Study I and with the additional aim of adding a social element to the investigation.

The first of these data collections was implemented using an online survey, wherein participants listened to and rated their liking for short musical excerpts from 12 genres in addition to filling out self-report measures of personality and dispositional empathy. In an initial round of collection, 210 participants completed the survey, whose data were analyzed and reported in Study II, which reports a novel method of stimuli selection and significant relationships between music preference and personality. Participants who completed the survey were given the opportunity to indicate their interest in completing a motion capture experiment, and those who indicated interest were contacted and recruited to participate in Study III. A motion capture experiment was designed in which a total of 73 participants attended a capture session in small groups and were recorded individually and in dyads dancing freely to a subset of the same stimuli used in Study II. Participants' preference ratings for these stimuli were analyzed prior to completion of the motion capture study, and participants were placed into balanced groups based on these ratings. Personality measures and dispositional empathy collected from the survey were also used in Study III. Motion capture data collected in Study III were used to create animated stimuli used in Study IV, which 33 participants viewed and rated. Relationships between these perceptual ratings, measures derived from movement data, and personality measures gathered from the survey were reported in Study IV.

The thesis employs a naturalistic data collection paradigm. Although it cannot be argued that it is typical, everyday behavior to come to a motion capture lab, put on a tight-fitting suit and be fitted with a set of reflective markers, the methodological aim of the current thesis is nevertheless to facilitate dance movement that is as naturalistic as possible. This aim is addressed by reducing experimental demand characteristics, providing real (that is, commercially available) music stimuli, and providing participants with a familiar context, such as dancing at a club or party, when giving instructions.

The following sections provides an overview of the methodologies used across studies: self-report tests used in Studies I, II, II and IV, the motion capture setups used in studies I and III, motion capture data processing used for Studies I, III and IV, and a description of the statistical methods used in Study III.

5 METHODOLOGIES

5.1 Self-report measures

5.1.1 Measures of The Big Five: TIPI and BFI

Over the last few decades, multiple instruments have been developed to measure Big Five traits of Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism, which range in size from as many as 240 items (Costa & McCrae, 1992) to as few as five (Gosling, Rentfrow, & Swann, 2003). Longer tests provide more detail, for example dividing each of the Big Five traits into six facets or sub-traits, but require as much as 45 minutes to complete, limiting their practicality for many research needs. The Big Five Inventory (BFI) (John & Srivastava, 1999) uses just 44 items, consisting of statements with which participants rate their agreement on a Likert scale of 1 to 5 regarding themselves. For example, an item measuring Extraversion is “I see myself as someone who is talkative,” while an item measuring Neuroticism is “I see myself as someone who gets nervous easily.” The Ten-Item Personality Inventory (TIPI) was developed and validated by Gosling, Rentfrow, and Swann (2003) from the BFI to meet the needs of researchers who may have particularly limited time to assess participants’ personality traits. The TIPI was further validated by Ehrhart et al., (2009), using latent factor analysis. Both studies found that the TIPI was adequately reliable and valid, although somewhat less so than longer measures.

Participants in Studies I, II and III completed the TIPI. Participants of Study III additionally completed the BFI during the motion capture data collection (their TIPI scores had already been collected through their participation in Study II).

5.1.2 Measures of dispositional empathy: IRI, EQ and SQ

Davis (1983) developed the Interpersonal Reactivity Index (IRI) with the intention of creating a measure that would assess cognitive and emotional aspects of empathy; that these are separate but related processes has been supported in subsequent literature (e.g., Shamay-Tsoory, Aharon-Peretz, & Perry, 2009; Smith, 2006). The IRI contains four different subscales: Perspective Taking, Fantasy, Empathic Concern and Personal Distress. Each of these scales includes seven 0 to 4 Likert scale items, such that scoring for each range from 0 to 28. The Perspective Taking subscale has specifically been related to cognitive empathy (Gerdes, 2011), and includes such items as "I try to look at everybody's side of a disagreement before I make a decision" and "When I'm upset at someone, I usually try to "put myself in his shoes" for a while." The Perspective Taking subscale, generally associated with cognitive empathy, was used in Study I.

The Empathy Quotient (EQ) was developed by Baron-Cohen and Wheelwright (2004). In contrast to the IRI, the EQ measures trait empathy as a whole, including both cognitive and affective aspects in a single trait. It was developed with the intent of measuring empathy alone, independently from other related social-emotional skills and traits such as sympathy and altruism. The short-form version of the EQ, developed and validated by Wakabayashi et al., (2006), is a 40-item instrument that includes items such as "I can easily tell if someone wants to enter a conversation," and "I am good at predicting what someone will feel," which participants rate their agreement with on a 4-point Likert scale. The authors of the EQ conceive of empathy mainly in terms of Theory of Mind (ToM) and intended the measure particularly to increase understanding of deficits of ToM in autism spectrum disorders (Baron-Cohen, 2009; Baron-Cohen & Wheelwright, 2004). With the aim of capturing a broad measure of empathy in a single descriptor, the EQ was used in Studies II, II and IV.

The Systemizing Quotient (SQ) was developed in close conjunction with the EQ, as the two tests together form the core of the empathizing-systemizing theory of autism, which posits that autism is characterized by particularly low empathy and particularly high systemizing compared to the general population (Baron-Cohen, 2009). Systemizing is defined as a drive or tendency to think analytically and in terms of systems; that is, in terms of predictable input, operation and output (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). Although trait systemizing and trait empathy vary independently of each other (rather than representing two opposite poles of a single trait), more than half of typical adults have been found to be stronger in one trait than the other (Lawson, Baron-Cohen, & Wheelwright, 2004).

For Study II, both empathy and systemizing were measured using short-form versions of the EQ and SQ, developed and validated by Wakabayashi et al. (2006). Participants' EQ scores were additionally used in Study III and Study IV.

5.2 Motion capture

5.2.1 History and theoretical overview

Motion capture is what it says on the tin: any method that is used to directly measure movement. This can take a variety of forms including video recording, the use of accelerometers and gyroscopes, magnetic detection systems, or, as in the current thesis, optical, infrared recording systems (for a review of the various types of systems, see Burger, 2013). It is, however, distinct from methods such as dance notation systems or the annotation of recorded movement in that motion capture measures movement directly.

How is it possible to measure movement directly? A brief detour into the thoughts of Greek philosopher Zeno (c. 490-430 BCE), who described a number of paradoxes related to the nature of space and time that resonates with current motion capture practices, provides some conceptual context. In what is known as the Dichotomy paradox, Zeno describes a situation wherein an actor wishes to walk to a target. However, before he reaches the target, he must reach the halfway point between his starting point and the target. Now, however, he must reach the halfway point between his current position and the target, and so on ad infinitum such that the target is never reached. Similarly, in the Arrow paradox, Zeno points out that motion of arrow is defined by its change in position over time as it flies towards a target. However, for any given instant of time, the arrow is not actually moving (as though we had taken a still picture of it), making motion essentially impossible.

Of course, one need minimal experience with human existence to realize that walking towards an object and the movement of an object through space are entirely possible, and these paradoxes have since been mathematically (if not philosophically) solved through the invention of calculus. Infinitely, increasingly smaller distances between mover and target are balanced by infinitely, increasingly smaller measures of time needed to halve them, making the zero-point possible on a practical level. However, even the most advanced motion capture systems bear some resemblance to Zeno's understanding of movement over time in that the collected data, whether in pixels or coordinates or acceleration magnitudes, are a temporally organized collection of points over time. Whether this “really” constitutes direct motion capture is perhaps best answered by an old joke: a line of boys stands opposite a line of girls at a school dance, and both groups of children are instructed to halve the distance between them on each step. When asked how long it will take them to reach one another, the mathematician argues they never will, the physicist that they will reach each other when time equals infinity, while the engineer points out that within one minute the children will be close enough to dance (P. Field & Weisstein, n.d.; Lynds, 2003). This researcher sides with the engineer.

In their review of the interest in and understanding of biological motion throughout Western history, Klette and Tee (2008) trace practical and aesthetic interests in human movement from the age of Aristotle to the present, noting da Vinci's careful observations of human actions and mathematical descriptions of human locomotion arising during the Enlightenment. However, what could arguably be called the first instance of direct motion capture came from French scientist Etienne-Jules Marey (1830-1904), who studied movement using specially-designed cameras to take multiple exposures over time within the same picture, a technique known as chronophotography that paved the way for cinematography. The capture and study of biological motion took another step forward with the work of Swedish psychophysicist Gunnar Johansson (1911-1998), who developed means of recording human movement as a series of light points by fitting lab assistants with small light bulbs or with reflective markers place on their joints. Very bright lights were then shone on the participants as they moved, providing a forerunner to modern optical, marker-based motion capture systems (Johansson, 1973). Noting that humans, in line with Gestalt principles, tend to perceive points that move together as being part of a single entity, Johansson chose the joints as the points on the human body which should be recorded to reflect motion because, "From a mechanical point of view, the joints of the human body are endpoints of bones with constant length and at the same time the points of connection between such motion units" (Johansson, 1973, p. 202).

In the electromagnetic spectrum, infrared light is that which has a longer wavelength and lower frequency than light that is visible to the human eye. Infrared cameras record light in this spectrum. By using markers that either emit or reflect infrared light, it is possible for an infrared camera to capture human motion in a manner less cumbersome than those derived by Johansson. Furthermore, when data are captured by several cameras at once, it is possible to reconstruct the three-dimensional location of a marker within a space, allowing for accurate measurement of the location of a point at a given frequency, over many points of time. This is the method of motion capture employed in the current thesis; the specifics of the system used are described in the following section.

5.2.2 Motion capture apparatus

For the current thesis, data were collected in the Music and Motion Lab that is housed by the Department of Music, Arts, and Culture at the University of Jyväskylä. The lab features a twelve-camera motion capture system (Qualysis Oqus 5+), with eight cameras mounted on the wall around the capture space at approximately 3m height, and four additional cameras that can be placed around the space on tripods. Cameras emit infrared light and record light that is bounced back to them from reflective markers at a rate of 120 frames per second (fps), recording time-series data. Data from the cameras are recorded into the accompanying software package, Qualysis Track Manager (QTM), where it is tracked over time and recorded in three dimensions (x, y, and z) within a Cartesian coordinate system. The coordinate system is determined at the start of each capture session by a process of calibration, wherein the system obtains the exact orientation and position of each camera in relation to still and moving rigid bodies.

Multiple cameras must be able to simultaneously record a marker in order for three-dimensional location to be assessed. Therefore, one vulnerability of systems such as this is in the possibility of marker occlusion: if part or all of the marker is hidden from cameras by an object such as a hand or fold of cloth, the marker cannot be recorded as long as it remains hidden, resulting in a gap in the recorded data. The risk of this can be minimized by strategic placement of markers on the body and careful demarcation of the floor area 'visible' to the most cameras. In addition, infrared light may be reflected by objects other than the intended markers, such as an earring or metal chair leg, resulting in the recording of false markers. As the capture system does not differentiate between individual markers, data are manually labeled post-capture, using models created in QTM. Depending on the number of gaps and false markers present in the recorded data and number of points to be labeled, this process can range from being relatively quick and automatic to notably time and labor intensive.

Upon arriving at the motion capture lab, participants are fitted with a motion capture suit consisting of close-fitting jacket, trousers, and hat, to which reflective markers can be easily affixed with Velcro. For a typical data collection, 28 markers are used in the following locations, which can be seen in Figure 1A and 1B: The location of the markers are as follows (L = left, R = right, F = front, B = back): 1: LF head; 2: RF head; 3: LB head; 4: RB head; 5: L shoulder; 6: R shoulder; 7: sternum; 8: spine (T5); 9: LF hip; 10: RF hip; 11: LB hip; 12: RB hip; 13: L elbow; 14: R elbow; 15: L wrist/radius; 16: L wrist/ulna; 17: R wrist/radius; 18: R wrist/ulna; 19: L middle finger; 20: R middle finger; 21: L knee; 22: R knee; 23: L ankle; 24: R ankle; 25: L heel; 26: R heel; 27: L big toe; 28: R big toe.

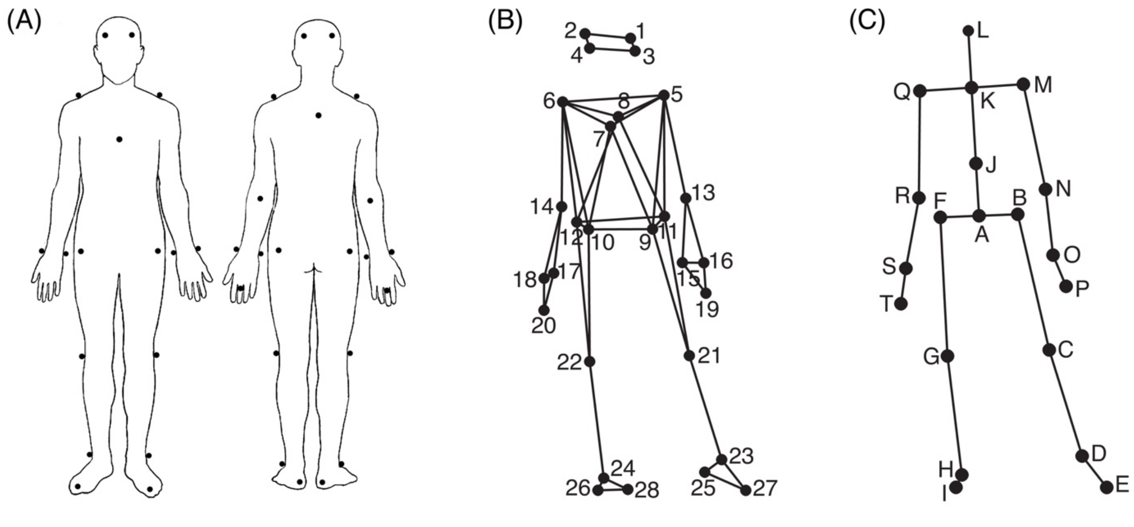

FIGURE 1 Location of markers and joints in typical motion capture data (Burger, 2013)

Participants are introduced to the motion capture space and given relevant instructions. Musical stimuli are played back via a pair of Genelec 8030A loudspeakers. A direct (line-in) audio signal of the playback and the synchronization pulse, transmitted by the Qualisys cameras when recording, are recorded using ProTools software in order to synchronize the motion capture data with the musical stimulus afterwards.

5.2.3 Adjustments to apparatus for dyadic capture

Some adjustments had to be made to the motion capture lab and data collection process during Study III compared to Study I to allow for the capture of multiple pairs of participants at once. The changes to the above typical lab structure were as follows:

- *Erection of a temporary wall to divide the capture space in half.* As a minimum of four participants per group was desired (see section 5.3 for an explanation), capturing each participant individually and in all dyads would require completing ten full conditions (four individuals, plus six dyads). Dividing the capture space in half with the wall allowed for two individuals or two dyads to be captured at once, making the data collection shorter.

- *Reduction of the capture space.* In order to further reduce the instances of marker occlusion, pilot testing was used to determine the largest visible capture space on either side of the wall. This space was marked off with tape. The capture space including the wall, extra cameras, and marked space can be seen in Figure 2A.

- *Modification of the marker configuration*. In order to limit marker occlusion and decrease the time and labor required to label data, the number of markers used per individual was reduced from 28 to 21. The location of the markers were as follows (L = left, R = right, F = front, B = back): 1: LF head; 2: RF head; 3: B head; 4: L shoulder; 5: R shoulder; 6: sternum; 7: stomach; 8: LB hip; 9: RB hip; 10: L elbow; 11: R elbow; 12: L wrist; 13: R wrist; 14: L middle finger; 15: R middle finger; 16: L knee; 17: R knee; 18: L ankle; 19: R ankle; 20: L toe; 21: R tow. These can be seen in Figure 2B.

- *Additional markers added for participant identification.* As differentiating one participant from another can be difficult in unlabeled motion capture data (Solberg & Jensenius, 2016), a solution was devised by placing one, two, three or four extra markers on the calves of each dancer such that each figure would appear unique, an example of which is shown in Figure 2B. These markers were not analyzed.

- *Addition of four extra cameras on tripods.* Pilot testing revealed that both the wall and the presence of another dance in the dyadic condition yielded significant instances of marker occlusion. To mitigate this, the number of cameras was increased from eight to twelve, with two cameras angled at each side of the division wall.

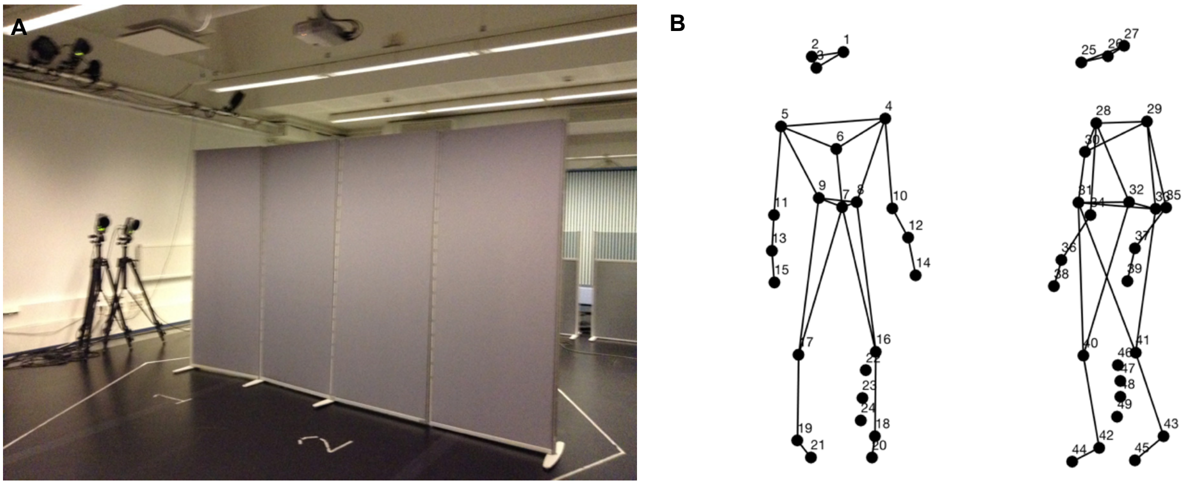

FIGURE 2 Motion capture space and marker configuration as modified for Study III, including identifying markers placed on the calves.

5.2.4 Data preprocessing

After data are labeled, they are exported from QTM for preprocessing and analysis. For the current thesis, preprocessing and analysis of motion capture data were carried out in MATLAB, primarily using the MoCap Toolbox version 1.5 (Burger & Toiviainen, 2013). The toolbox represents motion capture data as a mocap structure, which includes movement data, as well as information such as the file name, number of markers, the frame rate; most functions within the Mocap Toolbox, operate on mocap structures. After exportation of the three-dimensional position data time series from QTM, the first step of preprocessing mocap data is to fill gaps in the data that occur for the aforementioned reasons, using linear interpolation. Following this, if data have been collected using recorded music stimuli (as is typical in dance research), audio and motion data are synchronized and trimmed. For the current thesis, data were trimmed to the full 35-second length of the stimuli.

To reduce redundancy and for ease of analysis and interpretation, data are transformed into a reduced set of markers labeled a joint structure. The locations of these 20 joints are depicted in Figure 1C. For data collected in Study I, the locations of joints C, D, E, G, H, I, M, N, P, Q, R, and T are identical to the locations of one of the original markers, while the locations of the remaining joints were obtained by averaging the locations of two or more markers; Joint A: midpoint of the four hip markers (referred to as the root marker in the further analysis); B: midpoint of markers 9 and 11 (left hip); F: midpoint of markers 10 and 12 (right hip); J: midpoint of breastbone, spine, and the hip markers (mid-torso); K: midpoint of shoulder markers (manubrium), L: midpoint of the four head markers (head); O: midpoint of the two left wrist markers (left wrist); S: mid-point of the two right wrist markers (right wrist). For data collected in Study III, joints O and S (wrists) were additionally identical to the location of the original markers, joint A was the midpoint of the two hip markers, while, joint J was the midpoint of the two hips and two shoulders.

After preprocessing, a number of movement features were extracted from the data for further comparison in Studies I, III and IV. The calculation of these features is described in the following section.

1) Mean Movement (Studies I, III and IV)
This feature was calculated to summarize a dancer's overall amount of movement during a given stimulus. Acceleration, the second derivative of position data defined as the rate of change in velocity of an object over time, was used, as acceleration was previously identified as a key feature in allowing musicians to synchronize their playing to a conductor's gestures (Luck & Toiviainen, 2006). Data were first rotated such that the hip joints (A, B and F) aligned with the x-axis, and transformed such that joint A was identical to the origin. Instantaneous magnitude of acceleration for each of the 20 joints was calculated using numerical differentiation and a second order zero-phase digital filter. The mean was taken across time and across joints, resulting in a single value representative of mean movement.

2) Joint-specific mean movement
Using this same process, features were also calculated to summarize the mean acceleration over time for specific joints of interest. These features included:

- Hand Movement (Studies I[1], III and IV[2]), which was calculated from joints P and T
- Core Body (Study I), which was calculated from joint K
- Lower Body (Study I), which was calculated from joints I and E
- Head Movement (Study III), which was calculated from joint L

3) Period locking (Study IV)
This feature was calculated using three-dimensional velocity data from two members of a dyad. Data were divided into windows of 4 seconds, for which movement periodicity were calculated for all markers using autocorrelation. The absolute difference between dyad members between estimated periodicity per window was taken for each joint. Differences were then averaged and subtracted from 1 (1 - mean difference).

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1 This feature was labeled ‘Upper Limb’ movement in Study I
2 For study IV, this feature was calculated for each dyad member and added together

4) Orientation (Study IV)

This feature was calculated to summarize the degree to which dyad members were facing each other during a given stimuli. Using marker rather than joint data, the absolute angle between the orientation of the head of each dyad member relative to the orientation of the other dyad member was calculated across time. The mean of this measure was taken and subtracted from 180 degrees.

5.3 Statistical analysis of dyadic data

According to Kenny, Kashy, and Cook (2006), "The dyad is arguably the fundamental unit of interpersonal interaction and interpersonal relations," (p. 1). In studying typical psychological phenomenon, the usual experimental method would be to expose an individual participant to some stimuli and record their response, whether behavioral, physiological, biochemical, or neurological; repetition of this process with multiple participants responding to the same stimulus provides data that can be aggregated to provide a result. Studying social-psychological phenomenon such as dyadic behavior, however, necessitates that participants interact with other humans. One approach to this is the use of 'confederates,' or actors who always behave in a particular way who provide a controlled, consistent stimuli for the actual participants. This approach has been used in some of most famous early social psychology experiments (Griffin & Gonzalez, 2003), including previously mentioned studies demonstrating the importance of bodily mimicry in human interaction (e.g., Chartrand & Bargh, 1999; Lakin et al., 2003).

In response to concerns that researchers were influencing their findings regarding social cognition through experimental demand characteristics, William Ickes (1947-) introduced the "unstructured dyadic interaction paradigm" in the 1980s (Ickes, 1982; Ickes & Gonzalez, 1996; Malloy & Kenny, 1986). Rather than attempting to study social cognition by using highly controlled stimuli and measuring responses from participants individually, Ickes advocated a method of facilitating natural social interactions to occur between participants who believed they were only waiting for an experiment to begin, and who were both subsequently asked to rate the interaction on various scales. Techniques of gathering data about these naturalistic interactions include analysis of videotapes, asking participants to view and annotate video of their own interactions, or asking participants to rate their perception of their partner's personality traits or likeability (Ickes & Gonzalez, 1996).

Griffin and Gonzalez (2003) outline three methodological difficulties related to study such free, dyadic interactions. First, if both dyad members are free to act and respond to each other as they choose, a large amount of uncontrolled variation and covariation can be produced, antithetical to classical models of scientific experimentation. Secondly, parametric statistical tests assume that data are independent—that is, that one participant does not influence the score of another participant. Thirdly, analysis of data at multiple levels (individual-level, dyad-level and, perhaps, group-level) can result in incorrect cross-level inferences. The consequence of violating assumptions of independence is a marked increase in the likelihood of both Type I and Type II errors (Field, 2009; Nimon, 2012; Wiedermann & Von Eye, 2013), while failing to analyze data at the correct level can lead to wildly incorrect inferences (Griffin & Gonzalez, 2003). Such difficulties have led some researchers to find it safest to measure only one dyad member in interactive research (which itself creates problems with inference), or to avoid dyadic research altogether, limiting the study of dyadic and group processes (Griffin & Gonzalez, 2003; Ickes & Gonzalez, 1996). Kenny et al. (2006) additionally cite cultural bias towards individualism and emphasis within the discipline of psychology on individual phenomenon as contributing to the relative scarcity of dyadic studies.

However, multiple statistical models have been developed over the last few decades specifically for coping with, measuring, and interpreting the interdependence of dyadic data, which, after all, is exactly what is interesting about social interactions. These include the Actor-Partner Interdependence Model (APIM), which uses methods such as pooled regression to correct for interdependence by separating the degree to which an outcome variable is related to an individual's own predictor score and the degree to which it is related to their partner's score (Kenny et al., 2006). Other models include the latent dyadic model, which assesses the degree to which shared behavior or attitudes influence dyadic outcomes, and the slopes-as-outcomes model, which assesses relationships between dyad-level and group-level effects (Griffin & Gonzalez, 2003).

Such models are particularly useful for the study of specific relationships between dyads such as married couples, parent and child, best friends or roommates, and offer appealing advantages towards understanding how a partner may influence behavior. However, for less specifically defined relationships, considering a person within only one dyad (as opposed to multiple dyadic relationships) limits the degree to which findings generalize (Back & Kenny, 2010; Malloy et al., 2005). We can assume that married individuals are generally married to only one person at a time, for example, but the number of others one interacts with as friends, strangers, or fellow attendees of a dance party, is likely to be much higher. In such cases, more general knowledge can be obtained by considering how an individual behaves not just in one but in multiple dyads. This is the premise of the Social Relations Model (SRM) (Kenny et al., 2006; Kenny & La Voie, 1984).

In the SRM, multiple scores are obtained from each participant resulting from interactions with multiple partners. Data are analyzed to determine the degree of behavioral consistency across dyadic partners. This consistency is defined according to *actor effects,* or the degree to which an individual behaves consistently no matter who their partner is; *partner effects*, or the degree to which an individual causes their partners to behave in a consistent manner; and *relationship effects*, the degree to which behavior is unique within a dyad compared to other behavioral instances. The score of any given participant, say participant A, acting with another given participant, participant B, is thus defined by the following equation:

$$X_{AB} = \mu + \alpha_A + \beta_B + \gamma_{AB} + \varepsilon$$

where μ is the mean of all scores, α_A is participant A's actor effect, β_B is their partner's (participant B's) partner effect, γ_{AB} is the unique response of the individual and their partner after controlling for each other's actor and partner effects respectively, and ε is random error. In a Round Robin design, that is, a design in which each group member interacts with every other member, actor effects are calculated using the following equation:

$$\alpha_A = \frac{(n-1)^2}{n(n-2)} M_{aA} + \frac{n-1}{n(n-2)} M_{pA} + \frac{n-1}{n-2} M$$

where n is the group size, M_{aA} is the participant's actor scores, M_{pA} is the mean of the scores of their partners, and M is the mean of all observations within the group. Similarly, an individual's partner effect is given as:

$$\beta_A = \frac{(n-1)^2}{n(n-2)} M_{pA} + \frac{n-1}{n(n-2)} M_{aA} + \frac{n-1}{n-2} M$$

Finally, the relationship effect for a given dyad is estimated as:

$$\gamma_{AB} = X_{AB} - \alpha_A - \beta_B - M$$

Thus, each score is decomposed into the effects of the individual, the partner, and their unique, emergent dyadic properties. Data are necessary gathered within groups of at least four. For each group, the degree to which scores vary in relation to actor, partner, and relationship effects is used as an estimate of how influential these various factors are in determining outcome measures, providing general information about the degree to which a given behavior or phenomenon is dyadic or individual. Thus, a large *actor variance* would indicate that actor effects accounted for differences in scores across the sample, a large *partner variance* would indicate that partner effects (the degree to which behavior is determined by one's partner) accounted for variance between scores across the sample, while a large *relationship variance* would indicate that the unique qualities of each dyad accounted for variance in scores across the sample; that is, the degree to which the variable is fundamentally dyadic (Kenny et al., 2006). Individual actor and partner effects derived from the SRM can additionally be extracted for further comparison, for example with measures of individual difference. The SRM is employed in the current thesis to explore the degree to which characteristics of dance movement is dyadically determined, and to assess how individual differences relate to actor effects and partner effects in dyadic dance.

5.4 Perceptual measures

Research has shown that we perceive a range of information from a person's movements alone, from the emotions they might be feeling (Camurri, Lagerlöf, & Volpe, 2003; Dittrich, Troscianko, Lea, & Morgan, 1996), to their personalities to the tempo of the music to which they are dancing (London, Burger, Thompson, & Toiviainen, 2016). We can even identify our friends by only etheir walk (Little & Boyd, 1998; Loula, Prasad, Harber, & Shiffrar, 2005), and also make judgements about rapport based on entrainment between dyad members (Lakens & Stel, 2011; Miles, Nind, & Macrae, 2009), consistent with theories that group dance may have evolved partly to signal group affiliation (Hagen & Bryant, 2003); as discussed in section 5.2.1, such judgements can be made from stimuli as sparse as point-light 'stick figures' (see Figure 1C) Perceptual data were there collected for the current thesis to compliment and clarify the analysis of motion capture data.

6 METHODS

The following section provides an overview of the methods used to collect data for Studies I, II, III and IV.

6.1 Study I: Participants

Thirty participants (15 female) with a mean age of 28.2 (SD = 4.4) were recruited using e-mail lists and social media. Twenty-two participants had received music education at some point in their lives, 13 reported still actively playing or performing music, and four reported having received professional music education. Fourteen participants had participated in dance lessons.

6.2 Study I: Stimuli

The music stimuli consisted of the first 35 seconds of six Motown/Rhythm and Blues tracks commercially released in the 1960s and early 1970s, which were considered to be danceable, homogenous in style, and relatively well known. Tracks were no more than 3 BPM faster or slower than three 'core' tempo groups—105, 115, and 130 BPM—and were time-stretched using Audacity such that each track matched one of these BPMs exactly. Following this, each track was time-stretched again to create versions of each track that had a BPM that was 5% slower or 5% faster than the core tempo.

6.3 Study I: Procedure

Participants complete the experiment individually. Upon arrive at the lab, participants were fitted with motion capture suits and hats to which 28 reflective markers were attached using Velcro or double-sided tape. Stimuli were presented to participants in random order within blocks, each block containing both versions of a given stimulus type (fast or slow). The order of presentation of fast or slow stimuli was counterbalanced within participants.

While listening to fast- and slow-tempo versions of the stimuli, participants were asked to imagine that they were in a social setting such as a club or disco, and to move freely to the music as they desired. They were also instructed to stay within a marked capture space, to reduce instances of missing markers, and told that they should stay in time with the music.

Participants were allowed to take a break from dancing as needed. The experiment last around 45 minutes on average. Participation was rewarded with a movie ticket voucher.

6.4 Studies II and III: Data-driven stimuli selection

Musical genre and music preference have both been shown to influence music-induced movement (Luck et al., 2010; Luck et al., 2014), and music preferences have been implicated in interpersonal understanding (Rentfrow & Gosling, 2007), it was considered necessary to measure and control these elements in studying dance in a naturalistic, dyadic setting. However, genre is a complex construct that does not provide clear, objective ways to distinguish between categories of music, (Pachet & Cazaly, 2000; Shevy, 2008), and human selection regardless of expertise was considered to be subjective. Therefore, a data-driven approach to stimuli selection for the motion capture experiment was devised based on previous research, computational analysis of a large body of potential stimuli, and statistical analysis, with the aim of creating a stimulus set comprised of clear musical examples from a broad range of genres that were comparably suitable for dancing.

To accomplish this, a pool of genre labels was derived from the Revised Short Test of Music Preferences (STOMP-R), an updated version of the STOMP available online which includes genres beyond the original publication of the measure ("Short Test Of Music Preferences (STOMP) | Gosling," n.d.). Genres such as Opera and Classical were eliminated that were considered not suitable for dancing, leaving an initial pool of sixteen genres: Alternative, Bluegrass, Blues, Country, Dance/Electronica, Folk, Funk, Heavy Metal, Jazz, Oldies, Pop, Punk, Rap/Hip-Hop, Reggae, Rock, R&B and Soul.

Social tags are free text labels given by users to songs or artists on music-listening platforms such as Last.fm, which have previously been used to classify music according to emotion content and in developing hierarchical taxonomies (Lamere, 2008; Lorince, Joseph, & Todd, n.d.; Saari et al., 2013). A stimulus set originally collected by Saari & Eerola (2014) comprising 1,300,000 tracks (songs) associated with 924,000 tags from Last.fm was analyzed to identify tracks associated with tags such as 'danceable,' 'dancing' or 'head-banging,' which were also associated strongly with one and only one of the sixteen genre labels. This left a set of 2407 tracks, which were matched to records in Echo Nest and 7digital APIs. Tracks were retained which had non-zero danceability scores in Echo Nest; this score was based on extraction of acoustic features from each track. Tracks were further eliminated that did not fall between 118 and 132 beats per minute (BPM), and finally, four tracks per genre were randomly subsampled, eliminating genres with fewer than four suitable tracks. The authors listened to each track and further chose to eliminate the genres Alternative and Folk, as these were judged to be less suitable for dancing. This process resulted in a final set consisting of 48 tracks from twelve genres. A full listing of these tracks can be found in the Appendix of Study II.

This set of stimuli was further reduced for use in the motion capture study. Preference ratings from Study II were analyzed for each genre using only the data from participants in Study III. The two stimuli with the highest variability in preference ratings were chosen for each genre. Funk, Soul, Rock, and Oldies were eliminated due to less variability in preference ratings and smaller correlations between STOMP and ratings results in Study II. The final stimulus set for the motion capture study consisted of sixteen stimuli representing the following eight genres: Blues, Country, Dance, Jazz, Metal, Pop, Rap, and Reggae.

6.5 Study II: Survey participants

A total of 210 participants ranging in age from 19 to 68 years (M = 29.4, SD = 10.3) completed the experiment. The majority (69%) were Finnish, but the remaining participants represented 18 different countries, the next largest groups being from the US, Canada and Germany. Participants were well-educated, with 71% holding Bachelor's or Master's level degrees, while 49% reported some amount of formal musical training. Participants were recruited using e-mail lists and social media and entered into a draw to receive a free movie ticket.

6.6 Studies II, III and IV: Survey data collection

The survey was created and administered using Survey Gizmo (www.surveygizmo.eu). Participants were informed via an introduction page that they would be listening to musical excerpts and advised that they should complete the survey in a quiet place, preferably using headphones. Following this introduction, participants completed the Ten-Item Personality Inventory (TIPI), the Empathy Quotient (EQ) and the Systemizing Quotient (SQ).

For the listening experiment, participants were presented with 30-second clips of each of the 48 stimuli in a randomized order. Participants were allowed to listen to the excerpt as many times as they wished before rating their liking for the music using a seven-point Likert scale. After they had given ratings for all excerpts, participants completed a modified version of the STOMP-R which included only the 12 genres from which stimuli were selected. Participants additionally provided demographic data and information about their years of training in both music and dance.

6.7 Study III and IV: Motion capture data collection

6.7.1 Participants and groups

Participants were recruited from the pool of those who completed the survey in Study II and indicated they were interested in completing a motion capture experiment. A total of 73 (53 female) participants completed the experiment. They ranged in age from 19 to 40 (M = 25.6, SD = 4.5) and represented 25 different nationalities, with a majority (28.8%) from Finland. Forty-five reported at least one year of musical training, while 26 reported at least one year of dance training. A majority of 64% had completed a Bachelor's or a Master's degree.

Participants had to be placed into groups to complete the experiment. A data-driven approach to this was devised involving the analysis of participants' preference ratings for the stimuli to be used during data collection. Principal Component Analysis (PCA) was performed on the preference ratings of the 16 stimuli. Participants' component scores in the first two PCs were subject to a median split, such that they could be categorized as either high or low in each of the PCs and could thus be labeled as belonging to one of four subgroups: A (high-high), B (high-low), C (low-high) or D (low-low). Groups of four were then created such that each contained one A, B, C, and D participant. This approach provided some control over the music preference profiles of the groups such that dyadic interaction results could not be attributed solely to unexpected convergence or lack of convergence between dyad members' preferences while allowing for flexibility in scheduling groups of four.

Twenty groups completed the experiment. Due to several last-minute cancellations and no-shows, seven of these groups included only three participants, while the remaining 13 included the target four.

6.7.2 Procedures

Upon arrive at the lab, participants signed a consent form and were fitted with motion capture suits and hats to which 21 reflective markers were attached. These can be seen in Figure 2B. In order to differentiate participants from one another in the motion capture data, each participant was additionally fitted with one, two, three or four extra markers attached to their calf, which were not used in data analysis. In order for participants to be easily distinguished from by each other and the researchers during the data collection, each participant was given a felt badge displaying A, B, C or D.

Participants were then introduced to the motion capture system and informed that they would be asked to listen and move to music first individually and in then in pairs. They were told they would hear a wide variety of musical excerpts, and they should listen to the music and move freely as they desired, as they would in a social setting such as a club or party. Participants were advised to stay within the marked capture space and inform researchers if they needed a break or if one of their markers fell off. When participants were ready, stimuli were played in a randomized order using a Max patch running on a Macintosh computer.

In the first condition, participants moved alone in one half of the capture space. This condition was repeated such that two participants were captured at once, each in one half of the capture space, while the other two participants left the capture space and completed personality questionnaires in another room. Following this, participants were captured in two sets of dyads per condition, such that all possible dyads were captured. For groups of four this yielded six unique dyads, while for groups of three, this yielded three unique dyads.

To limit fatigue, participants were given a break of a few minutes as needed between each condition and offered water, juice, and biscuits. After all conditions were complete, participants filled out a form including demographic information, were debriefed about the experiment, and rewarded with two movie ticket vouchers. The full capture session lasted an average of two hours.

6.8 Study IV: Perceptual study

6.8.1 Data-driven stimuli selection

Given evidence that dispositional empathy can affect social mimicry (Otterbacher, Ang, Litvak, & Atkins, 2017; Sonnby-Borgström, Jönsson, & Svensson, 2003; Sonnby–Borgström, 2002), it was considered possible that dancers' empathy could reflect their tendency to imitate and interact with one another in dyadic settings. Dyads were therefore selected for the creation of perceptual stimuli according to their self-reported empathy, from those who had been motion captured for Study III. Participants from Study III whose scores fell into either to top or bottom quartile of EQ scores were considered; as this subset was not gender-balanced, and included more females than males, dyads including male dancers were eliminated. From the remaining participants, 12 dyads were selected wherein either both dancers were high in empathy, both dancers low in empathy, or in which one dancer had high and one low empathy. Stimuli were created by animating the mocap data from these dyads dancing to the two Pop music tracks, resulting in a set of 24 stimuli. Pop music was chosen both because it did not elicit strongly differentiated preference scores, and because movement data recorded during Pop tracks included relatively high variation in overall amount of movement, suggesting there would be discernable differences between the stimuli and that these effects could not be contributed entirely to differences in music preference.

6.8.2 Participants

Thirty-three (25 female) participants, who had not previously participated in Study III's motion capture experiment, were recruited via social media and University e-mail lists. They ranged in age from 23 to 56 (M = 30.1, SD = 7.2), had an average of 3.8 years of formal music education (SD = 6.2), and 1.6 years of formal dance education (SD = 3.5). They represented a broad range of nationalities, with the most represented nationalities being Finnish and Indian. Participants received a movie ticket voucher after completing the study.

6.8.3 Procedures

Stimuli were presented using a self-guided interface in Max run on a laptop in a private office. After the participants had provided basic demographic information, stimuli were presented in randomized order. Participants rated their level of agreement with the statements that dancers were "interacting with each other" and "dancing similarly to each other" on a scale from 0 to 100 using sliders. Each 20-second stimulus was looped such that the participants could observe the dyad as long as they wished before providing ratings.

7 MAIN RESULTS AND DISCUSSION

The following section provides and discusses the main results from each of the four studies. The results of the studies are then considered and evaluated as a whole.

7.1 Study I: Results and discussion

Study I investigated whether personality and dispositional empathy would affect movement responsiveness to small tempo differences between otherwise identical stimuli. Two-tailed, paired samples *t*-test compared the mean amount of acceleration between conditions and found greater levels of acceleration in the fast than slow condition ($t(28) = 7.81$ $p<.05$), suggesting that participants were able to make a difference overall in their movements in response to small tempo differences in otherwise identical stimuli. Conscientiousness related positively to the average difference between stimuli ($r = .59$, $p<.01$), and Extraversion negatively to the amount of difference ($r = -.36$, $p<.05$), leading to a focus on these two traits in further analysis. Perspective Taking was not significantly correlated with movement differences in response to tempo. Important joints in differentiation were identified using Principal Component Analysis (PCA) of the acceleration differences; the highest loading joint was extracted from the first three components leading to a focus on the core body, hands and feet in the later part of the analysis. Conscientiousness correlated positively with difference in the neck ($r = .36$, $p<.05$), the feet, ($r = .60$, $p<.001$), and hands ($r = .61$, $p <.001$), while Extraversion correlated negatively with differences in the neck, ($r = -.39$, $p<.05$), the feet, ($r= -.42$, $p<.05$), and the hands, ($r = -.22$, $p<.05$). Results suggested overall that that participants who were less extraverted and more conscientious made greater differences in response to these tempo differences than others, in line with previous work showing that conscientiousness relates to task performance (Finn et al., 2015; Judge, Erez, Bono, & Thoresen, 2003; Witt et al., 2002), and perhaps suggesting a perceptual or attention-based component to conscientiousness that underlies improved task performance. Regarding extraversion, previous work has shown, for example, that introverts are more sensitive to some stimuli than extraverts (J. A. Gray, 1970; Schaefer, Heinze, & Rotte, 2012), so it may be that extraverted participants were less sensitive to the relatively small tempo changes in this study.

To further explore these relationships, a series of partial correlations were performed. While controlling for Conscientiousness, Extraversion had no significant effects on movement differences between stimuli. While controlling for Extraversion, Conscientiousness had a significant effect on differences in the feet ($r = .55$, $p<.01$), and the hands, ($r = .58$, $p<.001$). These partial correlations suggest that conscientious participants may have particularly used their limbs rather than core body in differentiating between slow and fast conditions, which may be interpreted as intentional changes to movement related to a drive towards high task performance. Although non-significant, extraversion was most related to differences in the core body between conditions when controlling for conscientiousness, which may suggest that introverts used less limb movement in general, or possibly that their differences between conditions were made less consciously.

This study also demonstrated that, although it is a relatively broad measure, mean acceleration across time was sensitive to differences in movement related to slight (±5%) differences in tempo. It is, therefore, possible that it would be useful in capturing condition-level differences in other cases. From this, the study further demonstrates the usefulness of mean acceleration to represent a fundamental aspect of overall movement in a single number.

This study also represents a preliminary attempt to learn whether trait empathy is related to free, music-induced movements. Although Leman (2008) conceptualized embodiment of heard music as a form of empathy, dispositional empathy as measured by Perspective Taking did not significantly relate to greater responsiveness to tempo differences. This may have been due to confounds such as the relatively small sample size, or the use of a single genre of music that may have been differently preferred by different participants. However, it is also possible that, although the embodiment of music's forms can be considered an example or element of an empathic process, Leman's model may not specifically relate to dispositional empathy Dispositional empathy may relate to responsiveness to higher-level features in music, such as expressed emotion.

Evaluation of the results of this study led to some reconsideration of how empathy might be embodied in music-induced movement. Given that empathy relates directly to interpersonal perception and that this relationship is arguably metaphorical or representative in music perceptual processes, it is possible that embodied empathic processes are better manifested in explicitly social contexts. Finally, since the IRI dissociates cognitive and emotional empathic processes, it was thought possible that it represented too narrow a measure of dispositional empathy. Taking this insight, as well as the possible confounds mentioned above, into account, a new motion capture experiment was designed that gave rise to Studies II, III, and IV.

7.2 Study II: Results and discussion

Study II explored relationships between participants' personalities, dispositional empathy and their music preferences, using an online survey that included the task of rating computationally-selected music excerpts, the STOMP-R wherein participants rated their liking for certain genres, and several individual difference measures: the EQ, SQ and TIPI. There were significant, positive correlations between STOMP-R scores and mean excerpt rating for each genre. Correlations ranged from (r = .37) for Funk to (r = .84) for Metal. The generally high correlations between STOMP-R scores and mean excerpt ratings for each genre suggest that the data-driven stimulus selection process was, overall, successful in identifying tracks that accurately corresponded to most participants' understanding of the given genres. Genres with the highest correlations, such as Metal, may be narrower and therefore easier to represent with a few tracks; alternately, it could be that participants who liked Metal tended to like a wider variety within the genre than those who liked Funk.

To reduce the number of variables, preference ratings were subjected to Principal Component Analysis (PCA), in line with previous analysis of music preference that has employed factor models (e.g., Rentfrow, Goldberg, & Levitin, 2011; Rentfrow & Gosling, 2003; Zweigenhaft, 2008). Components were rotated using varimax rotation. PCA yielded four components that accounted for 75.5% of the total variance and were retained for further analysis. Components were labeled Danceable (high loadings for Pop, Dance, and Funk), Jazzy (high loadings for Blues, Jazz, and Soul), Hard (high loadings for Metal and Rock) and Rebellious (high loadings for Rap and high negative loadings for Country and Oldies). Participants component scores were correlated with TIPI, EQ and SQ scores to assess the relationship between individual differences and music preference. Liking for Danceable music correlated positively with Neuroticism (r = .14, p <.05). Liking for Jazzy music correlated positively with Openness (r = .20, p <.01) and negatively with Conscientiousness (r = -.17, p <.05). Liking for Hard music correlated negatively with EQ score (r = -.17, p <.05), negatively with Openness (r = -.21, p <.01) and negatively with Extraversion (r = -.16, p <.05). Liking for Rebellious music was positively correlated with SQ score (r = .16, p <.05) and negatively correlated with Agreeableness (r = -.21, p <.01). Additionally, EQ score was positively correlated with STOMP-R liking for Blues (r = .19, p <.01), liking for Funk (r = .25, p <.001) and Soul (r = .25, p <.001).

The positive correlation between Openness and liking for Jazzy music replicates multiple previous findings (Brown, 2012; Dunn et al., 2012; George et al., 2007; Greenberg et al., 2016; Langmeyer et al., 2012; Rentfrow & Gosling, 2003). The finding that Conscientiousness correlates negatively with a liking for

Jazz was also found by Dunn et al. (2012). That liking for Hard music was negatively correlated with Openness contradicts previous findings (Delsing et al., 2008; Dunn et al., 2012; Rentfrow & Gosling, 2003), although this could be due to cultural influence. Previous work shows that Finnish participants tend to like Metal significantly more than those from the U.K. (Purhonen, Gronow, & Rahkonen, 2009). The relationship between Agreeableness and liking for Country and Oldies aligns somewhat with previous work, as was the relationship between Neuroticism and liking for Danceable music (R. A. Brown, 2012). Results regarding empathy and systemizing could also be construed to align with previous research, although far fewer studies have examined the relationship between these traits and music preference (Greenberg, Baron-Cohen, et al., 2015).

This study represents an addition to previous work on the subject of personality and music preferences and introduces a novel, data-driven approach to stimuli selection. The correlations found in the study were generally weak to moderate in strength, in line with previous work exploring these relationships, suggesting that a small yet genuine effect is being detected. In the context of the thesis, Study II provides a controlled stimuli-set for subsequent use in Study III.

7.3 Study III: Results and discussion

Study III used motion capture and the Social Relations Model (SRM) to explore how spontaneous, free dance movements are affected by the presence of a partner. The overall effect of condition (individual vs. dyadic) on movement features was explored using two-way repeated-measures ANOVAs, with condition and stimuli genre as independent variables. There was a significant effect of condition on Hand Movement $F(1,51) = 182.46$, $p<.05$, with the dyadic condition having a higher mean Hand Movement than the individual condition. There was also a significant effect of genre on Mean Movement, $F(7,243) = 22.91$, $p<.001$, Head Movement, $F(7,137) =18.83$, $p<.001$, and Hand Movement, $F(7,176) =14.67$, $p<.001$, suggesting that genre features affected how participants physically responded to the music stimuli, in line with previous research (Luck et al., 2010). However, after SRM analysis was performed, two-way ANOVAs were used to compare actor, partner, and relationship variances and found no differences between genres, suggesting that, while participants moved differently depending on the heard genre, the overall degree to which their movements were affected by the dyadic context was stable across genres. Because of this, data were aggregated across genre for the remainder of the analysis to obtain higher statistical power.

Across genres, mean actor variance for Mean Movement was .66, while mean relationship variance was .58, suggesting individual qualities affected overall amounts of movement slightly more than relationship qualities. For Head Movement, mean actor variance was .44 while mean relationship variance was .69, suggesting that participants' overall amount of head movement was determined more by dyadic factors than individual factors. For Hand Movement, mean actor variance was .60 and mean relationship variance as .56, suggesting that hand movement was influence more or less equally by individual and dyadic factors. The importance of head movement in responding to a partner could suggest that, in dance, head nodding may be used to indicate affiliation, as in non-dance, non-verbal behavior. Nodding the head to the beat may also have been an easily accessible way for dyad members to entrain to each other as well as to the beat of the music. The relative importance of hand movement to overall amount of movement in responding to a partner is also in line with non-dance, non-verbal behavior, where the upper limbs are often used in communicative gestures. That actor effects remained relatively large for all three features supports the idea that individual factors such as personality or music preference continue to exert influence over a dancer even in a dyadic context.

For all features, partner variance was either very small or slightly negative, which is treated as zero variance in the SRM (Back & Kenny, 2010). This suggests that, across the sample, individuals did not drastically influence their partners' movements in a systematic way. This is in line with previous findings that, in behavioral data, partner effects are generally very small (Kenny & Malloy, 1988).

To assess how individual differences related to participants' behavior in the dyadic context, participants' mean actor and partner effects across genre were compared with self-report measures of Extraversion, Agreeableness, and Empathy. Correlation revealed a significant negative correlation (r = -.24, p<.05) between actor effect for Hand Movement and EQ score, suggesting that the overall amount of hand movement used by participants with higher dispositional empathy was determined less by themselves and more by other factors, most likely relationship (dyadic) factors. As previous research has suggested that there are differences between males and females in non-verbal behavior, personality and empathy (Baron-Cohen, 2009; Berry & Hansen, 2000; Hall, 1978; Terracciano, & McCrae, 2001; Koppensteiner & Grammer, 2011), comparisons were also made for each gender separately. For females alone, there was a small positive correlation (r = .30, p<.05) between Agreeableness and partner effect for Head Movement, suggesting that more agreeable females tended to reliably elicit some amount of head movement from their partners. A possible interpretation of this is that these dancers' agreeableness is reciprocated with head nodding, a nonverbal behavior associated with agreement and affiliation (Beck, Daughtridge, & Sloane, 2002; Helweg-Larsen, Cunningham, Carrico, & Pergram, 2004). For males alone, there was a negative relationship between EQ score and actor effect for Head Movement (r = -.47, p<.05) which could have a similar interpretation. For males, there was also a negative correlation between EQ and actor effect for hand movement, (r = -.49, p<.05) and a positive correlation between Agreeableness and actor effect for Hand Movement. These results, although tentative due to the small sample size when divided by gender, suggest that dispositional empathy may have a greater effect on male's dance movement than on females, although this could be due to males generally having slightly lower levels of trait empathy (Baron-Cohen & Wheelwright, 2004).

Overall, SRM results showed that participants varied their movements in response to the presence of a dance partner, and furthermore that participants varied their movements differently in response to different dance partners. Correlation results suggest that the degree to which participants responded to their partners was partly related to individual differences, including differences in dispositional empathy, as predicted. This also provided a rationale for examining movement features at the dyadic level, which was done in Study IV.

7.4 Study IV: Results and discussion

Study IV focused on exploring relationships between dyadic movement features, dancers' dispositional empathy, and perceptual ratings of dancers' Interaction and Similarity. Correlation analysis revealed a positive relationship between rated Interaction and rated Similarity, (r = .51, p<.05), suggesting some but not complete overlap between the concepts. One-way repeated measures ANOVAs were conducted to compare the effect of dyads' dispositional Empathy (either both dancers had high EQ scores, both low, or one high and one low) on perceived Interaction and Similarity. There was a significant effect of this Empathy combination on both perceived interaction $F(1,32) = 527.3$, p <.001, and perceived Similarity $F(1,32) = 614.65$, p <.001. Bonferroni-corrected pairwise comparisons showed that, for interaction, high-low dyads were rated as interacting significantly more than other dyads (p<.001), while, for similarity, high-high dyads were rated as less similar and other dyads (p<.05).

While it aligned with expectations that dyads in which both dancers were low in empathy would show lower levels of interaction as per previous research (e.g., Minio-Paluello et al., 2009; Sonnby–Borgström & Sonnby-Borgstrom, 2002; Taylor, Kluemper, & Mossholder, 2010), it was somewhat surprising that high-low dyads would be rated as the most interactive, as well as that high-high dyads would be rated as less similar. One explanation is the presence of a similar effect to that found by Isbister and Nass (2000), who showed that extraverts preferred interacting with introverts and vice versa. In this case, it could be that more empathic participants may have found it harder to adapt to a partner who was simultaneously adapting to them; a more plausible interpretation may be that empathic dancers were sensitive to their partners' desires *not* to interact, such that two empathic participants may have been able to mutually 'agree' that it was more comfortable for both to not interact than to interact. However, it is also possible that these results echo previous work showing that the relationship between dispositional empathy and prosocial behavior (to the degree that motoric imitation and interaction in dance might be seen as prosocial behaviors) is somewhat uncertain (Eisenberg & Miller, 1987;

Underwood & Moore, 1982), and may be moderated by additional factors such as empathic concern (Winczewski et al., 2016). It is also possible that, in some of the highly empathic participants, empathic responses such as motoric mimicry were inhibited due to some extraneous factor, such as introversion or shyness, or that these responses were occurring on levels not directly measured (e.g., through facial expressions rather than through dance-related movements).

To explore how participants may have assessed Interaction and Similarity, movement features were correlated with perceptual ratings. There were significant positive correlations between Period Locking and both Interaction ($r = .48$, $p<.05$) and Similarity ($r = .45$, $p<.05$), between Hand Movement and Interaction ($r = .64$, $p<.01$) and Orientation and Interaction ($r = .85$, $p<.01$). These results suggest that periodic entrainment is necessary but not sufficient for observers to perceive Interaction when watching dyadic dance movement. It is possible that orientation towards a partner and increased hand movement may both facilitate and communicate the intention of social interaction (Baldwin & Baird, 2001; Becchio, Sartori, Bulgheroni, & Castiello, 2008; Burgoon, Manusov, Mineo, & Hale, 1985), rather than an 'accidental' similarity of movement caused by common fate, that is, of merely being exposed to the same music stimulus.

This study represents a contribution to the understanding of how interaction may be defined in dance, and specifically in a spontaneous, free movement setting where it is not typical, at least in Western culture, to exactly replicate a partner's movements for any length of time. The results of this study suggest that dispositional empathy may play a role in determining dyadic interaction in dance, and also highlights that this relationship may not be a simple, linear one. The results therefore point to the need for further understanding of the relationships between empathy, movement, and dyadic movement.

8 CONCLUSION

8.1 General discussion of results

This thesis has used motion capture, self-report and perceptual data to investigate free, spontaneous dance movement in both individual and dyadic contexts, in relation to individual differences of personality and dispositional empathy. Regarding personality, results generally aligned with previous research in both dance and non-dance domains. Extraversion was shown to relate to smaller amounts of responsiveness to small changes in stimuli, Conscientiousness to better task-completion, and Agreeableness to interpersonal behaviors in a dyadic context. Big Five personality traits were also broadly found to relate to music preferences in similar ways as has been shown in previous research. However, some results regarding personality were also surprising, such as the finding that Extraversion did not relate to responsiveness to a partner in a dyadic context. This suggests that, even in the well-established tradition of personality research, there is more work to be done to understand to what degree our individual tendencies are consistent in or affected by non-individual (social) contexts.

Results were more varied and more often surprising regarding dispositional empathy. Empathy did not relate significantly to the embodiment of small tempo differences in musical stimuli and was only modestly related to music preferences. In Leman's (2008) model of empathic engagement with music, affective responses to music are caused by motoric responses to music. These results suggest that empathic dancers were no more physically responsive to music at the level of small tempo changes than others, although Leman's description leaves room for interpretation regarding whether motoric responses to music as part of an empathic process take place in responses to lower- or higher-level music features. More empathic participants could have physically imitated features such as melodic lines (i.e., similar to sound-tracing gestures explored by Godøy et al., 2016), or, at an even more abstract level, to the expressed emotion in the music. It may also be that dispositional empathy does not relate to empathic responses to music, or at least to *embodied* empathic responses to music. It may also be that, rather than trait empathy promoting embodied responses to music, a participant would have a greater affective response to a music stimulus after dancing to it rather than listening without movement. Further research is necessary to understand how empathy may or may not affect embodied responses to music in individual contexts.

In dyadic movement, however, empathy was shown to relate significantly to smaller actor effects in hand and (in males) head movement, suggesting that participants with greater empathy were more likely to show differences in their hand movements depending on who their partner was, in line with theoretical definitions of empathy as a process involving social mimicry, and suggesting that in dance this may be especially manifested through upper body gestures. Results also suggested the possibility that trait empathy has a greater effect on males than on females in terms of embodied responses to a dance partner, but further research is needed to support and clarify this finding. Analysis of the contribution of individual (actor) effects compared to dyadic (relationship) effects show that both were important contributors to the variance of participants' movements across partners, in line with previous work on behavioral dyadic effects and with theoretical frameworks in which behavior can be viewed as predictable with sufficient knowledge about both the individual and their current situation (i.e., who their dance partner is). This in turn suggests that the spontaneous, free dance paradigm is a valid means of studying human behavior and may yield insights beyond the domain of music-induced movement.

Perceptual results revealed higher levels of interaction and similarity not in dyads with collectively high amounts of reported dispositional empathy, but rather in dyads where one member reported high empathy and the other reported low empathy. This could suggest that empathic responding to a partner does not necessarily yield interaction, and could possibly even yield a lack of interaction, for example out empathic concern for the partner's comfort and ease. It is also possible that empathy between two dancers was expressed by means not visible in the motion capture data, such as through eye contact and facial expressions, leaving raters to rely on incomplete information, or that an unknown third factor (e.g., extraversion) could have moderated the results.

These results nevertheless contribute to our growing understanding of the complex relationship between empathy and music-induced movement. Empathy has been proposed to relate to engagement with music in a myriad of ways, many of them involving bodily movements. The results of the current thesis are mixed, but it should be noted that, in each of the four studies, empathy and its relationship to musical engagement is approached from a somewhat different perspective. The first two studies considered the individual: the first study presumed that dispositional empathy would relate to the theoretically empathic process of corporeal mimicry of an auditory stimulus (musical tempo), and the second that empathy would relate to musical engagement as a predictor of music preferences. The second two studies examined empathy from the perspective of dyadic engagement, the first as a moderator of motoric responsiveness to a dance partner, and last as a causal factor in movement similarity and engagement within a dyad. To put it more succinctly, the studies examined empathy moderating immediate, habitual, social and interpersonal responses to music, respectively, and found significant relationships in the latter three dimensions.

The question should be raised whether the results of Study III, that more empathic dancers altered their hand movements more in response to a partner, and Study IV, that dyads with a mix of high and low empathy were rated as more interactive and that dyads with high empathy used less hand movement, can be considered to conflict with one another. Strictly speaking, as Study III measured behavior across dyadic pairings and Study IV measured behavior and the perception of behavior within a subset of individual dyadic pairings, the results can peacefully co-exist. Still, many potential interpretations present themselves; could highly empathic participants have, in some cases, responded to a perceived desire in their partner *not* to interact? Could there have been, as in some previous research, a dissociation in some participants between high empathic understanding and motivation towards prosocial behavior? The results could suggest, for example, that empathic responding to a partner does not necessarily yield interaction, and could possibly even yield a lack of interaction, for example out empathic concern for the partner's comfort and ease. It is also possible that empathy between two dancers was expressed by means not visible in the motion capture data, such as through eye contact and facial expressions, although this would not adequately account for the results of Study III. The most likely explanation is that empathy is expressed in a wide variety of ways in dyadic dance, including but not limited to overall movement, and that a full understanding of the role empathy plays in dance will require the further exploration of many different aspects.

These remaining questions highlight the need for further investigation of how empathy affects specific behaviors across dyadic pairings.

Although not showing a clear relationship between dispositional empathy and interactive behaviors in dyadic dance movement, Study IV did demonstrate that perceived interaction could be predicted using computationally-derived movement features. There was only partial overlap between perceived similarity and perceived interaction in their relationship to movement features. It could be said that similarity of movement, operationalized in this case by periodic entrainment across the body, is necessary but not sufficient for interaction to be perceived, highlighting the complexity of defining interaction in a spontaneous, free dance movement setting. We could speculate that spatiotemporal entrainment may be to interaction in dance as empathy is to prosocial behavior; that is, a supportive factor allowing for and underpinning the behavior, but one that must be combined with dissociable, motivational factors for the behavior to appear. However, it is also possible that higher-order kinematic features such as movement complexity, and features not available from the current motion capture paradigm such as facial expressions and eye contact, may have played a role in how empathic participants related to one another. Again, there is much room for further study.

Several novel approaches to studying music-induced movement were used in this thesis. The first was the development and implementation of a data-driven process to select music stimuli used in the survey study of music preferences and subsequently in the second motion capture study. This approach provides a solution to the problem of researcher bias in selecting stimuli for research. The use of social-tags specifically also provides a solution for the problem of matching genre labels with representative music stimuli. The use of aggregated social-tagging data arguably provides greater validity than the use of genre-labels chosen by commercial media or the opinion of one or a few experts, and the method is applicable to a wide range of music psychology research beyond its current implementation.

The second novel aspect of this thesis is the collection and analysis of dyadic motion capture data using the Social Relations Model. Traditional approaches to the use of motion capture in the study of dance required modification for a dyadic setting, including modifications to the collection apparatus and the use of statistical analysis techniques that appropriately account for the existence of non-independence between data points. Previous research of dance movement in group contexts has tended to use single-marker measures of movement, to analyze groups as a whole rather than as a set of individual dancers, or to limit the movements of participants using pre-defined choreography. The current thesis demonstrates that it is possible to collect and analyze dyadic movement data in a way that more closely resembles the complex set of movement behaviors that can be seen in naturalistic dance settings such as a dance club, concert, or party. As previous social relations studies have generally assessed self-reported measures such as interpersonal liking rather than direct behaviors, this thesis also represents a contribution to the social relations literature in general.

8.2 Limitations and future work

A few limitations to the current work that could be addressed in future studies can be noted. First, although participants represented many nationalities, the majority were Finnish, so cultural influences specific to Finland could account for some aspects of the results, or limit the ability to which results can be generalized. Additionally, differences between participants based on prior music and dance experience were only analyzed in Studies I and II and could have played a role in the social contexts represented in Studies III and IV. One area for future research may be whether participants with music or dance training are better able to temporally entrain with a partner during free dance interaction.

Secondly, the use of the IRI in the first study and the EQ in subsequent studies makes the results of Study I more difficult to compare to the others.

However, the EQ was chosen for later studies due to its inclusion of emotional and cognitive aspects of empathy into a single measure, and its orientation towards Theory of Mind explanations of empathic processes. Given that empathy is still a disputed construct, future work exploring relationships between empathy, music, and movement may benefit from employing other, more specific measure of empathy. One option for future research is the Reading the Mind in the Eyes test, a performance-based measure in which participants are asked to identify the correct emotion shown by different facial expressions (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Hawco et al., 2017). Future work, particularly if it focuses on the advantages in social functioning that may be related to dance, should consider using measures related to social behavior rather than social perception (i.e., direct measures of pro-social behavior). Indeed, the possibility that dispositional empathy can be dissociated from interactive behavior in dance could arguably be an exciting insight, as supporting social functioning for those with deficits in empathic functioning is already a goal addressed in dance and music therapy (Bieleninik et al., 2017; Hardy & Lagasse, 2013; Koch, Mehl, Sobanski, Sieber, & Fuchs, 2015; Lee, Jang, Lee, & Hwang, 2015).

In both Study I and Study III, Big Five traits (Extraversion and Agreeableness) were found to relate to effects that were initially hypothesized to relate to empathy. The results of Study I may indicate that more introverted participants were more sensitive to small tempo differences in music, consistent with work relating Extraversion to physiological sensitivity to sensory stimuli. It is likely that, although Leman's (2008) model of corporeal articulation of engaging with music is labeled as an empathic process, individual differences beyond empathy may be manifested in this process at various levels, such as basic sensory perception. Further exploration of individual differences in processing music via corporeal articulation may take this into account and consider controlling for these differences. While there is evidence for some relationships between dispositional empathy and personality, particularly between empathy and Agreeableness, they are not identical constructs (Graziano, Habashi, Sheese, & Tobin, 2007; Wakabayashi & Kawashima, 2015). Disentangling these relationships in relation to music-induced movement could be a focus of continued research.

The stimuli used throughout the thesis were all fairly homogenous in that they represent examples of Western popular music. In addition to exploring dance movement in social settings using participants with different cultural backgrounds, it may also provide further insights to use different styles of music. Stimuli were chosen to induce movement and because their commercial availability afforded a high degree of ecological validity to the study, in line with a naturalistic research paradigm. However, the use of such natural stimuli leads to a higher number of uncontrolled variables. Lyrical content, for example, was not taken into account in the current study, although all stimuli included lyrics. Future work could explore the influence of lyrics by comparing movement and interaction in response to stimuli with and without lyrics.

Future work should also consider movement variables, particularly dyadic movement variables, as they unfold temporally rather than reducing movement to a single descriptor value. To a limited extent, this was done in the current thesis in Study IV, through the use of windowed analysis of periodic movement. However, the development and applications of more sophisticated measures to describe spontaneous, complex dance movement should be explored in future work. The development of quantitative measures of interaction and movement similarity should also be further explored. Such measures could be particularly valuable to study for dyadic movement in the context of music or dance therapy.

8.3 Concluding remarks

This thesis has provided an exploration of individual differences, empathy, and social functioning as they are manifested in free, spontaneous dance movement, from a variety of viewpoints. It is clear that there are differences between physically responding to music alone and in the presence of another, and that the quality and strength of these differences depends most highly on the unique combination of individuals from which dyadic effects emerge. Although empathy may play a role in determining how an individual will respond to a dyadic partner, it is clear from the results of this thesis that there are other, possibly more important, factors at work.

Within this thesis, methods of collecting and analyzing dyadic, full-body motion capture were developed and identified, as was a novel, data-driven approach to identifying and selecting naturalistic music stimuli. In addition to the results, these methodological developments represent a contribution to future music psychology research and particularly movement-based research interested in social aspects of music and dance. Finally, this thesis has raised questions to be explored in further research about the relationship between entrainment, empathy and social behaviors in music and dance. Given the inherently social nature of dance, it can be hoped that they will be considered questions worth asking.

YHTEENVETO (FINNISH SUMMARY)

Kun tanssimme, teemme sitä tavallisesti jonkun muun kanssa. Tanssi tapahtuu usein sosiaalisessa ympäristössä, esimerkiksi klubissa tai juhlassa. Tanssiessamme toisten kanssa omat liikkeemme voivat vaikuttaa näiden liikkeisiin, tai nämä voivat vaikuttaa omiimme. Tämä väitöskirja tutkii eräitä niistä tekijöistä, jotka voivat vaikuttaa 'musiikin synnyttämään liikkeeseen'—eli tanssimiseen—kuten personaalisuutta, empatiaa ja sosiaalista kontekstia. Väitöskirja koostuu neljästä tutkimuksesta. Ensimmäisessä tutkimuksessa 30 osallistujaa tanssi sellaisen musiikin tahdissa, jossa oli pieniä muutoksia tempossa. Tunnolliset ja vähemmän ulospäinsuuntautuneet koehenkilöt seurasivat tanssiliikkeillään tempomuutoksia enemmän kuin muut. Analyysi ei kuitenkaan paljastanut korrelaatiota empatian kanssa, mikä viittaa siihen, että empatia on merkityksellisempi sosiaalisessa kontekstissa.

Tätä hypoteesia testattiin jatkotutkimuksessa, jossa 73 koehenkilöä tanssi liikekaappauslaboratoriossa sekä yksin että pareittain muutaman eri tanssikumppanin kanssa kuunnellen kahdeksaa eri tyylilajia edustavaa musiikkia. Nämä oli valittu hyödyntämällä tietokonealgoritmia, joka valikoi *big data* -tietokannasta mahdollisimman luonnollisia musiikkinäytteitä, ja tätä prosessi on raportoinut kahdessa paperissa. Liikkeen kinemaattinen analyysi yhdessä Social Relations -mallin (SRM) kanssa näytti että empaattisemmat koehenkilöt muuttivat muita enemmän tanssiliikkeitään tanssikumppaniensa mukaisiksi. Viimeisessä tutkimuksessa, selvitettiin vuorovaikutuksen havaitsemista tanssiliikkeessä käyttäen liikekaappausdatasta laadittuja animaatioita. Analyysi osoitti, että pareissa, jotka koostuivat yhdestä empaattinen tanssija ja yhdestä vähemmän empaattisesta tanssijasta, havaittiin enemmän tanssijoiden välistä vuorovaikutusta. Kokonaisuudessaan nämä tulokset maalaavat moniulotteisen kuvan tanssin vuorovaikutuksellisesta puolesta ja sosiaalisen kontekstin merkityksestä joita on syytä tutkia edelleen myös tulevaisuudessa.

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ORIGINAL PAPERS

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CONSCIENTIOUSNESS AND EXTRAVERSION RELATE TO RESPONSIVENESS TO TEMPO IN DANCE

by

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Conscientiousness and Extraversion relate to responsiveness to tempo in dance

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ABSTRACT

Previous research has shown broad relationships between personality and dance, but the relationship between personality and specific structural features of music has not been explored. The current study explores the influence of personality and trait empathy on dancers' responsiveness to small tempo differences between otherwise musically identical stimuli, measured by difference in the amount in acceleration of key joints. Thirty participants were recorded using motion capture while dancing to excerpts from six popular songs that were time-stretched to be slightly faster or slower than their original tempi. Analysis revealed that higher conscientiousness and lower extraversion both correlated with greater responsiveness to tempo change. Partial correlation analysis revealed that conscientiousness remained significantly correlated with responsiveness when extraversion was controlled, but not vice versa. No effect of empathy was found. Implications are discussed.

1. Introduction

Most people respond to music with some form of bodily action, from tapping quietly along to the beat while hearing a symphony to dancing raucously to a pounding bass in a nightclub (Lesaffre et al., 2008). An inseparable relationship between action and knowledge was suggested as long ago as the fifteenth century by Wang Yangming in China (Tiwald & Van Norden, 2014), about two centuries before Descartes firmly severed the two in the West, but it is just in the last few decades that 'embodied cognition' has garnered interest from philosophers and researchers alike seeking to understand human cognition (Wilson, 2002). It is probably not a coincidence that current interest in embodied cognition has arisen concurrently with the discovery of the mirror neuron system that employs internal simulation of another's movements, suggesting that we understand others' actions via knowledge of our own capacity for action (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Iacoboni, 2009),

The idea that perception of and interaction with the physical world is central to the development and functioning of cognitive processes (Lakoff & Johnson, 1999; Wilson, 2002) challenges the classical distinction between body and mind. Studies have shown, for example, that participants' facial expressions can influence their affective judgments (Strack, Martin, & Stepper, 1988), that making a fist can increase willpower (Hung & Labroo, 2011; Schubert & Koole, 2009), and that posture can moderate affective, social and even pain responses to various stimuli (Bohns & Wiltermuth, 2012; Briñol,

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Petty, & Wagner, 2009; Welker, Oberleitner, Cain, & Carré, 2013). Conversely, properties of the mind influence the characteristics of bodily movements; it would be strange to imagine a depressed person skipping along briskly, or an extravert to carry herself with slumped shoulders or to stay stuck to one spot on the floor while dancing (Ada, Suda, & Ishii, 2003; Hicheur, Kadone, Grèzes, & Berthoz, 2013; Michalak et al., 2009).

In the domain of music-induced movement, similarly intuitive results have been found. Music does not move each of us in the same way, but interacts with our individual traits such as personality or mood to affect music-induced movement (Burger, Saarikallio, Luck, Thompson, & Toiviainen, 2013; Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2014). It has also been suggested that music perception involves mental simulation of sound-producing movements (Godøy, 2003; Leman, 2008)—an idea supported by evidence that motor and auditory neural networks are quickly linked in the learning of sound-producing actions (Lahav, Saltzman, & Schlaug, 2007) and in rhythm perception more generally (Chen, Penhun, & Zatorre, 2008). In light of such findings, Leman (2008) has proposed 'embodied music cognition' as a framework for new music cognition research, and developed the idea of subjective, corporeal interaction with 'moving sonic forms' as the basis for direct musical experience. Within this paradigm, internal (mental) and external (physical) imitation of the music's 'movement' define our cognitive understanding of music. The individual differences in our movements in response to music can be considered reflections of our individual differences in perception and processing of music, for example in our ability to experience affective change as a result of hearing music (Sandstrom & Russo, 2013). Other differences that might be reflected in embodied responses to music might include age, previous learning, unique experiences and associations, physical or cognitive illnesses or disabilities, cultural influences, elements of the music itself, and personality.

Early personality theory emphasized the body by positing that physiological differences of sensory processing moderated behavioral engagement (e.g. Eysenck (1967), Gray (1972)). Further study led to the development of the Five-Factor Model (FFM) of personality, defined by five bipolar traits: neuroticism, extraversion, openness, agreeableness, and conscientiousness (Digman, 1990; McCrae & Costa, 1987). The FFM is used widely in research, and its factors have been shown to relate to individual differences in task performance, motivation, and social interaction (Cuperman & Ickes, 2009; Hurtz & Donovan, 2000; Judge & Ilies, 2002). Bodily movement can play an important role in the expression and perception of personality (Ball & Breese, 2000). DeGroot and Gooty (2009) found that, when either only visual or only vocal cues were available to participants assessing interviews, visual cues were sufficient to distinguish conscientiousness while vocal cues were sufficient to distinguish extraversion. Koppensteiner (2011) found that participants were able to reliably recognize personality traits from just the movements of an animated black circle.

Links between music and personality have also been found, for example between FFM traits and music preference (Dunn, de Ruyter, & Bouwhuis, 2012; Gosling, Rentfrow, & Swann, 2003; Vuoskoski & Eerola, 2011; Zweigenhaft, 2008) and between FFM traits and free-movement dance performances. Luck, Saarikallio, Burger, Thompson, and Toiviainen (2010) correlated several movement feature dimensions with high and low scores in each of the FFM traits, and found that agreeableness, extraversion and conscientiousness correlated positively with global movement (use of space), while extraversion, openness and neuroticism correlated positively with local movement (limb movement). Personality traits may also interact with the listener's affective state, perceived musical emotion, and the music's timbre, beat and metrical features of the music in influencing music-induced movement (Burger et al., 2013; Luck et al., 2014).

Existing research, however, leaves many gaps in our understanding of how individual differences are expressed in music-induced movement. Personality traits may relate to movement characteristics via dissimilar mechanisms; highly conscientious and highly extraverted participants, for example, might respond to music with more global movement for different reasons. There could also be important factors yet unexplored. Leman (2008) has suggested, for example, that the internal and external imitation of music is a form of empathy (p. 123). This idea has not yet been empirically examined, though it is rooted in a strong theoretical tradition: aesthetic philosophers posited hidden imitation as the mechanism behind empathy even before the discovery of the mirror neuron system (Carr et al., 2003; Verducci, 2000; Zahavi, 2010). Under Leman's model, a more empathic person could be expected to respond with greater sensitivity to musical stimuli. Previous studies have linked musical engagement with increased empathy (Kirschner & Tomasello, 2010; Rabinowitch, Cross, & Burnard, 2013), further suggesting that empathy may play a role in music-induced movement. Previous work in empathy also suggests that it may play a role in human responsiveness and movement to music (Juslin & Laukka, 2004).

Although previous music and movement research has used high-level music features like genre or expressed emotion as factors in comparisons, changes in lower-level features, such as tempo or timbre, can also affect music-induced movement (Burger et al., 2013) and have yet to be thoroughly explored in relation to individual personality differences. Since it has been shown that low-level features are processed pre-attentively (Koelsch, Schroger, & Gunter, 2002; Tervaniemi, Ilvonen, Karma, Alho, & Näätänen, 1997), they may be better suited to teasing out subtle differences in personality. Responsiveness to tempo and changes therein has been extensively studied in sensorimotor synchronization literature via tapping studies (e.g. Repp (2005), Repp and Su (2013)), but not in the naturalistic context of full body movements, and not in relation to individual differences. Participants who are highly empathic might be more sensitive to subtle changes in tempo, and may more readily adjust their movements accordingly. Participants who are highly conscientious might also be expected to adjust their dance movements in response to tempo, as previous research has suggested the importance of conscientiousness above other traits in determining task performance (Barrick & Mount, 1991; Judge, Erez, & Bono, 1998; Judge & Ilies, 2002), As other research has suggested that extraversion, for example, may also play a roll in task performance (Witt, 2002), the possibility for other personality traits to affect tempo responsiveness remains open as well. The following research questions have therefore emerged from the existing literature:

RQ 1) How might personality and trait empathy relate to dancers' embodied sensitivity to differences in a basic musical feature (tempo)?
RQ 2) How are dancers' personality traits related to their embodied responses to music?

The current study aimed to address these questions by using motion capture to measure the amount of acceleration in dancers' free movement responses to stimuli that had been manipulated to have slight differences in tempo, and comparing these responses with dancers' self-reported personality and empathy traits. Previous research suggests that participants move differently to music based on musical qualities such as genre or expressed emotion, that empathy is related to responsiveness to music, that personality is related to task performance, and that interactions between traits may also influence behavior. Therefore, we proposed the following specific hypotheses based on previous research:

H1. Conscientiousness will relate positively to differences in the amount of movement dancers make in response to tempo-differentiated stimuli.

H2. Empathy will relate positively to the amount of difference dancers make in response to tempo-differentiated stimuli.

2. Method

2.1. Participants

Thirty participants (15 female, 15 male, average age: 28.2, SD of age: 4.4) were recruited locally using various e-mail lists and social media outlets. Participants comprised university students of 15 nationalities. Four participants had received professional music education. Twenty-two participant had received music education as children or adults, of whom 13 were still actively playing and instrument or singing. Fourteen participants had taken dance lessons of various styles. Participation was rewarded with a movie ticket (value ≅10.00€). All participants gave their informed consent prior to their inclusion in the study and were free to discontinue the experiment at any point. Ethical permission for this study was not needed, which was according to the guidelines stated by the university's ethical board.

2.1.1. Stimuli

The stimulus material consisted of the first 35 s from six classic Motown/Rhythm and Blues (R&B) songs from the mid-1960s to the early 1970s (see Table 1). The songs were chosen for their danceability, related to the notion of groove (Janata, Tomic, & Haberman, 2012), their homogeneity of musical, and ubiquity in popular music culture. All songs employed simple duple meters with light to moderate amounts of swing; while the duplet divisions of the beat were not played perfectly straight, there were no overt triplet divisions of the beat. Furthermore, the songs were divided into three distinct core tempo groups of around 105, 115, and 130 BPM and slightly time-stretched (using Audacity ver. 2.0.5) to match these BPMs exactly (see Table 1 for the exact original and final tempi).[1] This tempo range was chosen as it falls within the preferred beat rate for spontaneous tempo (Fraisse, 1984), and could thus be expected to afford a comfortable range of movement. The stimuli were time-stretched a second time to produce tactus rates at ±5% of the three core rates, resulting in a slow and a fast version of each song, each slightly shorter or longer than the original. The stimulus length was chosen to keep the experiment sufficiently short while being long enough to induce movement.

2.2. Apparatus

Participants' movements were recorded using an eight-camera optical motion capture system (Qualisys Oqus 5+), tracking, at a frame rate of 120 Hz, the three-dimensional positions of 28 reflective markers attached to each participant. The locations of the markers can be seen in Fig. 1A and B. The location of the markers were as follows (L = left, R = right, F = front, B = back): 1: LF head; 2: RF head; 3: LB head; 4: RB head; 5: L shoulder; 6: R shoulder; 7: sternum; 8: spine (T5); 9: LF hip; 10: RF hip; 11: LB hip; 12: RB hip; 13: L elbow; 14: R elbow; 15: L wrist/radius; 16: L wrist/ulna; 17: R wrist/radius; 18: R wrist/ulna; 19: L middle finger; 20: R middle finger; 21: L knee; 22: R knee; 23: L ankle; 24: R ankle; 25: L heel; 26: R heel; 27: L big toe; 28: R big toe. The musical stimuli were played back via a pair of Genelec 8030A loudspeakers using a Max patch (www.cycling74.com) running on an Apple computer. The direct (line-in) audio signal of the playback and the synchronization pulse transmitted by the Qualisys cameras when recording were recorded using ProTools software in order to synchronize the motion capture data with the musical stimulus afterwards. Additionally, a video camera was used to record the sessions for reference purposes.

[1] This was done for the purpose of a perceptual experiment for which these data were also used.

Table 1
Overview of the six Motown songs used in the experiment.

Artist	Song	Original BPM	Core BPM	Slow BPM	Fast BMP	R&B chart rating (year)
Temptations	Get Ready	134.5	130	123.5	136.5	#1 (1966)
Supremes	Where did Our Love Go?	133	130	123.5	136.5	#1 (1964)
Supremes	Stop, in the Name of Love	117	115	109.25	120.75	#2 (1964)
Wilson Pickett	The Midnight Hour	113	115	109.25	120.75	#1 (1965)
Stevie Wonder	Signed, Sealed, Delivered	105.5	105	99.75	110.25	#1 (1970)
Temptations	My Girl	103	105	99.75	110.25	#1 (1964)

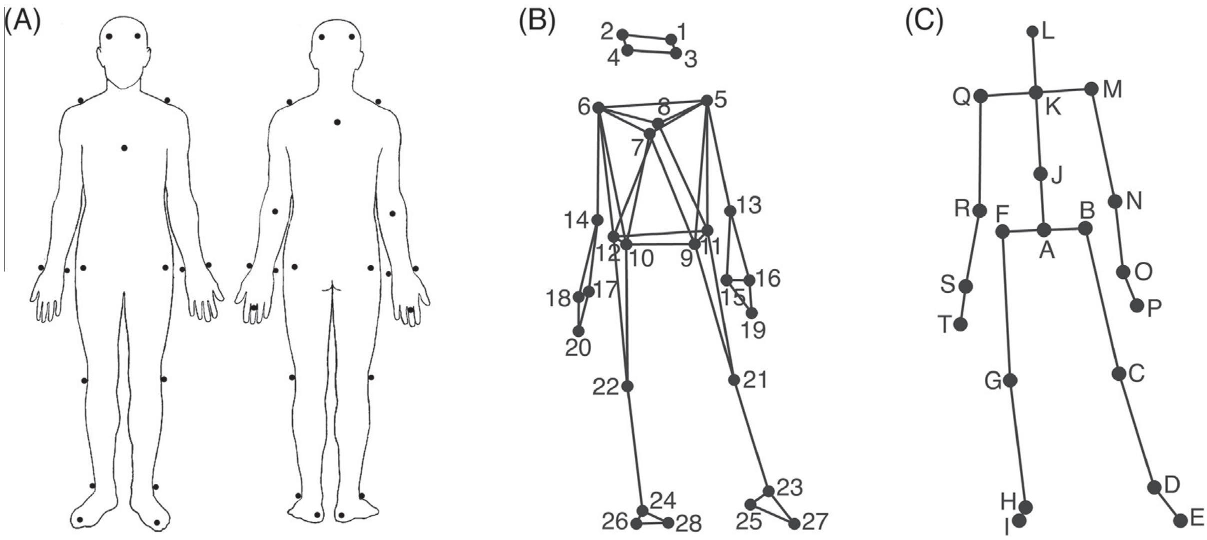

Fig. 1. Marker and joint locations. (A) Anterior and posterior view of the marker placement on the participants' bodies; (B) anterior view of the marker locations a stick figure illustration; (C) anterior view of the locations of the secondary markers/joints used in the analysis.

2.3. Procedure

Participants were recorded individually. They were asked to imagine being in a social setting such as a dance club. The six songs were presented in random order for each participant, in blocks including both fast and slow versions of each particular stimulus, in an order that was counterbalanced among the participants. Participants were asked to dance freely and were further advised to remain synchronized to the music and stay in the capture area marked on the floor (appr. 3×4 m). Participants were informed that they would hear the same stimuli at multiple tempos. They were free to rest whenever they wished during the experiment. Experimental trials lasted an average of 45 min.

After the movement data collection, participants responded to a set of questionnaires (programmed into a Max patch running on an Apple iMac computer), which included participant background information as well as personality measures for FFM traits and Empathy. FFM traits were measured using the Ten-Item Personality Inventory (TIPI), developed and validated by Gosling et al. (2003) and further validated by Ehrhart et al. (2009) using latent factor analysis. Empathy was measured using the Interpersonal Reactivity Index (IRI). Davis (1983) developed the IRI to assess cognitive and emotional aspects of empathy, including four subscales of different types of empathy: Perspective Taking, Fantasy, Empathic Concern and Personal Distress, the first of which is generally considered cognitive while the others are considered affective. For the purposes of this study, we chose to use only the Perspective Taking (PT) subscale, as it is most easily relatable to basic definitions of empathy as the understanding of another (Gerdes, 2011; Verducci, 2000; Zahavi, 2010).

2.4. Movement data processing

Using the Motion Capture (MoCap) Toolbox (Burger & Toiviainen, 2013) in MATLAB, movement data of the 28 markers were first trimmed to match the exact duration of the musical excerpts. Gaps in the data were linearly filled. Following this, the data were transformed into a set of 20 secondary markers – subsequently referred to as joints. The locations of these 20 joints are depicted in Fig. 1C. The locations of joints C, D, E, G, H, I, M, N, P, Q, R, and T are identical to the locations of one of the original markers, while the locations of the remaining joints were obtained by averaging the locations of two or more markers; Joint A: midpoint of the four hip markers (referred to as the root marker in the further analysis); B: midpoint of markers 9 and 11 (left hip); F: midpoint of markers 10 and 12 (right hip); J: midpoint of breastbone, spine, and the hip markers (midtorso); K: midpoint of shoulder markers (manubrium), L: midpoint of the four head markers (head); O: midpoint of the two left wrist markers (left wrist); S: mid-point of the two right wrist markers (right wrist). Subsequently, the data were rotated so that the hip joints (A, B, and F) were aligned to be parallel to the x-axis on average, and transformed to a local coordinate system with joint A as the origin.

While responsiveness to tempo in synchronization tasks is traditionally assessed at the beat level, previous studies have typically employed a model in which all participants' movements are restricted to a small, more or less identical movement (finger tapping) that is easily comparable between participants. In the case of naturalistic, whole-body movements as in the current study, the potential for vast differences between dancers due to height and weight differences as well as differences in dancers' chosen movement responses to the music stimuli make such analysis very complex, although such analysis has been done (Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2014). Since the research questions of the current study relate not to synchronization accuracy but rather to responsiveness to tempo, beat-level analysis was considered inappropriate in this case, particularly as participants might easily over- or under-adjust to tempo changes for myriad reasons. Instead, analysis focused on overall adaptation to tempo. Acceleration was chosen to assess the participants' overall amount of movement in each condition, as this was considered to be the most reflective of complex movement. Acceleration and has been previously identified as a key movement feature in allowing musicians to synchronize to conductors' gestures (Luck & Toiviainen, 2006), and could thus be expected to give some broad information about the overall tempo of the movements in each performance, allowing for comparison between dancers despite differences in dancers' free responses. Acceleration in three dimensions of the joints was calculated using numerical differentiation and a Butterworth smoothing filter (second order zero-phase digital filter). For each participant, the instantaneous magnitudes of acceleration were estimated for each joint and stimulus, and subsequently temporally averaged over each stimulus, resulting in a mean amount of overall bodily acceleration (in mm/s^2) for each dance performance. These values were subsequently averaged over contralateral joints. Thus, for each participant, acceleration means for the following 11 joints were obtained: head, neck, torso, hips, knees, ankles, feet, shoulders, elbows, wrists and hands. The degree to which movement features differed between the two tempo conditions was obtained by subtracting participant means of acceleration values between conditions, positive values indicating higher amounts of movement in the faster conditions.

3. Results

Analysis focused on determining the relationship between dancers' personality traits and their movement responses to differences in tempo between stimuli. Data were first checked for normality of distribution. Out of 30 participants, 24 rated themselves 8 or higher on the Openness scale of the TIPI, creating a negative skewness. The other scales were not skewed. As previous research has shown that high levels of Openness predict involvement in music and the arts (McManus & Furnham, 2006; Rawlings & Ciancarelli, 1997), this skewness could have reflected the fact that the majority of the participants were musicians. To assess this, independent-samples *t*-tests were used to compare means between formally trained musicians and non-musicians, and between participants currently active in music making and those not currently active. Results showed a significant difference between formally trained musicians (M = 7.55, SD = 1.23) and non-musicians (M = 5.80, SD = 1.62) in Conscientiousness $t(28) = 3.3$, $p = <0.01$. No other differences in personality were found between formally trained musicians and non-musicians (p ranged from 0.08 to 0.84, t ranged from −1.8 to 1.5). Independent-sample *t*-tests showed no significant differences in personality between participants currently active in music-making and those not currently active (p ranged from 0.14–81, t ranged from −0.15 to 1.3). Thus musicianship did not explain the negative skew of Openness. Additionally, *t*-tests were run to assess any differences between participants with and without dance training. No significant differences were found (p range from 0.43 to 0.58, t ranged from −0.78 to 0.55), thus dance training also did not explain the negative skewness of Openness. One possible explanation could be that open individuals may be more likely to participate in experiments. Due to this negative skewness, the Openness scale was not considered in this analysis, as the participants were not expected to reflect a typical population.

TIPI and PT scores were first correlated with participants' mean acceleration scores, following previous research done by Luck et al. (2010). The mean amount of acceleration across all joints was moderately negatively correlated with Conscientiousness, $r(28) = -0.48$, $p < 0.01$, and non-significantly positively correlated with Extraversion $r(28) = 0.16$, $p = 0.38$.

To determine whether the differing stimuli resulted in differences in movement, a two-tailed, paired samples *t*-test comparing means of the slow and fast conditions showed a significant difference between the slow ($M = 13412.59$, $SD = 5908.33$) and fast ($M = 15267.11$, $SD = 6474.07$) in mean acceleration scores $t(29) = 7.81$, $p < 0.0001$, suggesting that the stimulus tempo indeed affected the participants' dance movements. Next, the difference between conditions in acceleration was correlated with TIPI and PT scores. There was a significant positive correlation between Conscientiousness and mean acceleration difference, $r(28) = 0.59$, $p < 0.01$, and a significant negative correlation between Extraversion and mean acceleration difference, $r(28) = -0.36$, $p < 0.05$, suggesting that participants who were more conscientious and introverted made greater differences between conditions. There were no other significant correlations between difference scores and FFM scores, and no correlations with trait empathy. Therefore, only the Conscientiousness and Extraversion scales were included in further analysis.

Further analysis focused on feature selection and examination of key bodily movement features for a more detailed picture of how participants responded to tempo differences. Principal Component Analysis (PCA) was performed on the difference in the amount of acceleration (determined by subtracting acceleration means for each condition per participant)

Table 2
Variable loadings for PCA results.

Joint	PC1	PC2	PC3
Hips	0.34	0.15	0.00
Knees	0.08	0.47	−0.00
Ankles	0.01	0.58	−0.02
Feet	−0.08	**0.62***	0.02
Shoulders	0.36	0.01	0.11
Elbows	0.20	−0.01	0.35
Wrists	−0.04	0.02	0.61
Hands	−0.08	−0.00	**0.68***
Mid-torso	0.45	0.04	−0.06
Neck	**0.49***	−0.12	−0.04
Head	0.48	−0.01	−0.04

* Indicates variable with the highest loading for each variable.

Table 3
Correlations between personality traits and movement components, DF = 28.

	E	C	Core body	Lower limbs	Upper limbs
C	−0.30	–			
Core body	−0.39*	0.36*	–		
Lower limbs	−0.42*	0.60***	0.56**	–	
Upper limbs	−0.22	0.61***	0.67***	0.68***	–

Note. E: Extraversion; C: Consciousness.
* $p = 0.05$.
** $p = 0.01$.
*** $p < 0.001$.

between conditions for each of the 11 joints. This was done order to address collinearity between related variables (movements of the elbow are related to movements of the wrist, for example) and reduce the number of variables needed for further analysis. The first three components collectively contained more than 95% of the variance, and were therefore chosen for further examination. To simplify the interpretation, components were rotated to align with coordinates using varimax rotation, the results of which can be seen in Table 2. The resulting first principal component (PC1) explained 82% of the variance and had the highest loading for differences between conditions in the neck, followed by the hip and torso, suggesting the importance of the core body in differentiating between tempi. The next component explained a further 8.2% of variance and had its highest loading on the toe markers, followed by the ankle and hip, reflective of differences made in the lower extremities. A third component explained an additional 5.7% of the variance and included highest loadings on the finger markers, reflecting differences in the upper extremities.

Joints with the highest loadings for each of the first three components (neck, foot and hand, respectively) were selected for further analysis, as joint data were considered to be more easily interpretable than component scores. Mean acceleration across conditions was calculated for these key joints, as well as the acceleration difference between conditions. As indicated by the loading structure, these markers reflect the movement of neighboring joints in the kinematic chain (see Table 2), therefore these components are subsequently referred to as core body, lower limbs, and upper limbs. Condition means and differences for all three key joints were correlated with Extraversion and Conscientiousness scores. Previous research has indicated that musicians may process temporal information more efficiently than non-musicians (e.g. Rammsayer and Altenmüller (2006)). To assess this, independent samples *t*-tests showed no significant differences between musicians and non-musicians in any of these measures (p ranged from 0.43 to.91, t ranged from −0.12 to 81), suggesting that the current results were not driven by musicianship. Independent samples *t*-tests also showed no significant differences between participants with and without dance training in any of these movement variables (p ranged from 0.12 to 0.97, t ranged from −0.03 to 1.56), suggesting that the current results were also not driven by dance training.

As shown in Table 3, there were significant positive correlations between Conscientiousness and upper limb responsiveness to tempo, lower limb responsiveness to tempo, and core body responsiveness to tempo. There were significant negative correlations between and Extraversion and lower limb and core body responsiveness to tempo. There was a negative correlation between Extraversion and upper limb responsiveness to tempo, but it was non-significant.

As both Extraversion and Conscientiousness appeared to significantly affect participants' responsiveness to tempo changes, further analysis was necessary to clarify the influence of each trait. Therefore, two partial correlations were performed on the data, using Extraversion and Conscientiousness respectively as control variables. Fig. 2 shows the relationships between Extraversion and tempo responsiveness variables with and without using Conscientiousness as a control

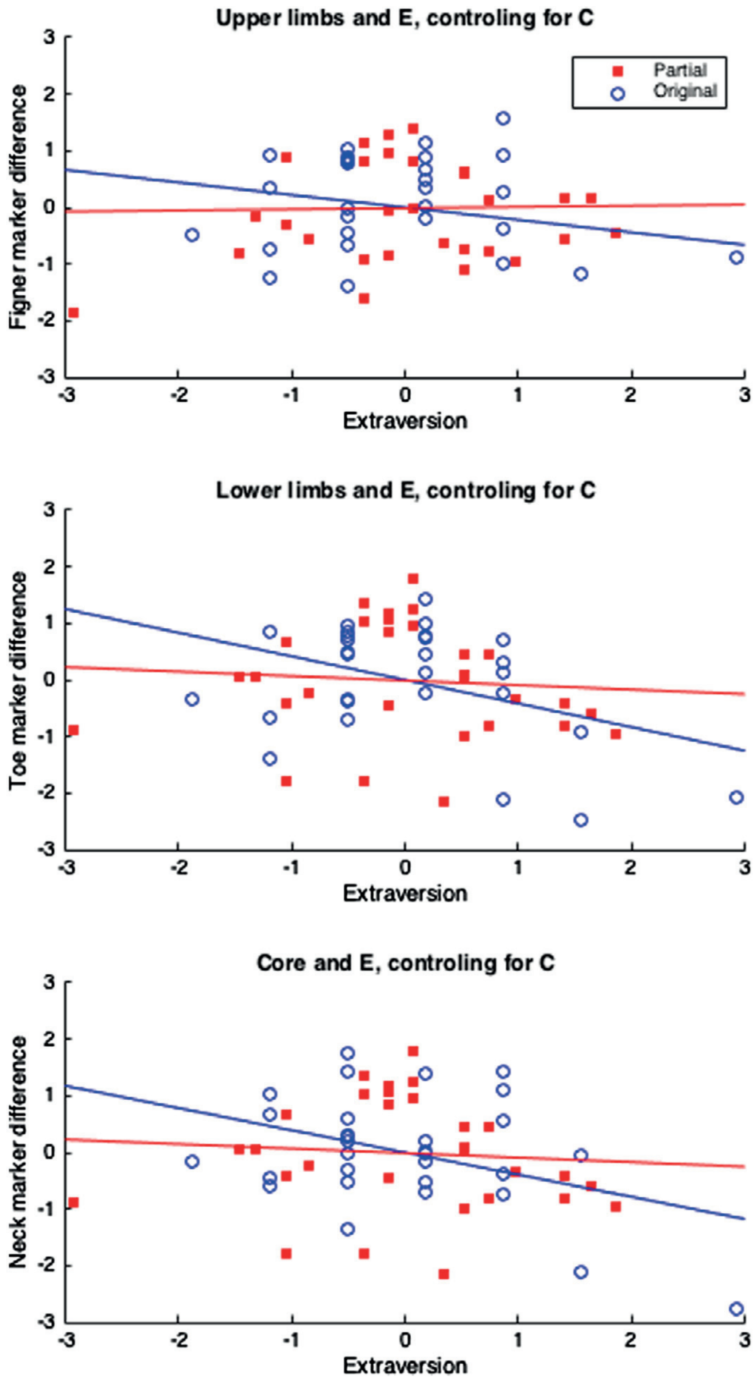

Fig. 2. Scatter plots showing original (circles) and partial (squares) correlations between Extraversion and tempo responsiveness variables. Lines represent least squares solutions.

variable. When controlling for the effect of Conscientiousness, Extraversion had a negative but non-significant effect on the amount of difference in acceleration between conditions in the core body responsiveness $r(27) = -0.32$, $p = 0.09$, and the lower limb responsiveness, $r(27) = -0.31$, $p = 0.10$, but virtually no relationship with the amount of difference in the upper limb responsiveness, $r(27) = -0.05$, $p = 0.80$.

Fig. 3 shows the relationships between Conscientiousness and tempo responsiveness variables with and without using Extraversion as a control variable. When controlling for the effect of Extraversion, Conscientiousness remained positively but non-significantly correlated with acceleration difference in the core body responsiveness $r(27) = 0.28$, $p = 0.13$, was still significantly correlated with lower limb responsiveness $r(27) = 0.55$, $p < 0.01$, and remained significantly correlated with upper limb responsiveness, $r(27) = 0.58$, $p = 0.001$.

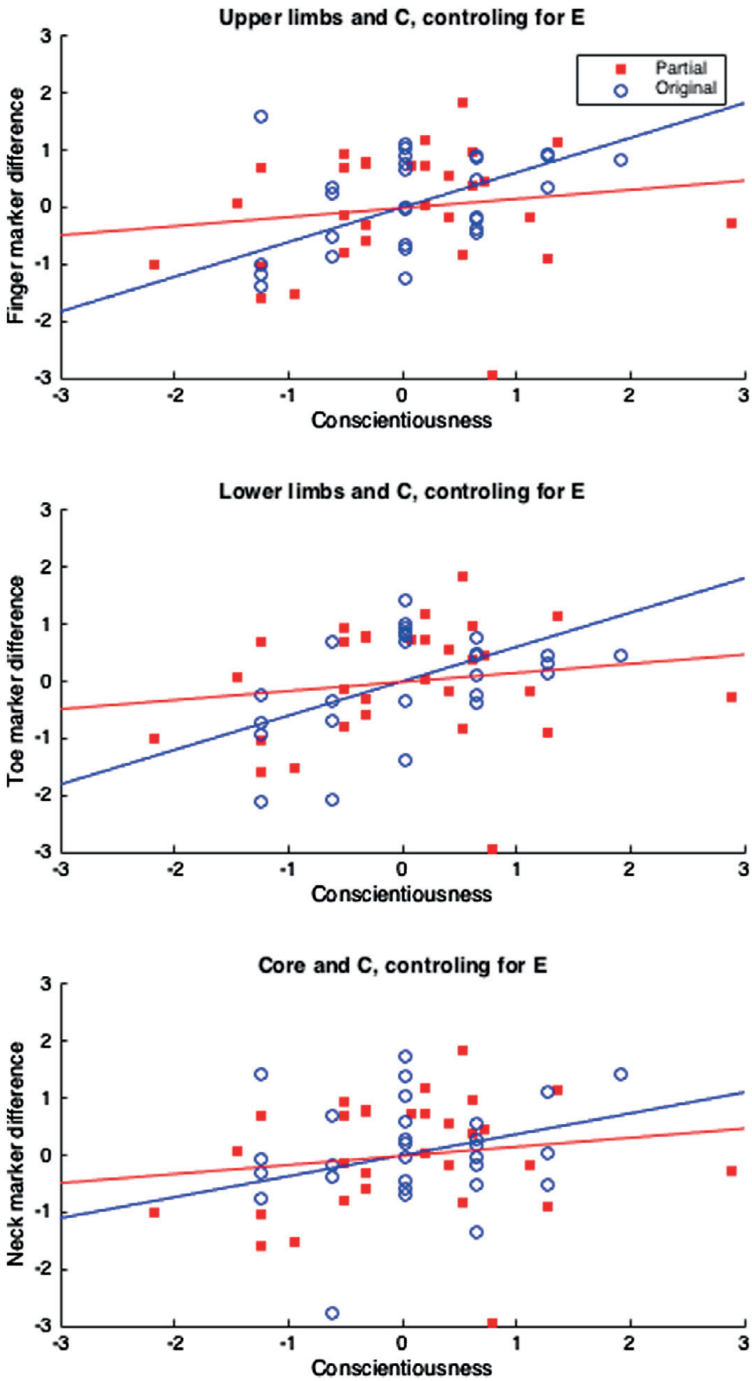

Fig. 3. Scatter plots showing original (circles) and partial (squares) correlations between Conscientiousness and tempo responsiveness variables. Lines represent least squares solutions.

4. Discussion

The current study examined how personality traits affect embodied tempo using data from free movement responses to artificially time-stretched songs by 30 participants. Over both conditions, it was found that extraversion related positively and conscientiousness related negatively to the amount of acceleration. For extraversion, this is similar to the findings by Luck et al. (2010). The lack of significance may indicate an overall effect of the more constrained task of synchronizing to different tempi compared to a completely free music-induced movement, or the fact that extreme scorers were used in that study. For conscientiousness, this trend is somewhat in conflict with the results of Luck et al., possibly suggesting that the presence of tempo differences and the instruction to synchronize to the music had a greater effect on conscientious participants. Conscientious participants may for example have inferred from the stimuli that good 'task performance' in this case might mean embodying the tempo differences as much as possible, meaning they slowed more for slower tempos. *T*-tests indicated that, although formally trained musicians rated themselves as more conscientious than non-musicians, results related to movement features were not driven by formal musical training or current involvement in music.

Further results support this interpretation. Although *t*-tests suggested that all participants made a significant difference between slow and fast stimuli in their dancing, conscientiousness participants made greater differences while extraverted participants made smaller differences. When key joints on the core body and upper and lower limbs were identified, the effects of personality became clearer. Conscientiousness was positively associated with the amount of acceleration difference between conditions in the core body, upper limbs and lower limbs, while extraversion was negatively associated with the amount of difference in all three key joints. When extraversion was controlled for, conscientiousness was still significantly related to tempo responsiveness in the limbs but not the core body. The significant correlations between extraversion and tempo responsiveness were not significant after partial correlation with conscientiousness as the control variable.

Conscientiousness has previously been associated with better task performance in various non-music domains (Barrick & Mount, 1991; Judge & Ilies, 2002; Judge et al., 1998). The current results support these previous findings and extend them to music- and dance-related domains, and further support our hypothesis that dancers higher in conscientiousness would create bigger differences in response to differing stimuli. Nevertheless, pinpointing the mechanism by which conscientiousness may have affected performance is tricky because, as pointed out by Roberts, Chernyshenko, Stark, and Goldberg (2005), "there is little conceptual or empirical agreement concerning the underlying structure of Conscientiousness" (p. 105). Various taxonomies have included facets like carefulness, thoroughness, vigilance, achievement, dependability, impulse control, and persistence (Digman, 1990; McCrae & Costa, 1987; Roberts et al., 2005). Conscientious participants may have been motivated to perform the dancing task well and have been particularly conscious of the tempo differences in light of instructions that they should stay synchronized to the music. This may point to achievement motivation and perhaps thoroughness as important aspects of conscientiousness in driving these results.

Partial correlations between extraversion and acceleration differences in core body and lower limb markers were moderate despite being non-significant, making explanations of the mechanism by which extraversion influenced results worth considering. Extraverts may have moved more overall, creating a ceiling effect; this idea would be supported by the results found by Luck et al. (2010), but not the current results as there was no significant correlation between extraversion and overall acceleration. Another explanation could be found in Eysenck's (1967) theory of personality, which explains differences along the extraversion dimension in terms of differences in biological mechanisms governing arousal and inhibition. This idea has been supported by research, for instance in showing that introverts had greater peaks in brain activity in response to auditory stimuli than extraverts (Stelmack, Achorn, & Michaud, 1977), and that introverts' directed attention resulted in less distraction, measured by brainstem startle response, than for extraverts (Blumenthal, 2001). Research has furthermore suggested that extraversion is associated with faster stimulus habituation (LaRowe, Patrick, Curtin, & Kline, 2006), and that introverts may prepare movement more quickly in response to a stimuli compared to extraverts (Stahl & Rammsayer, 2004). This evidence, taken with the current results, may suggest that introverts may have been more sensitive than extroverts to the stimuli influencing their movement output. It is possible that the primary mechanism by which extraversion affected dancers' movements was preconscious or taking place at a lower level of cognitive processing, while the mechanisms by which conscientiousness affected results was more conscious. That extraversion had no notable effect on responsiveness in the upper limbs after controlling for conscientiousness, suggests that when participants consciously embodied the different tempi they tended to use their hands.

It may be noted that, in this interpretation, introversion essentially takes the place of empathy in our predictions regarding participants' responsiveness to the music stimuli on a basic level. Extraversion did not correlate with empathy in our study, although it has done in previous studies (Del Barrio, Aluja & García, 2004; Mooradian, Davis, & Matzler, 2011). Whether this inconsistency highlights weaknesses in Leman's (2008) theories or in current understandings of empathy is a matter of speculation. Empathy is a multi-faceted and often poorly defined concept which some believe is more complex than mental or motoric simulation as a means of understanding. Zahavi (2010) points out that it is not impossible to recognize happiness in a dog in the absence of a corresponding tail to wag. Although the IRI is designed to assess multiple types of empathy, it was developed just prior to the popularization of the mirror-neuron theory of empathy as mental imitation (Carr et al., 2003; Iacoboni, 2009), and thus may not be an appropriate measure of the low-level processing that may correspond to Leman's definition of empathy in music processing (Gerdes, 2011; Leman, 2008). In further research, more recently developed measures of empathy such as the Empathy-Quotient (Baron-Cohen & Wheelwright, 2004) could be explored to address this discrepancy. It is also possible that new conceptualizations of introversion and empathy will be needed to account for individual differences in responsiveness to musical stimuli.

Some limitations to the current study need to be considered. That the majority of participants were musicians may decrease the generalizability of the current study. However, *t*-tests indicate that musicianship was a non-significant factor in determining these results. Additionally, the current study employed the TIPI for measurement of the FFM, which may not be as sensitive as longer FFM tests, but did allow for reasonable demands on participants' time and attention.

The results of the current study highlight the need for further investigation to increase understanding of the relationship between individual personality differences and music-induced movement. These results suggest that both conscious and unconscious mechanisms stemming from individual differences may have an effect on how participants embodied tempo changes in the music stimuli. Continued research could seek to further distinguish between effects of conscientiousness and extraversion, as well as other FFM traits, by choosing extreme scorers as participants. Further study could also specifically examine motoric imitation and empathy as mechanisms of music cognition, and also use other measures of empathy to determine whether these may prove more relevant to music-induced movement research. Finally, further study is needed to determine any relationships between whole-body movement responsiveness to tempo using finer-grained measures of sensorimotor synchronization.

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II

PERSONALITY AND MUSICAL PREFERENCE USING SOCIAL-TAGGING IN EXCERPT-SELECTION

by

Carlson, E., Saari, P., Burger, B., & Toiviainen, P. (2017)

Psychomusicology: Music, Mind, and Brain, 27(3), 203-212.

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III

DANCE LIKE SOMEONE IS WATCHING: A SOCIAL RELATIONS MODEL STUDY OF MUSIC-INDUCED MOVEMENT

by

Carlson, E., Burger, B., & Toiviainen, P. (accepted 28.9.2018)

Music and Science

Abstract

Although dancing often takes place in social contexts such as a club or party, previous study of such music-induced movement has focused mainly on individuals. The current study explores music-induced movement in a naturalistic dyadic context, focusing on the influence of personality, using Five Factor Model (FFM) traits, and trait empathy on participants' responses to their partners. Fifty-four participants were recorded using motion capture while dancing to music excerpts alone and in dyads with three different partners, using a round-robin approach. Analysis using the Social Relations Model suggested that the unique combination of each pair caused more variation in participants' amount of movement than did individual factors. Comparison with self-reported personality and empathy measures provided some preliminary insights into the role of individual differences in such interaction. Self-reported empathy was linked to greater differences in amount of movement in responses to different partners. When looking at males only, this effect persisted for the whole body, head and hands. For females, there was a significant relationship between participants' Agreeableness and their partners' head movements, suggesting that head movement may function socially to indicate affiliation in a dance context. Although consisting of modest effect sizes resulting from multiple comparisons, these results align with current theory and suggest possible ways that social context may affect music-induced movement and provide some direction for future study of the topic.

Keywords: dance; motion capture; personality; empathy; dyadic movement

Despite the ubiquity of posters, t-shirts, and internet memes urging us to "dance like no one is watching," dance often takes place in social contexts such as clubs, concerts, or parties, where being seen by others is almost inevitable. Being seen may even be part of the point of dance; recent studies have suggested that synchronizing with others to music can promote social bonding (Quiroga Murcia, Kreutz, Clift, & Bongard, 2010; Rabinowitch et al., 2015; Vicary, Sperling, Von Zimmermann, Richardson, & Orgs, 2017) and even increase pain tolerance (Tarr et al., 2016), supporting evolutionary theories that music and dance developed to support social cooperation necessary for human survival, in contexts such as group chorusing or sexual selection (Hodges, 2009; Huron, 2001; Phillips-Silver, Aktipis, & Bryant, 2010; Wang, 2015). Factors such as personality, felt and perceived emotion, music preference, and even sexual attractiveness have been related to qualities of free dance movements (Burger, 2013; Burger, Saarikallio, Luck, Thompson, & Toiviainen, 2013; Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010; Saarikallio, Luck, Burger, Thompson, & Toiviainen, 2013), all of which could possibly be decoded by observers, allowing dance to function as a kind of social signaling.

Previous studies of dance have tended to focus on individual participants, and have shown free dance movement to be reflective of individual qualities such as personality, or felt or perceived emotion (e.g., Burger, 2013; Carlson, Burger, London, Thompson, & Toiviainen, 2016; van Dyck, Maes, Hargreaves, Lesaffre, & Leman, 2013; Luck et al., 2010). A few recent studies suggest that social context plays an important role in such music induced movement. Solberg and Jensenius (2017) used a naturalistic Electronic Dance Music (EDM) setting to show that the presence of and increased movement with other dancers increased subjective enjoyment of the dance experience. De Bruyn, Leman, and Moelants (2008) found that, in nine-year-old children, movement intensity as measured by Wii-remotes was increased in a social compared to individual setting, while van Dyck and Moelants et al. (2013) found evidence for group entrainment in that there were greater correlations between dancers' tempos and activity within rather than between groups. Using choreographed movement exercises, von Zimmermann, Vicary, Sperling, Orgs, and Richardson (2018) found that movement similarity between dyads in a group predicted group affiliation better than synchronization of the full group. However, while these studies provide valuable information about interpersonal coordination and the behaviors of a group, they are unable to provide information about how an individual's improvised, spontaneous dance movements, such as have been shown to reflect personality (Luck et al., 2010), might be influenced by the presence of another dancer in a naturalistic setting. Do we, in fact, dance differently when someone is watching, and moreover when we are watching someone else dance?

There is reason to believe that we do. Although there is a wealth of evidence that personality is generally stable across condition and time and indeed may be biologically based (Digman, 1990; Jang, Livesley, & Vemon, 1996; Letzring & Adamcik, 2015; Schaefer, Heinze, & Rotte, 2012; Soldz & Vaillant, 1999), there is similar evidence from social psychology research on that social context is a major determinant of behavior (Holtgraves, 2011; Malloy, Barcelos, Arruda, DeRosa, & Fonseca, 2005; Webster & Ward, 2011). It is thus imperative to consider both an individuals' own tendencies and the influence of other individuals (and their own natural tendencies) when exploring social behavior (Griffin & Gonzalez, 2003; Wagerman & Funder, 2009). The widely-used Five Factor Model (FFM) of personality provides a useful measure of behavioral tendency through the measurement of five bipolar traits: Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism. Of these, Agreeableness and Extraversion are considered to be primarily interpersonal and therefore most relevant to social functioning, while Openness, Neuroticism and Conscientiousness are primarily intrapsychic (Ansell & Pincus, 2004). Agreeableness, which has also been labeled "likeability" and "friendliness," is characterized by tact, kindness, warmth, conformity and compliance (Graziano & Tobin, 2002), and has been linked to pro-social behavior (Graziano, Habashi, Sheese, & Tobin, 2007; Jensen-Campbell et al., 2002). Extraversion is characterized by positive affect, interest in social engagement and sensation-seeking (Ashton, Lee,

& Paunonen, 2002; Digman, 1990; Gray, 1970) and has been related to peer acceptance, goal-oriented behavior, and modest advantages in decoding nonverbal behavior (Berry & Hansen, 2000; Jensen-Campbell et al., 2002; McCabe & Fleeson, 2012). Across cultures, females report higher levels of both Extraversion and Agreeableness than males (Costa, Terracciano, & McCrae, 2001; Schmitt, Realo, Voracek, & Allik, 2008). There is evidence that high levels of both Extraversion and Agreeableness provide advantages in social interactions, although this can depend on the particular combination of personalities in a given dyad (Berry & Hansen, 2000; Cuperman & Ickes, 2009; Isbister & Nass, 2000).

Dyadic interactions may also be influenced by empathy. Empathy may be broadly defined as a complex psychological process, including both cognitive and affective components, which allows for the understanding of others' emotions and perceptions (Decety & Jackson, 2004; Harari, Shamay-Tsoory, Ravid, & Levkovitz, 2010; Shamay-Tsoory, Tomer, Goldsher, Berger, & Aharon-Peretz, 2004; Zahavi, 2010). As with Agreeableness and Extraversion, males tend to report lower levels of trait empathy than females, while neuroimaging has shown differences between males and females in brain networks recruited for empathy (Schulte-Rüther, Markowitsch, Shah, Fink, & Piefke, 2008). Empathy is particularly important to study in the context of music and dance, as deficiencies and abnormalities in empathic function, such as autism and schizophrenia, have been associated with various serious mental disorders currently being treated in clinical-music and dance- therapeutic settings (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2015; LaGasse, 2017; Lee, Jang, Lee, & Hwang, 2015), Promisingly, some studies have suggested a relationship between engaging in rhythmic entrainment, such as joint drumming activities or being swung in synchrony with a partner, and increased empathy or pro-social behavior (Kirschner & Tomasello, 2009; Rabinowitch et al., 2015; Rabinowitch, Cross, & Burnard, 2013; Rabinowitch & Meltzoff, 2017). Regarding free dance movement, Bamford and Davidson (2017) found that trait empathy was associated with better adjustment to abrupt tempo changes, while Carlson et al. (2016) found no relationship between empathy and adjustment to small tempo differences across stimuli. Both studies included individual dancing only; it may be that the effect of empathy on dance and other music-induced movement is clearer in an overtly social context. In the area of music performance, Novembre, Ticini, Schütz-Bosbach, and Keller (2014), found that more empathic participants appeared to rely more on motor simulations when adjusting their piano playing to a partner, supporting the importance of a social context in studying empathy in a dyadic movement context. Taken together, the previous work discussed above suggest that examining how individuals respond to a social setting in the context of free dance, taking both individual and social factors into account, is likely to provide new insights into music-induced movement in general.

Using movement variables gathered simultaneously from two dyad members to investigate the influence of one dancer on the other (and vice versa) raises unique analytical complications that do not come up in individual dance research. Parametric statistical tests assume independence (Field, 2009), violations of this assumption can have serious consequences for tests of significance, with marked increases in the likelihood of both Type I and Type II errors (Field, 2009; David A. Kenny & La Voie, 1984; Nimon, 2012; Wiedermann & Von Eye, 2013), and may take the form of partner effects, the influence of one participant on another, mutual influence between partners, or common fate, where both partners are exposed to the same conditions resulting in similar responses (Kenny, 1996). For example, Dancer B might wave her hands while dancing thereby encourage Dancer A to dance more vigorously than he would otherwise; this would be a partner effect. Dancer A and Dancer B may try to outdo each other in who can jump up and down the most, so the more Dancer A jumps the more Dancer B jumps and vice versa; this is an example of mutual influence. Finally, Dancer A and Dancer B may both be pretending to be chickens because they are both listening to The Chicken Dance; this is common fate. Untangling these influences on behavior is one of the main tasks of dyadic data analysis.

One approach to this problem has historically been the use of confederates whose behavior is constrained (Griffin & Gonzalez, 2003). Although this simplifies matters statistically, multiple researchers have pointed out that to capture truly naturalistic behavior, both actors should be free to respond to the other as they wish (Ickes, 2009). Various statistical models have been developed to cope with, explore and understand such non-independence, such as the Actor-Partner Interdependence Model (APIM) (Kenny et al., 2006) which considers the causal contribution of members of unique dyads while correcting for non-independence, or the latent dyadic model which assesses shared variance between members (Griffin & Gonzalez, 2003). However, considering a person within the context of only one dyad, as opposed to multiple dyads, entails some notable limitations for generalization (Back & Kenny, 2010; Malloy et al., 2005). Imagine, for example, that the reason Dancer A dances more vigorously when Dancer B waves her hands is that Dancer A wants to please Dancer B because they are friends. We might erroneously conclude that hand-waving is related to vigorous dancing, whereas Dancer A may dance *less* vigorously if Dancer C waves her hands, because he does not particularly like Dancer C. These are examples of *relationship effects*, knowledge of which are crucial in understanding dyadic effects, but which, as can be seen in the example, can be mathematically determined only if each participant has more than one partner. The Social Relations Model (SRM) provides a structure for determining general knowledge about dyadic phenomena by comparing an individuals' behavior with multiple partners (Back & Kenny, 2010; Gill & Swartz, 2001; Kenny et al., 2006). The aim of SRM is to separate causality of a given behavior as it takes place in a dyad (vigorous dancing, for example) into *actor effects* (the degree to which an individual tends to dance very vigorously), *partner effects* (the degree to which an individual tends to cause *their partners* to dance vigorously) and *relationship effects* (the degree to which an individual and a given partner have unique effects on the vigor of each other's dancing when compared to their behaviors with other partners). Across a sample, these are expressed in terms of variances. If we wished to investigate whether the presence of a partner influences hand-waving in dance and found a very large *actor variance* and a very small *partner* and *relationship* variances, we might conclude that the amount of hand-waving in dance depends chiefly by the person doing the hand-waving, regardless of their partner. On the other hand, if we found a very large *partner variance*, we could conclude that the amount of hand-waving would vary depending on who a person's partner is for a given interaction.[1] Similarly, a large *relationship variance* would indicate that the amount of hand-waving in determined by unique characteristics of a given dyad, such as friendship, liking, attraction, personality and so on (Back & Kenny, 2010; Kenny et al., 2006; Kenny, Mannetti, Pierro, Livi, & Kashy, 2002; Kenny & Cook, 1999).

The aim of the current study is to explore the relative influence of actor, partner and relationship effects using full-body motion capture in a naturalistic, free dance movement context using the Social Relations Model, taking into account individual differences of personality and empathy. The following research questions are posed:

RQ1) Does the presence of a partner moving to the same music affect music-induced movements of the individual?

RQ2) Do characteristics of an individual, specifically Agreeableness, Extraversion and trait Empathy, relate to responsiveness to a partner in a dance setting?

While previous work has been limited in its ability to extract movement from more than one body part per dancer (e.g., De Bruyn et al., 2008; Solberg & Jensenius, 2017), the current study employs full-body motion capture, making it is possible here to consider where specifically in the body social behavior might manifest in dance. While the whole body may be considered globally in

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[1] Note that this does not necessarily imply that hand-waving begets hand-waving, as in the case of mutual influence. If every one of Dancer B's partners immediately begins break-dancing when the music starts (meaning that Dancer B would be having have a very strong partner effect), it *may* be because Dancer B is always break-dancing, but it may also be because she is standing stark still while holding a sign that reads "break-dance now, or else." The current analysis does not tell us directly which scenario is true.

dance (Carlson et al., 2016), in a social context we may also expect the hands to be important as hand gestures are particularly associated with communication (Bernardis & Gentilucci, 2006; Goldin-Meadow, 2006; Krauss, Chen, & Chawla, 1996) . Head movements have also been shown to be important in communication, particularly in non-verbally communicating rapport (Beck, Daughtridge, & Sloane, 2002; Helweg-Larsen, Cunningham, Carrico, & Pergram, 2004; Tickle-Degnen & Rosenthal, 1990). Both may be implicated in musical contexts as well (Davidson, 2001; Luck & Thompson, 2010; Thompson & Luck, 2012). In an eye-tracking study, Woolhouse and Lai (2014) found that observers focused relatively little on dancers' feet and core body, focusing more on the head. Therefore, in addition to the body as a whole, head and hand movement are considered separately in the current study.

Kenny and Malloy (1988) reviewed SRM literature and found across samples that, against their expectations, partner effects (the degree to which an individual elicits consistent responses from all of their partners) were weak in affective and cognitive domains, virtually non-existent in behavioral domains, except to be slightly more apparent in nonverbal communication. It is therefore reasonable to assume there may be a similar pattern in the current context. They suggest that this may be due to individual differences as well as experimental context. Given these observations, as well as previous findings and theoretical considerations regarding personality and empathy, we make the following predictions:

H1) Participants will respond to the presence of a partner in a free dance context by changing aspects of their movement, specifically the overall amount of movement in the whole body, the head and hands (e.g. Goldin-Meadow, 2006; Helweg-Larsen et al., 2004; Kenny & Malloy, 1988).

H2) In line with previous behavioral research, participants' movements will be affected by the presence of a partner and their individual characteristics such that SRM analysis will show moderate actor and relationship effects and weak partner effects for movement of the whole body, hands and head, in dyadic condition (Kenny & Malloy, 1988).

H3) Participants will respond to the presence of a partner in a free dance context by changing aspects of their movement, specifically the overall amount of movement in the whole body, the head and hands (e.g. Goldin-Meadow, 2006; Helweg-Larsen et al., 2004; Kenny & Malloy, 1988).

H4) Participants who are high in Empathy, Agreeableness or Extraversion will vary their movement quality more in response to their partners, leading them to have smaller actor effects; as empathy and personality differ by sex, these correlations may also differ by sex (e.g., Baron-Cohen, 2009; Graziano, Habashi, Sheese, & Tobin, 2007; Riggio & Riggio, 2002; Schmitt et al., 2008).

2. Methods

2.1. Stimuli

Since music preference and genre have previously been related to qualities of music-induced movement (e.g., Burger, 2013), a stimuli set including multiple genres was considered desirable, both to allow for non-independence related to common fate, and to ensure that dyadic effects could not be attributed to the characteristics of a single genre. As genre in music is notably difficult to define (Pachet & Cazaly, 2000), to avoid researcher bias in stimuli selection a data-driven approach was devised using the methods described by Carlson, Saari, Burger and Toiviainen (2017). A total of 2407 tracks were collected from Last.fm which had been tagged by users as "danceable," "dancing," "head banging," or "headbanging," and which also were tagged with one and only one genre label (e.g. "Country" or "Jazz"). Tracks were retained only if they had a non-zero danceability score according to Echo Nest (which is determined by computational analysis of a given track's acoustic features including beat strength, tempo and loudness), and only if the track's tempo fell between 118-132 BPM. Four randomly selected excerpts from each genre were checked for tempo and stylistic consistency by the researchers, leaving 48 stimuli from 12 genres: Blues, Country, Dance, Funk, Jazz, Metal, Oldies, Pop, Rap, Reggae, Rock, Soul. For a complete description of this stimuli-selection methodology, see Carlson et al. (2017). Participants (n = 210) were recruited using University student and departmental e-mail lists and social media to rate their preference for these 48 excerpts in an online listening experiment using Survey Gizmo (www.surveygizmo.eu). Participants were entered into a lottery to win one of ten movie ticket vouchers, and were given feedback about their music preferences and personality upon completing the survey. Participants who completed the survey were also given the chance to sign up for the motion capture study.

For the motion capture study, the number of genres was reduced from 12 to eight, and the number of stimuli per genre from four to two, in order to keep the experiment sufficiently short and limit the effects of fatigue. From each genre, two stimuli with the highest variability in preference ratings were chosen. This resulted in a final set of 16 from the following eight genres: Blues, Country, Dance, Jazz, Metal, Pop, Rap and Reggae. Funk, Oldies, Rock and Soul had the least variability in preference ratings and were therefore eliminated. Stimuli were 35-seconds long, including a 2.5-second fade-in and 2.5-second fade-out as well as a sinusoidal beep at the start of each excerpt to mark the beginning for later synchronization with the motion capture data.

2.2. Participants

A total of 73 participants (54 females) completed the motion capture experiment. However, due to several cancelations and no-shows, only 52 (38 female) completed the experiment in groups of four. Since the SRM requires a minimum of four participants (Kenny, Kashy & Cook, 2006), only data from these groups were included in the current analysis. Thus, each group consisted of four participants, resulting in six dyads per group. Participants ranged in age from 19 to 40 years (M = 25.74, SD = 4.72). Thirty held Bachelor’s degrees while 16 held Master’s degrees. Thirty-three reported having received some formal musical training; five reported one to three years, ten reported seven to ten years, while 16 reported ten or more years of training. Seventeen participants reported having received some formal dance training; ten reported one to three years, five reported four to six years, while two reported seven to ten. Participants were of 24 different nationalities, with Finland, the United States and Vietnam being the most represented. For attending the experiment, participants received two movie ticket vouchers each. All participants spoke and received instructions in English.

2.3. Participant grouping

Previous work has shown small but fairly consistent relationships between personality and music preference (e.g., Greenberg et al., 2016; Rawlings & Ciancarelli, 1997; Rentfrow, Goldberg, & Levitin, 2011;). While it is not known how music preference affects music-induced movement in a dyadic setting, it is known that people make social judgements based on the music preferences of others (Rentfrow & Gosling, 2007; Rentfrow & Gosling, 2006; Rentfrow, McDonald, & Oldmeadow, 2009, Schäfer et al., 2015). Therefore, groups with evenly varied musical preferences were sought such that effects were not confounded by unusual similarity or unusual difference in preference between participants in a given group.

To achieve this, Principal Component Analysis (PCA) was performed on the participants' preference ratings of the 16 stimuli. The first component accounted for 22.6% of variance and included high negative loadings for both Metal excerpts, and moderately high positive loadings for Reggae, Rap and Pop excerpts, while loadings for other excerpts were small, suggesting preference for upbeat, contemporary, danceable music and a dislike for Metal. The second component accounted for 22.1% of variance and included high positive loadings for both Jazz excerpts and moderately high positive loadings for Metal, suggesting preference for one may relate to disliking of the other. Scores for these first two components were subjected to a median-split, and participants were subsequently divided into four categories: high in both components, low in both components, or high in one and low in the other respectively. Participants were grouped such that there was one member of each category in each group, limiting the possibility that movement effects could be attributed to unexpected convergence or lack of convergence in the dancers' music preferences. This approach allowed for the use of multiple genres while still allowing for participants to have varied music preferences.

Although an effort was made to prevent participants who knew each other well from being in the same group (for example, not granting requests from participants to be grouped with friends), a minority of participants (n ≈ 12) were acquainted before the experiment.

2.4. Personality Measures

Five Factor Model (FFM) personality dimensions were measured using the Big Five Inventory (BFI), a 44-item self-report measure in which participants rank their agreement on a seven-point Likert scale with statements such as "I see myself as someone who is talkative" or "… tends to be lazy" (Pervin & John, 1999). Only the Agreeableness (A) and Extraversion (E) scales were used in analysis, as these are considered interpersonal traits, most relevant for social functioning (Ansell & Pincus, 2004). In addition to personality, trait empathy was also measured. The Empathy Quotient (EQ), developed by Baron-Cohen and Wheelwright (2004), measures trait empathy as a whole, including both cognitive and affective aspects. For the current study, trait empathizing was measured using short-form (22-item) version of the EQ, developed and validated by Wakabayashi et al. (2006).

2.5. Apparatus

The SRM dictates that, to calculate actor and partner effects, each individual must act with a minimum of three different partners. It was therefore necessary for participants to attend the experiment in groups of four, allowing for the creation of six unique dyads, and to capture not only multiple dancers but multiple dyads at once. Participants' movements were recorded using a twelve-camera optical motion capture system (Qualisys Oqus 5+), tracking, at a frame rate of 120 Hz, the three-dimensional positions of 21 reflective markers attached to each participant. Eight cameras were mounted on the ceiling, and four were placed near the wall of the capture space (see Figure 1). The locations of the markers were as follows (L = left, R = right, F = front, B = back) 1: LF head; 2: RF head; 3: B head; 4: L shoulder; 5: R shoulder; 6: sternum; 7: stomach; 8: LB hip; 9: RB hip; 10: L elbow; 11: R elbow; 12: L wrist; 13: R wrist; 14: L middle finger; 15: R middle finger; 16: L knee; 17: R knee; 18: L ankle; 19: R ankle; 20: L toe; 21: R tow. These can be seen in Figure 1A. As multiple dancers in a motion capture space may also be difficult to differentiate once captured (Haugen & Nymoen, 2016), each participant was given either one, two, three or four extra markers attached to their leg. These markers were not used in data analysis. The musical stimuli were played in a random order in each condition via four Genelec 8030A loudspeakers and a sub-woofer using a Max patch (www.cycling74.com) running on an Apple computer. The direct (line-in) audio signal of the playback and the synchronization pulse transmitted by the Qualisys cameras when recording were recorded using ProTools software in order to synchronize the motion capture data with the musical stimulus afterwards.

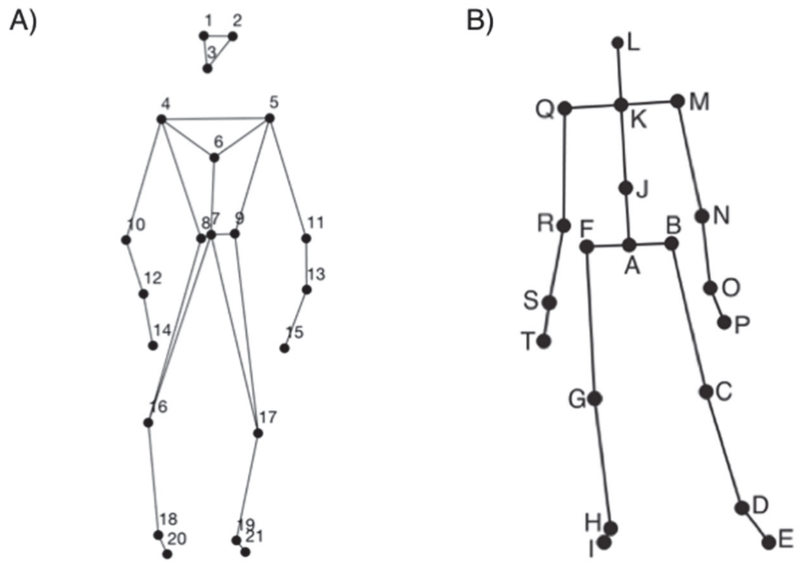

Figure 1: Marker and joint locations (A) Anterior view of the marker locations a stick figure illustration; (B) Anterior view of the locations of the secondary markers/joints used in the analysis.

To keep the experiment sufficiently short, it was necessary to capture multiple dancers and multiple dyads at once without their seeing one another. To facilitate this, a wall was installed that divided the visible capture space in half. An additional screen stood between the researchers and the capture space during motion capture to provide the participants with privacy from immediate observation so as to increase their comfort level. To minimize missing data, the capture space

visible to the cameras was marked off on the floor using tape, and four of the cameras were set up on tripods on either side of the wall mitigate marker occlusion (Haugen & Nymoen, 2016). Additionally, Arabic numerals 1 through 4 were marked on the floor in order to guide participants where to be during dyadic conditions. The capture space set-up can be seen in Figure 2.

Figure 2: motion capture space and divider wall

2.6. Procedure

For each group of four, participants were labeled A, B, C, or D, and were given a felt badge so they could be easily identified amongst themselves and by the researchers. Participants were told to imagine that they were dancing in a social setting such as a club or party, and that they would hear a wide variety of music. They were asked to listen to the music and move freely as they desired, staying within the marked capture space. The aim of these instructions was to create a naturalistic paradigm, such that participants would feel free to behave as they might in the real world. Stimuli were presented in a randomized order. In the first condition, participants moved alone in one half of the capture space. As only two participants could be captured at once in this way, this condition was repeated such that two participants completed their ‘individual’ condition while the other two participants left the laboratory and completed personality questionnaires. In the remaining conditions, participants were organized into dyads on either side of the wall, such that all six possible combinations were record over three conditions: AB, AC, AD, BC, BD, CD. This design is referred to as Round Robin in SRM research; see section 2.8 for more detail (Back & Kenny, 2010). Participants were told that they could interact or not interact with their partner as they felt comfortable, but were asked not to hold hands or switch places in the capture space to avoid undue difficulty in labeling the data. To limit the effects of fatigue, participants were given 3- to 10-minute breaks between each condition and were offered water, juice and biscuits as light refreshment. Participants were informed that they were free to ask for a break or to stop the experiment at any time.

After all conditions were complete, participants filled out a form providing demographic information, were debriefed about the experiment, and given the opportunity to ask questions and share feedback. The experiment took approximately 2 hours.

2.7. Movement data processing

Using the Motion Capture (MoCap) Toolbox (Burger & Toiviainen, 2013) in MATLAB, movement data of the 21 markers were first trimmed to match the exact duration of the musical excerpts. Gaps in the data were linearly filled. Following this, the data were transformed into a set of 20 secondary markers – subsequently referred to as joints. The locations of these 20 joints are depicted in Figure 2B. The locations of joints B, C, D, E, F, G, H, I, M, N, O, P, Q, R, S, and T are identical to the locations of one of the original markers, while the locations of the remaining joints were obtained by averaging the locations of two or more markers; Joint A: midpoint of the two back hip markers; J: midpoint the shoulder and hip markers; K: midpoint of shoulder markers; and L: midpoint of the three head markers.

Acceleration data was chosen to assess participants' overall amount of movement, and to reflect participants' global complex movement in response to stimuli. Acceleration has been identified as a key movement feature in allowing musicians to synchronize to conductors' gestures (Luck & Toiviainen, 2006), and has previously been used to give broad information about overall amount of movement within whole performances (Carlson et al., 2016). This approach allows for wide variety to exist between dancers' free, improvised movements, as individuals may choose to embody the music in many different ways while still responding to and interacting with each other. Using overall acceleration also mitigates potential differences in dancers' movements related to culture, while still providing broad information on essential aspects of their movements. Acceleration in three dimensions of the joints was calculated using numerical differentiation and a Butterworth smoothing filter (second order zero-phase digital filter). For each participant, the instantaneous magnitudes of acceleration were estimated for each joint and stimulus, and subsequently temporally averaged over each stimulus.

Previous research has shown that rhythmic, timbral and structural features as well as perceived emotional content of music can affect music-induced movement (Burger, Saarikallio, et al., 2013; Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2013; Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2014; Solberg & Jensenius, 2017). Since such features may vary significantly between genres (Lidy & Rauber, 2005; Pachet & Cazaly, 2000; Sordo et al., 2008), acceleration was averaged across genre rather than condition (condition in this case refers to all stimuli danced to with a given partner) to avoid the potential confound. Thus, for each participant, for each genre in each condition, mean acceleration across all 20 joints was obtained, as well as mean acceleration for the head and across the hands. These variables are hereafter referred to as Mean movement, Head movement, and Hand movement, respectively. These variables were analyzed using the Social Relations Model (SRM).

2.8. Statistical Analysis

Social Relations Model (SRM) analysis was implemented in MATLAB using a Round Robin design. An example of the Round Robin design can be seen in Table 1.

Table 1: Example of Round Robin design

		Partner			
		A	B	C	D
Actor	A	_	4	3	4
	B	3	_	7	5
	C	2	3	_	
	D	6	3	2	_

In the hypothetical data presented in Table 1, participant A's score when dancing with participant B is 4, while participant B's score while dancing with participant A is 3. Participant A's *actor effect* can be determined via scores in row A, as each of these represent participant A's scores in various conditions (with various partners). Participant A's *partner effect* can be determined via the scores in column A, as these represent the scores of each partner when they were acting with participant A. Were participant A to score a six regardless of who their partner was, this would indicate a strong actor effect. Similarly, were each of participant A's partners to score a six when acting with participant A, this would indicate a strong partner effect; that is, participant A would have a similar effect on all of his partners (see Kenny et al., 2006, p. 194-198 for a thorough discussion of the estimation of SRM effects). Using the SRM, the score of a given participant dancing with a given partner, for example A dancing with B, is modeled using the following equation:

$$X_{AB} = \mu + \alpha_A + \beta_B + \gamma_{AB} + \varepsilon$$

where μ is the mean of all scores, α_A is participant A's actor effect (i.e. A's level of consistency across interactions), β_B is participant B's partner effect (i.e. the consistency of responses of B's partners to B), γ_{AB} is the unique response of A and B after controlling for each other's actor and partner effects respectively, and ε is random error. To take an example from the context of dyadic dancing, the amount that Dancer A waves his hands while dancing with Dancer B is estimated as the group mean amount of hand waving plus Dancer A's tendency to wave his hands, plus Dancer B's tendency to elicit hand-waving from her dance partners, plus Dancer A's unique response to Dancer B, plus random error. Participant A's actor effect can be estimated as:

$$\alpha_A = \frac{(n-1)^2}{n(n-2)} M_{aA} + \frac{n-1}{n(n-2)} M_{pA} + \frac{n-1}{n-2} M$$

where *n* is the group size, M_{aA} is the participant's actor scores (row A), M_{pA} is the mean of their partners' scores (column A), and M is the mean of all observations. Similarly, participant A's partner effect can be estimated as:

$$\beta_A = \frac{(n-1)^2}{n(n-2)} M_{pA} + \frac{n-1}{n(n-2)} M_{aA} + \frac{n-1}{n-2} M$$

The *relationship effect* of dancer A with dancer B, or the degree to which dancer A's response to dancer B is unique given A's actor effect and B's partner effect, is estimated using the above terms as follows:

$$\gamma_{AB} = X_{AB} - \alpha_A - \beta_B - M$$

Actor, partner and relationship variances are used to indicate the degree to which effects vary across individuals. In our example, the actor variance would indicate the degree to which some participants tend to wave their hands in dancing a lot while some tend to wave their hands very little. Variances are calculated using the Mean Squares of scores within and between dyads. The mean of variances is taken across groups. For further details of the estimation of the SRM can be found in Kenny et al., (2006), and well as Appendix B of Kenny (1994).

3. Results

To assess overall differences between individual and dyadic conditions, and to check for significant differences between genres, a two-way repeated-measures ANOVA was run for each of the three movement features using condition (individual or the mean of dyadic conditions) and genre as within-subject factors. For Genre, Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated for Mean Movement $\chi^2(27) = 85.97$, $p < .001$, Head Movement $\chi^2(27) = 208.30$, $p < .001$, and Hand Movement $\chi^2(27) = 148.23$, $p < .001$. Mauchly's Test of Sphericity was also significant for Genre*Condition for Mean Movement $\chi^2(27) = 64.76$, $p < .001$, Head Movement $\chi^2(27)$ 210.06, $p < .001$, and Hand Movement $\chi^2(27) = 190.55$, $p < .001$. Therefore, a Greenhouse-Geisser correction was used in these cases.

Results showed that there was a significant effect of Condition on Hand Movement $F(1,51) = 182.46$, $p < .05$, but not on Mean Movement or Head Movement. There was a significant effect of Genre on Mean Movement, $F(7,243) = 22.91$, $p < .001$, Head Movement, $F(7,137) = 18.83$, $p < .001$, and Hand Movement, $F(7,176) = 14.67$, $p < .001$. There was a significant interaction of Genre*Condition for Hand Movement only, $F(2.8,144) = 3.97$, $p < .01$. Bonferroni-corrected pairwise comparisons revealed a number of significant differences movement features differed per genre. Results are summarized in Figure 3, which shows that movement patterns per genre are similar across individual compared to dyadic conditions, with dyadic conditions showing more movement. Figures indicate that Metal stimuli resulted in the most head movement while Jazz stimuli resulted in the most movement overall. Results can be viewed in detail in the Appendix.

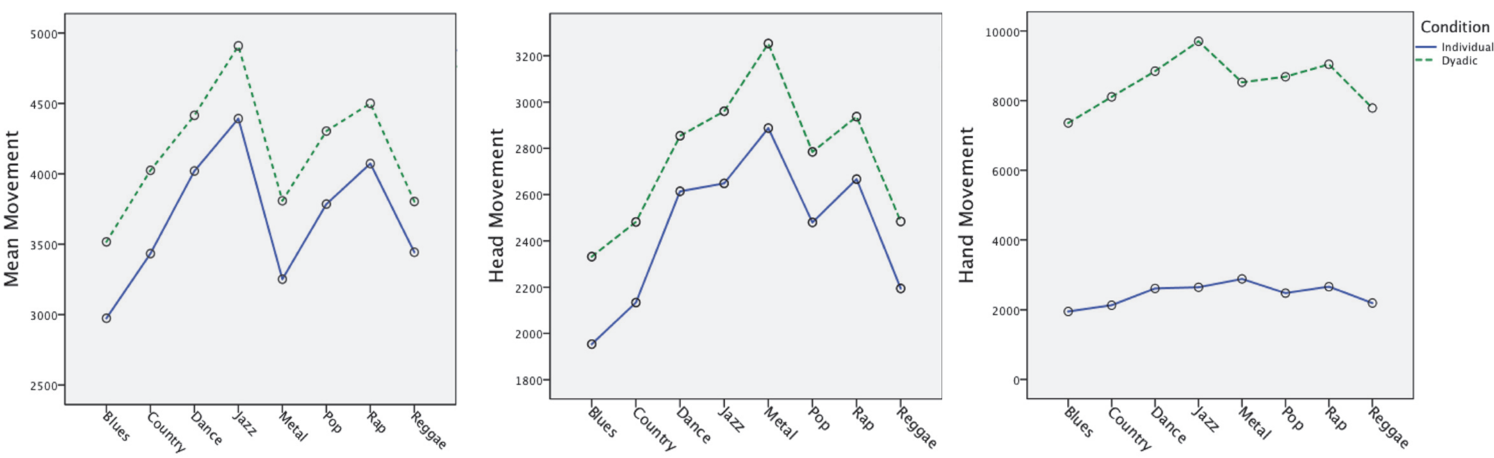

Figure 3: Estimated marginal means of Mean Movement, Head Movement and Hand Movement for individual (solid line) and the mean of dyadic (dotted line) conditions, in mm/s²

To check whether these movement differences between genres affected SRM results, actor and partner variances were calculated for each genre separately. The mean of these was taken to obtain an overall measure of variances. Actor variances (AV) and relationship variances (RV) by genre can be viewed in Table 2. As all partner variances were very close to zero or slightly negative (a statistical anomaly that can occur in the SRM, see Kenny et al., (2006) for an explanation), these variances are considered to be zero and not reported here.

Table 2: Actor and relationship variances for all genres across the 13 groups

	Mean Movement		Head Movement		Hand Movement	
	AV	RV	AV	RV	AV	RV
Blues	.64	.62	.31	.80	.50	.64
Country	.47	.75	.47	.66	.40	.74
Dance	.73	.52	.49	.63	.56	.56
Jazz	.51	.66	.19	.89	.64	.52
Metal	.75	.50	.58	.60	.68	.52
Pop	.54	.68	.49	.63	.51	.65
Rap	.77	.51	.49	.67	.77	.44
Reggae	.86	.42	.52	.66	.74	.43
Mean[2]	**.66**	**.58**	**.44**	**.69**	**.60**	**.56**

AV = Actor Variance; RV = Relationship Variance

[2] Some readers may find it useful to compare these above mean variances to the variances obtained when dyads were paired randomly (i.e., the SRM is run on data from dancers who did not in reality dance together) resulting in a 'false' data set: actor variance was .90, partner variance was 0, relationship variance was .26. There were no significant correlations between actor effects, partner effects, and personality/empathy using this false data.

Actor variance ranged from .19 to .86 while relationship variances ranged from .42 to .89, suggesting that, between all dyads, movement features were differently influenced by characteristics of the individual, by characteristics of each given dyad, and that this differed somewhat by genre. Partner effects did not vary noticeably within any movement feature, suggesting that individual dancers did not tend to reliably elicit similar movement features from their different partners. These variances are more or less in line with results found by Kenny and Malloy (1988), suggesting that free dance may be similar to other socially interactive behaviors in terms of these relative contributions to variance.

To assess whether genre had a significant effect on SRM estimates, a two-way repeated-measures ANOVA was run for actor, partner, and relationship variances using movement feature and genre as within-subject factors; as variances are calculated across each group, the subject in this case is each group of four participants. Results showed no significant effect of genre or movement feature on variances (*p* ranged from .21 to .96), suggesting that, although genres elicited different movement features from individual dancers, genre did not significantly affect dancers' responses to each other on the chosen movement features. Because of this, individual actor and partner effects were averaged across genre for comparison with self-report variables, to reduce the number of overall comparisons made.

To assess the possibility of individual difference affecting overall movement quality (Luck et al., 2010), the mean of movement variables was taken across conditions and correlated with individual personality scores. However, there were no significant relationships between Agreeableness (A), Extraversion (E), and Empathy Quotient (EQ) scores across conditions. Next, to assess the degree that individual differences influenced participants' responses to their partners, participants' A, E, and EQ scores were correlated with their actor and partner effects for Mean movement, Head movement, and Hand movement, controlling for group. The results are summarized in Table 3.

Table 3: Correlation of Actor and Partner effects for all participants (n = 54, df = 51)

	Mean Movement		Head Movement		Hand Movement	
	AE	PE	AE	PE	AE	PE
E	-.13	.10	.05	.13	-.18	.12
A	.21	.03	.13	.15	.04	.16
EQ	-.19	.02	-.19	-.13	-.24*	-.21

* $p < .05$. AE = actor effects, PE = partner effects. E = extraversion, A = agreeableness, EQ = empathy quotient.

Effect sizes were small to moderate. There was a significant negative correlation between Empathy and actor effect for hand movement, suggesting empathic participants changed their hand movement more across partners. Previous research has suggested difference between males and females in non-verbal behavior, personality and empathy (Baron-Cohen, 2009; Berry & Hansen, 2000; Hall, 1978; Terracciano, & McCrae, 2001; Koppensteiner & Grammer, 2011). Independent sample *t*-tests were first carried to assess differences between male and female actor and partner effects. As no significant differences were found in actor and partner effects overall, correlation analyses were also carried out for both sexes separately to assess differences in relationships between personality and SRM variables, controlling for group. Correlation results for males can be seen in Table 4.

Table 4: Correlation of Actor and Partner effects for males (n = 16, df = 13)

	Mean Movement		Head Movement		Hand Movement	
	AE	PE	AE	PE	AE	PE
E	.00	.05	-.02	-.08	-.06	-.06
A	.26	-.07	.15	-.12	.46*	-.01
EQ	-.12	-.06	-.47*	-.23	-.49*	-.30

* *p* <.05. AE = actor effects, PE= partner effects. E = extraversion, A = agreeableness, EQ = empathy quotient.

Although effect sizes are moderate, they should be taken cautiously due to the very small sample size and multiple comparisons made. For males alone, there were significant negative correlations between Empathy and actor effects of both head movement and hand movement. There was a significant positive correlation between Agreeableness and Actor effect for Hand movement, and no significant relationships between Extraversion and actor or partner effects. The results for female participants can be seen in Table 5.

Table 5: Correlation of Actor and Partner effects for females (n = 38, df = 35)

	Mean Movement		Head Movement		Hand Movement	
	AE	PE	AE	PE	AE	PE
E	-.20	.14	.14	.18	-.19	.17
A	.20	.10	.09	.31*	-.12	.27
EQ	-.26	.07	-.09	-.10	-.14	-.17

* *p* <.05. AE = actor effects, PE = partner effects. E = extraversion, A = agreeableness, EQ = empathy quotient.

For females alone, there was a significant positive correlation between Agreeableness and partner effect of head movement. There were no other significant correlations.

4. Discussion

The current study used the Social Relations Model (SRM) to examine music-induced movement in a dyadic context, taking individual differences and sex into account. Previous research has largely employed individual contexts (e.g., Burger, 2013; Carlson, Burger, London, Thompson, & Toiviainen, 2016; Luck et al., 2010), stylistically trained dyads (Haugen, 2014) or aggregated group data (Solberg & Jensenius, 2017), but to the knowledge of the authors, this is the first study of music-induced movement to examine dyads that has employed SRM analysis.

Our first hypothesis (H1), that participants would change their movements in response to the presence of a partner was partly supported by ANOVA results comparing individual and dyadic movement. In general, participants tended to move more during dyadic conditions than individual conditions, although this was only significantly so of hand movement. This may indicate that the presence of another dancer increased participants' desire to move, and corroborates evidence that hand movement may be particularly communicative (Goldin-Meadow, 2006; Krauss et al., 1996). Some increased movement could be attributed to order effects, as participants became used to the laboratory setting and mocap equipment, but it is also possible that increased hand movement in dyadic conditions indicates that the presence of a partner afforded more movement through interaction, or protected against the effects of fatigue and boredom, in line with previous results (De Bruyn et al., 2008).

Overall, results regarding actor, partner and relationship variances support our second hypothesis (H2), that SRM results would show higher actor and relationship variances and lower partner variances. SRM analysis showed moderately large actor variances for movement variables, suggesting that characteristics and tendencies of the individual to act in a consistent manner, rather than characteristics of their partner or their dyadic relationship, accounted for a significant amount of variance of these features. That the ANOVA results showed significantly different movement profiles between genres, but not significantly different variances, suggests that common fate related to dyads' exposure to the same stimuli did not overwhelm other aspects of non-independence, specifically actor and relationship effects. Mean actor variances were higher for mean movement and hand movement than for head movement, suggesting that the latter variable was more influenced by the presence of a partner. Actor variance was lowest and relationship variance highest for head movement, suggesting that head movements may be particularly indicative of how participants respond to and engage with a partner. Though differences between genres were not found to be significant, it can be noted that both Country and Jazz showed relatively low actor variance and relatively high relationship variance across movement features, suggesting these genres might particularly afford interaction.

There were no variables for which there was a quantifiable amount of partner variance, suggesting that individuals generally did not consistency elicit the same types of responses from all their dance partners. This is in line with previous research into actor and partner variances, which suggests that, overall, individuals do not typically elicit consistent behavioral responses across partners (Kenny & Malloy, 1988; Malloy et al., 2005). In music and movement research, partner effects may be more evident in contexts other than free dance, such as overt synchronization tasks, leader-follower tasks, or trained dance styles such as tango. Partner effects may also be visible in contexts such as music or dance therapy, wherein the therapist may have the overt intention to affect the movements of the client. The highest mean variances were relationship variances, suggesting that the individual relationship between partners strongly affected dancers' movements. There are quite a few variables that could contribute to the uniqueness of each dyad, including similarity or differences of personality or empathic abilities, cultural similarities or differences, or sex makeup of the dyad; and such variables have been shown to affect the quality of non-dance social interactions (e.g. Berry & Hansen, 2000; Cuperman & Ickes, 2009; Webster & Ward, 2011). Additionally, individual differences exist in music preference (Rentfrow et al., 2011) and rhythmic and synchronization ability (Pecenka & Keller, 2011). Individuals may well differ in terms of higher-level forms of entrainment such as a tendency to imitate a partner's specific dance moves.

Analysis found no significant relationships between personality dimensions Agreeableness and Extraversion and extracted movement features across conditions. Since previous studies have used extreme scorers to observe movement differences related to personality (e.g., Luck et al., 2010), it may be that personality differences were subtler in the current sample and therefore not captured by this analysis. However, since previous research used individual conditions only, it is possible that the presence of various partners influenced participants differently across conditions, obscuring personality effects in analysis of the individual. Agreeableness and Extraversion, however, also did not show any significant relationships with individuals' actor and partner effects regarding movement features across the whole group, contrary to our third hypothesis (H3). Empathy was related negatively to actor effects for hand movement, indicating that more empathic participants' hand movement was determined less by themselves than by other actors. In the experimental context, the most salient changing factor would be their dance partner, so from this, we can tentatively conclude that empathic participants may have responded more to their partners than non-empathic participants, in line with some theoretical definitions of empathy and providing partial support for our third hypothesis (H3) that empathy would relate negatively to actor effects (Gerdes, 2011; Iacoboni, 2005; Tomei & Grivel, 2014; Zahavi, 2012). Further research could explore the relationship between this finding and previous work showing that higher empathy is related to increased automatic mimicry (Sonnby-Borgström, Jönsson, & Svensson, 2003; Sonnby–Borgström, 2002), and the close link between empathy and motoric representation of and responsiveness to a partner in music performance (Novembre et al., 2012, 2014). As the effect size of this finding is relatively small, these interpretations are tentative and further research should be conducted to corroborate this finding. An example of a dancer with low actor effect can be viewed in the supplementary material, video 1, while an example of a dancer with a high actor effect can be seen in the supplementary material, video 2.

While this relationship did not persist significantly when females were analyzed separately, it did persist for male participants. For males, there was additionally a negative relationship between empathy and actor effect for head movement, suggesting that empathic males may have adjusted their amount of head movement to their partners more than less empathic males. This may relate to previous findings showing that males tend to have lower levels of empathy than females, (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Baron-Cohen & Wheelwright, 2004; Baron-Cohen, 2009), as behavioral adjustments may be more unusual in males and thus more easily detected by statistical analysis. However, as the current sample included only a small number of males, these interpretations are made cautiously. Further research involving larger samples is needed to corroborate and clarify these results.

A few significant relationships emerged for Agreeableness and actor and partner effects when divided by sex. For females, Agreeableness was associated positively with partner effect of head movement, indicating that agreeable females elicited relatively consistent responses in the head movement in their partners. This further supports the idea of head movement as a particularly important feature for dyadic movement. Nodding is a nonverbal behavior associated with agreement and affiliation (e.g., Beck, Daughtridge, & Sloane, 2002; Helweg-Larsen, Cunningham, Carrico, & Pergram, 2004), while head-bobbing to music has been associated with spontaneous music-induced movement and rhythmic perception. It may be that, in dyadic contexts, head movement is a natural way to express affiliation or to rhythmically entrain. For males, Agreeableness was positively related to actor effects for hand movement. Agreeableness is associated with prosocial behavior and "the desire to contribute" (Graziano & Tobin, 2002, p. 584), so it may be that this correlation reflects a social motivation. Further study with a larger sample size, and a gender-balanced design, are needed to corroborate and clarify this finding.

The lack of significant findings related to Extraversion bears noting. Although one of the defining features of Extraversion is a drive towards social interaction, the current results do not indicate that extraverted participants adjusted their movements to their partners, nor did they elicit any type of consistent movement patterns from their partners. It is possible that extraverted participants might respond to music and to the presence of a partner with movement and even communicative intent, but this behavior is relatively consistent across dance partners. In other words, extraverts tend to respond in an extraverted way to everyone they meet.

Some limitations of the current study should be noted. Though the minimum requirement of four participants per group was met, Kenny et al. (2006) note that, in an SRM study, using smaller group sizes can limit statistical power. Thus, although this study as demonstrated the feasibility of the application of the SRM to motion capture movement research, the results should be interpreted with caution. Replication of the current study could strengthen the results. Future research could also attempt a similar methodology using larger group sizes, although this would create practical difficulties that need to be addressed (capture space size, time required to complete experiment, fatigue). The varied cultural background of the participants could also have contributed to the current results, although the authors believe that the use of a course-grained measure of movement (acceleration) may have mitigated some cultural differences in music-induced movement. That some (approximately twelve, although data was not formally collected about this) participants were acquainted with one another while others were strangers may be a limitation to the current research. Future work might address this weakness by specifically recruiting well-acquainted and non-acquainted dyads. Future work should also include the exploration of how various dyadic interactions during dance are perceived by others, and as well as analysis of dyads' synchronization to the music and to each other over time.

These limitations notwithstanding, the current study shows that the SRM can be meaningfully applied to motion capture data of free dance movement. The results of the current study suggest that the presence of another person can indeed affect our movement to music, and that the unique characteristics of a given dyad have the greatest influence over how our movements change, providing rationale for further study of free dance movement focused on dyads. Further research could focus, for example, on measures of synchronization and movement coupling between dancers or of leader-follower relationships, which might be compared with dyadic indexes representative of individual differences, such as measures of similarity between partners' personality scores or music preferences (Cook & Kenny, 2005; Kenny et al., 2006; Levesque, Lafontaine, Caron, Lyn Flesch, & Bjornson, 2014). Further study on the relationship between empathy and dyadic aspects of free dance movement is also needed, as well as replication and expansion of the methodologies described here. This study represents a first step in the application of the SRM to dance data to quantify how social context affects free dance movement, and a further step in understanding how who we are is manifested in our embodied responses to music.

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Appendix

Results of post-hoc pairwise comparisons comparing genre

Tables show differences in mean between genres in Mean Movement using a Bonferroni correction for multiple comparisons. Values are rounded to the nearest whole number. Negative values indicate that the column genre has a lower mean than the row (e.g. Blues is lower than Country). Non-significant differences are shown in gray for easier reading.

1) Mean Movement

	Blues	Country	Dance	Jazz	Metal	Pop	Rap
Country	-484	-					
Dance	-972*	-489	-				
Jazz	-1405*	-921*	-433	-			
Metal	-285	199	688*	1120*	-		
Pop	-799*	-315*	173	606*	-514	-	
Rap	-1041*	-558	-69	363	-757*	-242	
Reggae	-378	105	594	1027*	-93	421*	663*

* *p*<.001

2) Head Movement

	Blues	Country	Dance	Jazz	Metal	Pop	Rap
Country	-164	-					
Dance	-591*	-426*	-				
Jazz	-661*	-497*	-70	-			
Metal	-927*	762*	-336	-266	-		
Pop	-489*	-324	102	172	438	-	
Rap	-659*	-494*	-68	2	268	-169	
Reggae	-196	-31	394*	465*	731	293*	463*

* *p*<.001

3) Hand Movement

	Blues	Country	Dance	Jazz	Metal	Pop	Rap
Country	-465	-					
Dance	-1074*	-610	-				
Jazz	-1521*	-1056*	-446	-			
Metal	-1051	-586	24	470	-		
Pop	-928*	-463	146	592	122	-	
Rap	-1198*	-734*	-124	322	-148	-240	
Reggae	-334	130	740*	1186*	-716	594	

* *p*<.001

IV

EMPATHY AND ENTRAINMENT IN DYADIC MUSIC-INDUCED MOVEMENT: PERCEPTUAL AND COMPUTATIONAL PERSPECTIVES

by

Carlson, E., Burger, B., & Toiviainen, P.

(submitted, request a copy from the author)