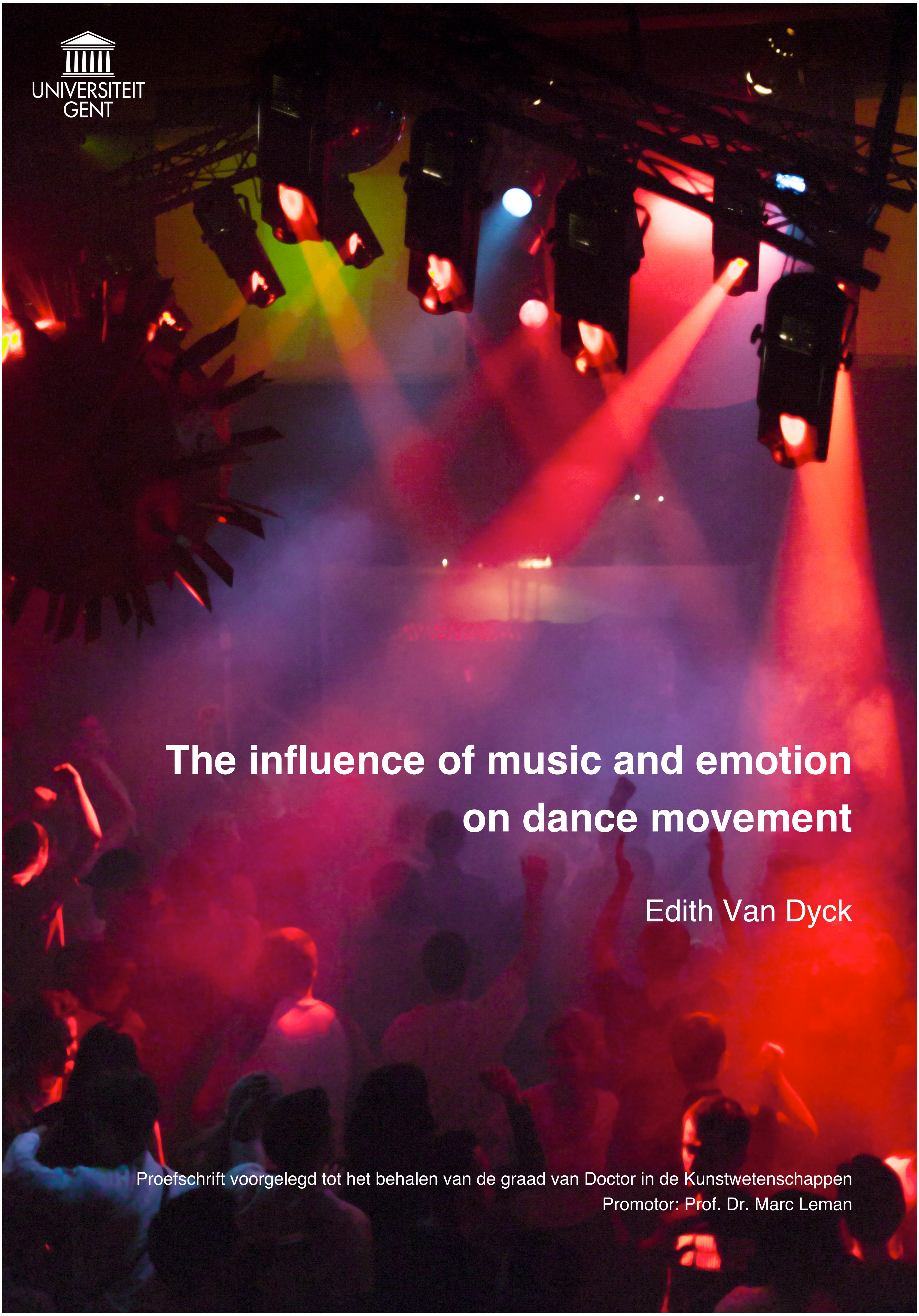

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The influence of music and emotion on dance movement

Edith Van Dyck

Proefschrift voorgelegd tot het behalen van de graad van Doctor in de Kunstwetenschappen
Promotor: Prof. Dr. Marc Leman

For Gerda, Greta, Francis and Mattie.

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Ghent University
Faculty of Arts and Philosophy
Department of Art, Music and Theatre Studies

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Institute for
Psychoacoustics and
Electronic
Music

Thesis submitted to fulfill the requirements
for the degree of Doctor in Art Sciences
Academic year 2013-2014

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Ghent University
Faculty of Arts and Philosophy
Department of Art, Music and Theatre Studies

Promotor:	Prof. Dr. Marc Leman
Reading committee:	Dr. Tom Fritz Prof. Dr. Matthieu Lenoir Dr. Micheline Lesaffre Prof. Dr. Dirk Moelants Dr. Katie Overy
Examination committee:	Prof. Dr. Jean Bourgeois (chair) Dr. Tom Fritz Prof. Dr. Matthieu Lenoir Dr. Micheline Lesaffre Prof. Dr. Dirk Moelants Dr. Katie Overy Prof. Dr. Katharina Pewny Prof. Dr. Christel Stalpaert

Ghent University
Faculty of Arts and Philosophy
Department of Art, Music and Theatre Studies
IPEM – Institute for Psychoacoustics and Electronic Music
Technicum Blok 2, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium
Tel.: +32 (0)9 264 41 26 Fax.: +32 (0)9 264 41 43

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“The truest expression of a people is in its dances and its music. Bodies never lie.”

Agnes De Mille

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Ieper, August 2013
Edith Van Dyck

Table of Contents

List of acronyms

A

ANOVA	Analysis Of Variance
AOI	Area Of Interest

B

BDL	Bass Drum Level
BPM	Beats Per Minute
BVH	Biovision Hierarchy

D

DI	Directness Index

F

FDA	Functional Data Analysis
FFT	Fast Fourier Transform

I

IR	Infrared

K

KS	Kolmogorov-Smirnov

L

LED	Light-Emitting Diode
LMA	Laban Movement Analysis

P

PA	Positive Activation
PANA	Positive Activation - Negative Activation
PCA	Principal Component Analysis

Q

QoM	Quantity of Motion

R

RED	Remote Eye tracking Device
RMS	Root Mean Square

N

NA	Negative Activation
NIOSH	National Institute for Occupational Safety and Health

S

SMS	Sensorimotor Synchronization
SPL	Sound Pressure Level

Summary

When people listen to music, a spontaneous reaction typically occurs. Depending on the type of music, the quality of the sounds, and the character of the rhythm, they tap their feet, nod their head, wiggle their fingers, shake their hips, and so on. In other words, when they are listening to music, people generally start to dance. Dance can be conceived as a creative act of expression, communication, imitation and reflection. People like to dance for a wide variety of reasons; for instance, to express themselves and their feelings or moods, to communicate experiences and ideas of personal significance, to celebrate special events, to relax, to exercise, to have fun, to make friends, and so on. In this doctoral dissertation, the phenomenon of music-induced movement is examined more closely, specifically focusing on 'how' people move to music. The debate concerning 'why' people dance when they perceive music and sound has been going on for many years now. Yet, the specific kinematic characteristics of music-induced movement have only more recently started to gain more attention. In the presented research project, music-induced movement is examined in order to gain more knowledge about the way in which people move to music. In the course of this dissertation, not merely musical qualities are explored, but also emotions are correlated with bodily gestures to gain deeper insight into the topic of music-induced dance movement.

The research presented here is rooted in the theory of embodied music cognition, which regards the body as a natural mediator between musical intentions, meanings, and significations on the one hand, and music itself on the other (Leman, 2008). Thus, music perception is seen as a phenomenon that can not be detached from the body with which it interacts and in which action and perception are tightly coupled. In addition, music perception can be influenced by the emotional state of the individual dancing to/perceiving music, as emotions routinely affect what we perceive, how we perceive it, and the way in which we respond to it. Thus, not only can emotion be affected through the perception of music; it can also shape (and even be shaped by) dance movement. In other words, music perception, movement and emotion are tightly linked and it is on that particular link that the focus of this research project is directed.

In order to gain more knowledge about the coupling between music, emotion, and dance, a number of behavioral experiments were conducted. First, the theoretical framework on which these experiments were based, is presented. In PART 1, the theoretical roots of the rationale behind music-induced movement are considered and the possible impact of certain characteristics of sound and music on gestures is discussed. It is also explored how human emotions can influence body movement. Moreover, the methodological approach behind the experimental studies is presented. Second, four empirical studies are discussed; two on the influence of musical features on dance movement and two on the effect of emotions on dance. The general research question of these studies are:

"How and to what extent do musical features and emotional states influence music-induced dance movement?"

In PART 2, two empirical studies on the impact of musical features on dance movement are presented. The first study (see Chapt. 2), aims to gain a better insight into the connection between music and dance by examining the dynamic effects of the bass drum on a dancing audience in a club-like environment. Participants (N = 100) moved freely in groups of five to a musical sequence that comprised six songs. Each song consisted of one section that was repeated three times, each time with a different sound pressure level of the bass drum. Results revealed that the dancers modified their bodily behavior according to the dynamic level of the bass drum when they moved to music in a social context. They danced more actively and displayed a higher degree of tempo entrainment as the sound pressure level of the bass drum increased. In general, this study demonstrates the significance of the bass drum in contemporary dance music; in addition to its function as a stylistic element, the bass drum proved to have a strong impact on dancing itself. In a second study (see Chapt. 3), the influence of musical style (*heroic* vs. *lyric*) on dance movement is examined. In addition, it is investigated how people's linguistic, metaphorical descriptions of perceived musical expressiveness are related to their corporeal articulations. A dimensional model based on the Effort-Shape theory of Laban is introduced in order to target musical expressivity from an embodied perspective. In addition, it is investigated whether a coupling between action and perception is dependent on the musical background of the participants (i.e., musically trained versus musically untrained) (N = 36). The results of this study show that the physical appearance of free body movement performed in response to music is linked to the linguistic descriptions of musical expressiveness in terms of the underlying quality. Moreover, this phenomenon is found to be independent of the participants' musical background.

In PART 3, two experimental studies on the expression and perception of emotion with regard to music-induced dance movement are discussed. A first study (see Chapt. 4) examines the influence of two basic emotions, happiness and sadness, on dance movement. Participants (*N* =32) were induced to feel emotional states of either happiness or sadness and then danced intuitively to an emotionally 'neutral' piece of music, composed specifically for the experiment. Based on an Effort-Shape analysis of movement, corporeal articulations were captured and seven different movement cues were examined in order to explore whether differences in bodily responses between the happy and sad condition existed. Results revealed that in the happy condition, participants moved faster, with more acceleration, and made more expanded and more impulsive movements than in the sad condition. A last study (see Chapt. 5) applies emotion induction techniques and free movement in order to examine the recognition of emotional content from dance. Observers (*N* = 30) watched a set of silent videos, showing depersonalized avatars of the participants of the study reported in Chapter 4. After every film clip, the observers were asked to make forced-choices concerning the emotional state of the dancers. Results revealed that observers were able to identify the emotional state of the dancers. Moreover, emotions were more often recognized for female dancers than for their male counterparts. Finally, the results of this study unveiled that observers primarily focus on movements of the chest when decoding emotional information from dance movement. The findings of the studies reported in Chapters 4 and 5 demonstrate that not merely portrayed emotions, but also induced emotions can be successfully expressed through and recognized from free dance movement.

Overall, these four empirical studies show that emotions and musical characteristics influence the way people move to music and that emotions can be successfully recognized from dance movement.

Finally, a general discussion and conclusion is presented in PART 4. In this part, an overview of the results is provided, the contributions and limitations of the research are discussed, and possible future work is considered.

List of publications

Publications in peer-reviewed international journals

Van Dyck, E., Moelants, D., Demey, M., Deweppe, A., Coussement, P., & Leman, M. (2013). The impact of the bass drum on human dance movement. *Music Perception, 30*, 349–359.

Van Dyck, E., Maes, P.-J., Hargreaves, J., Lesaffre, M., & Leman, M. (2013). Expressing induced emotions through free dance movement. *Journal of Nonverbal Behavior, 37*, 175–190.

Van Dyck, E., Vansteenkiste, P., Lenoir, M., Lesaffre, M., & Leman, M. (Submitted). Recognizing emotions of happiness and sadness from dance movement.

Maes, P.-J., Van Dyck, E., Lesaffre, M., Kroonenberg, P.M., & Leman, M. (In press). The coupling of action and perception in musical meaning formation. *Music Perception*.

Publications in peer-reviewed international conferences

Van Dyck, E., Moelants, D., Demey, M., Coussement, P., Deweppe, A., & Leman, M. (2010). The impact of the bass drum on body movement in spontaneous dance. In S. M. Demorest, S. J. Morrison, & P. S. Campbell (Eds.), *Proceedings of the 11th International Conference on Music Perception and Cognition (ICMPC11)*, Seattle, USA.

Van Dyck, E., Maes, P.-J., Hargreaves, J., ., Lesaffre, M., & Leman, M. (2012). The impact of induced emotions on free movement. In E. Cambouropoulos, C. Tsougras, P. Mavromatis, & K. Pastiadis (Eds.), *Proceedings of the 12th International Conference on Music Perception and Cognition (ICMPC)/8th Triennial Conference of the European Society for the Cognitive Sciences of Music (ESCOM)*, Thessaloniki, Greece.

Introduction

Music: Often when we hear it, a spontaneous reaction occurs, sometimes as a conscious response to the perceived sounds; on many occasions, it happens unintentionally. Depending on the type of music, the quality of the sounds, the character of the rhythm, etc., we start to tap our feet, nod our head, wiggle our fingers, shake our hips, or make other kinds of gestures. But why does this happen? Why do we feel the urge to make such particular dance movements to a certain tune that suddenly invades our auditory turf? And how are these corporeal articulations shaped by musical stimuli? Moreover, does music also affect our emotional state? And are these emotions also reflected in our body movements?

This doctoral dissertation discusses the questions above both from theoretical and experimental perspectives, and with a particular focus on dance movement. The research presented here is rooted in the embodied music cognition paradigm, which considers music perception from the viewpoint of interaction between action and perception as opposed to examining perception alone. Thus, the paradigm implies that musical intentions, meanings, and significations on the one hand, and musical sounds on the other, are mediated through the body (Leman, 2008). As such, perception and action are essentially intertwined, in accordance with the notion of action-perception coupling. The aim of this dissertation is to validate this 'embodiment' approach empirically by showing how changes in the characteristics of music correlate with changes and variations in dance movements. Moreover, the influence of human emotions on dance is considered. Typically and traditionally, perception, action, and emotion are regarded as separate domains of study. However, in this doctoral dissertation, we consider them to be less separable than usually assumed.

In PART 1, a theoretical background on the relation between mind, body, and music; between music and dance movement; and between emotion and movement is provided. Moreover, the methodological approach behind the empirical research is discussed. Next, in PARTS 2 and 3, the different empirical studies are described; two on the impact of musical features on dance movement and two on the effect of emotions on music-induced dance movement. Finally, a general discussion of the contributions, limitations, and future outlook of the research is provided in PART 4.

PART 1:
THEORETICAL FRAMEWORK

Chapter 1

Theoretical framework: an overview

This chapter provides a theoretical framework for the empirical studies presented in the following chapters. In Section 1.1, the theoretical roots of the rationale behind music-induced movement are introduced. Next, in Section 1.2, the possible impact of characteristics of sound and music on corporeal articulations is discussed and in Section 1.3, it is explored how human emotions can influence body movement. Finally, in Section 1.4, the methodological approach behind the empirical studies is presented.

1.1. Mind, body and music

'Why does music make us move'? This question has troubled many musicologists, philosophers, psychologists, neurologists and others in the past, and nowadays the issue is still a hot topic in the field of systematic musicology. In this section, the general aim is to respond to this question, citing several concepts and models which are essential to the discussion on the coupling of mind, body, and music.

1.1.1. Mind-body dualism

In order to theorize how and why music makes us move, we must first refute the dualistic idea that our mind and body are two separate entities, or the belief in a disembodied mind. Plato (390-347 BC/1995), for example, was convinced that the soul and the physical body are two entirely separate entities and that the soul has the ability to migrate to a new physical body. One of the most vigorous defenders of the idea of a division between mind and matter, René Descartes, believed that minds are essentially thinking instruments that are regulated by principles of reason. According to Descartes, these principles are distinct from and can not be reduced to principles of mechanical combination and association. Modern-day Cartesian dualists claim that the mind and body interact exclusively at the pineal gland (Descartes, 1647/1985), a small endocrine gland in the vertebrate brain which produces melatonin (Macchi & Bruce, 2004). However, neuroscientific research has provided strong arguments demonstrating that a disembodied mind as such does not exist. The brain does not contain an empirically identifiable center that links the non-physical mind and its physical extension (e.g., Damasio, 1999; Jeannerod, 2002). Therefore, mind and body should not be considered as two entirely separate entities, but as mutually influential components, interacting with each other in every activity of every day.

1.1.2. Embodied cognition

On that account, we support the notion of embodied cognition. The embodied mind thesis proposes that all aspects of cognition are determined by characteristics of the body. The motor system influences our cognition, just as the mind affects our bodily behavior. The foundations of this theory were laid down by Kant and Merleau-Ponty, amongst others. Kant supported the idea of a bodily grounding of all mental functioning, such that the mind is not detached from the body, but concerns a manifestation of it, considered from another (specifically human, rational) perspective. Therefore, it is not the mind that creates the physical world. Rather, our knowledge of objects is necessarily structured by a set of unconscious assumptions about the physical world (Kant 1781/1998; Palmquist, 2011).

Merleau-Ponty stated that being in its most fundamental existential sense is corporeal being. He rejected the distinction between mind and body altogether, as well as the division between subjective and objective reality. From this viewpoint, every meaningful experience is defined both by corporeal and perceptual dimensions. Moreover, he stressed the superiority of practical over reflective manifestations as our primary connection with the world is less a matter of reflective thought, than it is of practical involvement and mastery (Merleau-Ponty, 1945/2002). Merleau-Ponty also supported the notion of the *body schema*. The body schema is most often described as the way in which humans move in an intelligent, effective, and efficient manner in the world whilst not being conscious that they are doing so. It is a generic label for the manner in which the body is connected with bodily sensation, affect, movement, and perception so that they can be experienced without reflection. The body schema is constructed through the complex combination of those corporeal articulations that have become routines and which we have automated and refined through practice. Combined, these practiced movements and proprioceptive adjustments enable movement without reflection concerning each and every property of a specific action, for example when we drive a car or ride a bicycle (Lymer, 2011). Similarly, cognitive linguist George Lakoff (1987) stated more recently that cognition is based on knowledge that comes from the human body and that other domains are mapped onto our embodied knowledge using a combination of conceptual metaphors, image schemas, and prototypes. According to him, the majority of human cognition, even the most abstract reasoning, depends on such concrete and low-level properties as our sensorimotor system and emotions.

1.1.3. Embodied music cognition

The embodied cognition theory considers the human body as a necessary biologically-defined mediator between mind and physical environment. In this view, not only does the body function to transfer physical energy to a mental level; conversely, it shifts mental representations into material or energetic configurations. Adding music to the equation, the implication is that musical intentions, meanings, and significations (*mind*) on the one hand, and musical sound and other types of energy that afford human action (*matter*) on the other, are mediated through the body (Leman, 2008). We use our bodies not only to produce sounds, but also to perceive and understand music and sounds and to respond to them. In general, the embodied music cognition approach takes music perception to be based on action. Therefore, musical meaning-formation is believed to be corporeal rather than cerebral as it is understood through movements of the body.

Interaction with music is often based on linguistic or verbal descriptions. In addition, our contact with music can also be rooted in symbolic or visual signs (e.g., scores) which describe musical features based on visual representations. However, the embodied music cognition approach assumes that, alongside these linguistic/symbolic interactions, we should also envision musical interaction based on mimetic skills or skills acquired through practice (e.g., when playing an instrument), derived from culture-dependent goal-directed gestures (e.g., symbolic gestures; a conductor's downbeat), but also rooted in direct episodic action sequences (e.g., emotional responses). Obviously, actions are subjective; action skills can be acquired through learning, generally they have a cultural signification, and they also depend on the biomechanics of the human body. Therefore, actions form a link between the mental and physical worlds (Leman, 2008).

Several studies have investigated the nature and strength of the link between music perception and body movement. Neurophysiologic studies have shown that passive music listening activates motor areas in the brain (e.g., Alluri et al., 2011; Chen, Penhune, & Zatorre, 2008; Zatorre, Chen, & Penhune, 2007). In addition, behavioral research demonstrated that, from early childhood, people are equipped with a spontaneous urge to move to music (Retra, 2010). Furthermore, previous research has shown that spontaneous corporeal articulations in response to music, reflect its inherent structural and affective features (Caramiaux, Bevilacqua, & Schnell, 2010; Leman, Desmet, Styns, Van Noorden, & Moelants, 2009).

1.1.4. Mimetic theories

When we embody a piece of music, we create a meaningful engagement with it, which facilitates a better understanding and conceptualization of its expressive qualities. This notion is rooted in the concept of *motor-mimesis*, also referred to as *mirroring*. It embodies the idea that perception in general can be conceived as simulated action. When we interact corporeally with music, we mirror or imitate the perceived expressive patterns of the sounds through movement of our own body (Lesaffre & Leman, 2013). According to Godøy (2003), a motor-mimetic element is incorporated in music perception and cognition, such that mentally we imitate sound-producing actions when we listen attentively to music, or such that we may imagine actively to be tracing or drawing the contours of the music as it unfolds. Thus, motor-mimesis translates sounds into images by simulating sound-producing actions, both for singular sounds and for more complex musical phrases and textures, creating motor programs that recode musical sounds and enable their storage in our minds. Sometimes, the reverse can also occur; motor-mimesis can translate visual images into sounds by retracing the visual contours as sound-producing actions, or sonifying visual images. These motor-mimetic responses to music should not merely be considered as spontaneous reactions to what has been perceived; the process involves a mechanism through which we familiarize ourselves with sounds, progressively enhancing our capacity to discriminate between and understand their various properties (Godøy, 2010).

Like Godøy, Cox (2001, 2011) developed a mimetic theory which holds that a part of our understanding of human movement and sound production relates to our experience of making identical or similar movements and sounds. In other words, our responses to music are motivated by subconscious attempts to recreate what we listen to. This means that, in order to understand music, we need implicit knowledge of the physicality of the sound source. This process of comparison involves both *overt* and *covert* imitation of the source of auditory information. When we imitate someone or something overtly, we embody the perceived behavior in our own skeletal-motor system but also in related neural activity and blood chemistry. In the case of a covert imitation of a person or an action, the observed behavior is represented in a similar way, except that the executions of the motor actions are inhibited and the changes in other systems are attenuated (Cox, 2011). Figure 1.1 represents the process by which human-made sounds are understood through overt and covert mimetic participation.

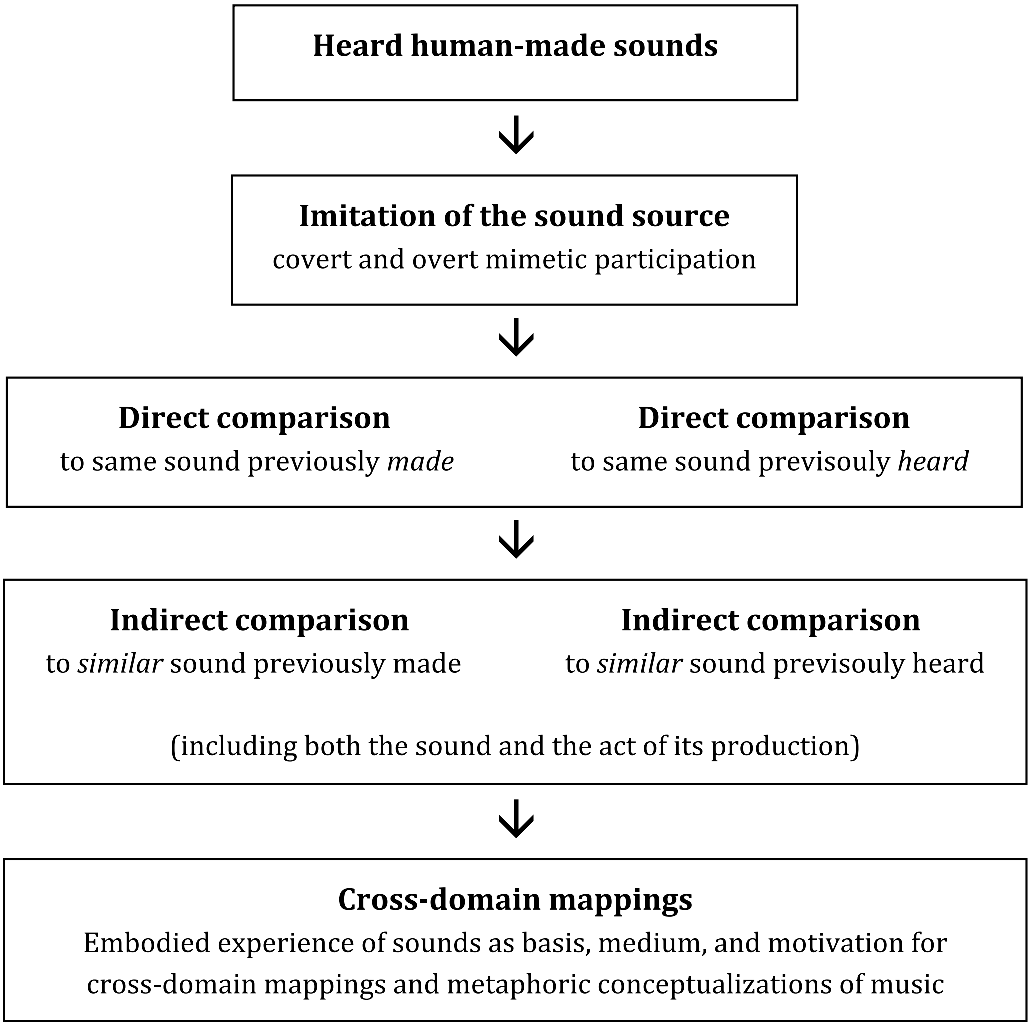


Figure 1.1.: Representation of Cox' (2001) model for the understanding of sounds.

Besides the distinction between overt and covert imitation, two other variables are involved in the process of imitation, namely *intentionality* and *consciousness*. Imitation might be intentional, but most often it is unintentional. In addition, it may be conscious, but again, generally this is not the case. Cox (2011) states that mimetic comprehension in adults is most often unintentional, nonconscious, and covert. However, a lack of awareness of mimetic engagement with music does not indicate that it does not occur. Inevitably, these variables are shaped by the cultural context; for example, responses in a concert hall will generally tend to be very different from those in a dance venue. They also depend on the historical context underlying particular pieces of music and/or specific dance movements. Finally, although mimetic comprehension is universal, it also varies among individuals, subcultures, cultures, and so on.

According to Cox (2011), all perceptible features of music (pitch, duration, timbre, intensity, and location) can be imitated to a certain degree of fidelity. Furthermore, differences in styles of music, performance interpretations, and individual music preferences will *afford* or invite different kinds of mimetic engagement. For nearly everybody, and for most kinds of music, music practically *demands* mimetic participation (either overt or covert). However, it is the task of empirical research to analyze the impact of specific musical properties on body movement rigorously, in order to understand the mapping of audio patterns in music on to motor patterns of the human body more thoroughly.

1.1.5. Conclusion

In this section, several views on the distinction between mind and body have been described. Instead of understanding mind and matter as two separate entities, we consider them as closely linked. We believe that all aspects of cognition are determined by characteristics of the body and that by moving, we tend to form a way of understanding the world. In this action-based approach, direct involvement with music is assumed to be rooted in physical energy that has an impact on the human body and mind. This approach, based on the notion of corporeality, provides a possible foundation for bridging the gap between musical mind and matter. In daily life, when we perceive a musical stimulus, we tend to imitate the properties of the music in a corporeal fashion. How we mimic musical features is discusses in more detail in the next section.

1.2. Musical features and movement

Building on the previous section, which showed that changes in sound quality can be mirrored in the action-oriented ontology of a person, this section will explore the mirroring process more thoroughly, discussing several types of musical gestures and distinct degrees of corporeal imitation.

1.2.1. Musical gestures

Godøy & Leman (2010) pointed out that the encoding of musical gestures in sound may be based on different types of body movements. They make a useful distinction between different types of gesture:

1. *Sound-producing gestures* are those that create sound. They can be further subdivided into gestures of excitation and modification.

2. *Sound-facilitating gestures* support sound-producing gestures in various ways, for example, to enable phrase shapes or to help follow the contour of sonic elements.

3. *Communicative gestures* are mainly used among musicians or between musicians and audience to communicate.

4. *Sound-accompanying gestures* are those that are generally not made by the musician himself, but by the audience, for example.

Perhaps the most straightforward example of bodily interaction with music might be a musician playing an instrument: his/her movements create the sound of the music (*sound-producing gestures*). However, some of the musician's movements do not produce sound directly, instead serving to accompany those that do (*sound-facilitating gestures*, such as posture changes to facilitate high or low singing). The third class of gesture is used to define bodily movements used for communication between musicians themselves, and/or with their audience (*communicative gestures*). For example, our musician might gesticulate with his/her hands to heighten the expressivity of the performance. Finally, the fourth type of corporeal interaction with music, which is of particular interest to this dissertation, occurs when we perceive music, for example when we listen to the radio, go to a dance venue, or when we simply hear a few notes as we pass by a shop or bar where music is played (*sound-accompanying gestures*). Consciously or not, we respond corporeally. The main characteristic of this type of interaction is body movement, which is manifest in brain activity, physiological responses, and behavioral reactions.

Inevitably, as mentioned above, circumstantial factors such as the historical and cultural context in which music is heard, the personality of the dancer, the setting in which the music is played, and so on, can shape corporeal responses to music to a certain extent. In empirical research, however, the challenge is to control these factors as far as possible, in order to be able to draw precise conclusions concerning the influence of specific musical features on body movement. In this dissertation, the focus is on sound-accompanying gestures. In other words, here we study how people move, and in particular, how they *dance*, to music.

1.2.2. Degrees of corporeal imitation

As mentioned above, engagement with music inheres corporeal imitation of sounds. Callen (1985) claimed that imitating music with the body shapes and enhances our appreciation of a music performance or piece of music significantly. Moreover, several studies have shown that corporeal articulations can influence people's perception of musical features (e.g., rhythm, pitch, melody, etc.) (Phillips-Silver & Trainor, 2005, 2007; Repp & Knoblich, 2009). Several levels of corporeal imitation can be distinguished, including entrainment, attuning, and empathy (Leman, 2008).

1.2.2.1. Entrainment

Entrainment can be conceived as a type of corporeal articulation that closely adheres to low-level sensorimotor mechanisms. According to Leman (2008), it is a natural tendency to be attracted to, move along with, or imitate a given pattern in music and in principle, entrainment can take place without our having to pay much attention to the physical stimulus. Entrainment may lead to *sensorimotor synchronization* (SMS) (Repp, 2006). SMS, or the coordination of rhythmic movement with rhythmic sensory stimuli, is a human skill that is believed to be fundamental to music and dance (Merker, 1999-2000). Previous studies have revealed that entrainment with an auditory stimulus is a common and universal phenomenon, whereas entrainment with purely visual rhythms is a rare sensation (Repp & Penel, 2004).

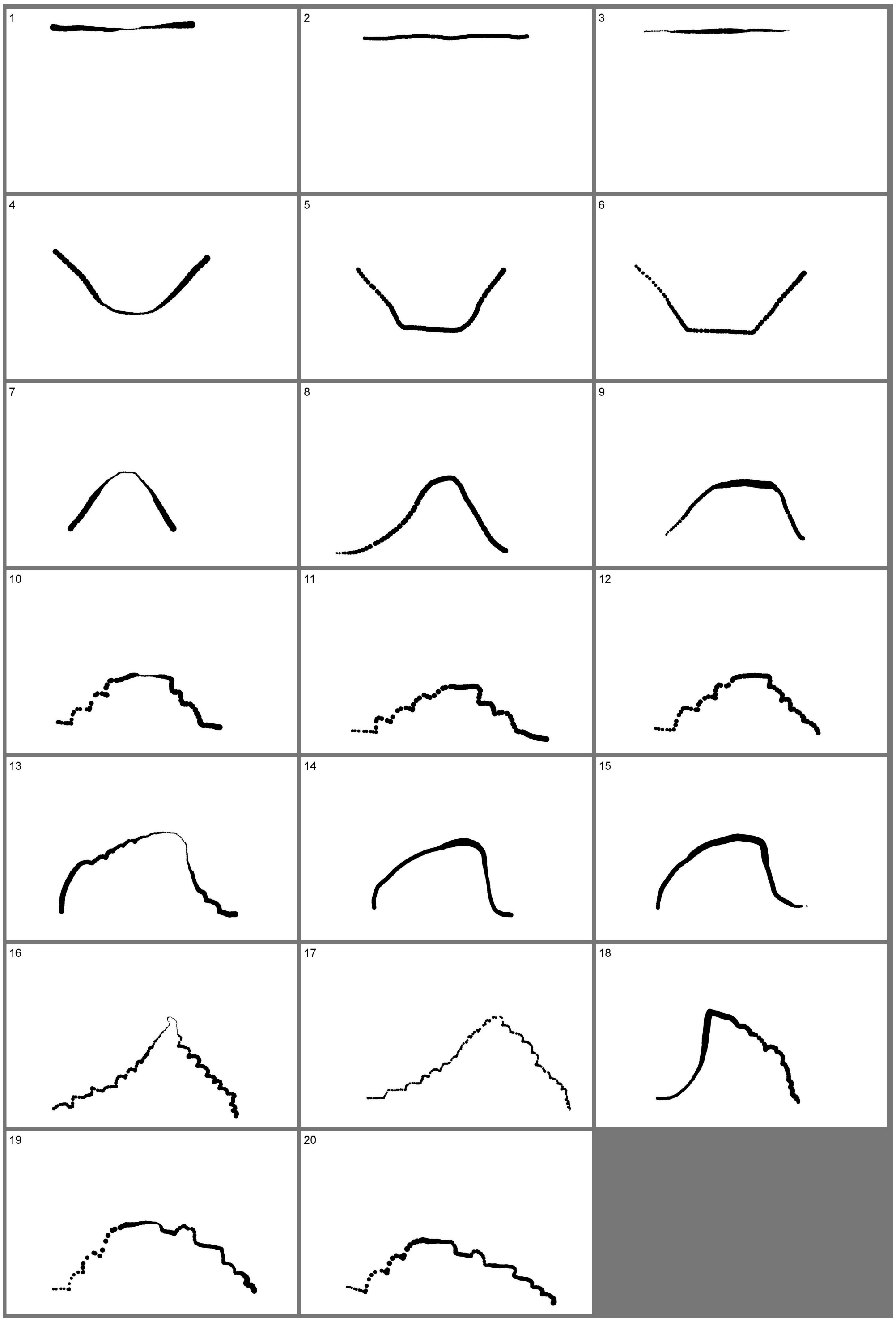
SMS is clearly observable in the proclivity to tap along with the beat of music using body parts such as the hands, fingers, feet, and so on. Such tapping enables a person to feel (corporeally) and understand a basic element of musical structure (Thaut, 2005). Several studies have examined the effect of the tapped beat. Fraisse (1982), for example, showed that increases (or decreases) in tempo will result in corresponding increases (or decreases) in the rate of tapping. Moreover, when people tap in time with music, the tap itself tends to precede the tones by a few tens of milliseconds and generally, people are unaware of this tendency (Miyake, 1902). Only a few studies have investigated entrainment activities other than tapping along with music. Nonetheless, it is safe to assume that the basic principles revealed in tapping experiments also apply to other forms of entrained movement (e.g., dancing), particularly when they involve periodic contact with a surface (e.g., a dance floor) (Repp, 2006).

In Chapter 2, a study that investigated the impact of the sound pressure level of the bass drum (the beat of the music presented in the low-frequency domain) on tempo entrainment is described. The experiment showed that people are capable of entraining with the tempo of the music, using movements other than tapping movements (in this case, dance movements). Moreover, the study unveiled that the sound pressure level also influences the level of tempo entrainment, that is, the degree in which subjects entrain to the musical tempo.

1.2.2.2. Attunement

Attunement brings the human body into accord with one or more specific features of the music, for instance when we dance, draw or sing along with music. Whereas entrainment is based on low-level sensorimotor activity, attunement addresses higher-level features such as melody, harmony, rhythm, timbre, and so on. To consider attunement is to presume that the perceived musical cue is salient within the musical texture to the extent that it can be reproduced. This implies a more active role for the perceiver of the music and an engagement in higher-level intentional processes (Leman, 2008).

A recent study by Küssner (2013) illustrates the idea of embodied attunement. Musicians and non-musicians were asked to represent sounds and music by drawing their visualizations on an electronic graphics tablet (see Fig. 1.2). The sound stimuli comprised sequences of pure sine tones varying in pitch, loudness, and tempo, as well as two recordings of the beginning of Chopin's Prelude No. 6. Afterwards, differences between the drawings were examined. Results revealed that the majority of all participants, both musicians and non-musicians, represented pitch along the vertical axis of the tablet and loudness with the thickness of the line. Generally, musicians depicted pitch and loudness with greater accuracy than non-musicians who used the same representation strategies. Additionally, musicians took tone duration into account, whereas non-musicians did not. The results of this study suggest that attunement is a phenomenon common to all, although they also show that musical training enables the fine-tuning of a person's ability to attune to musical stimuli.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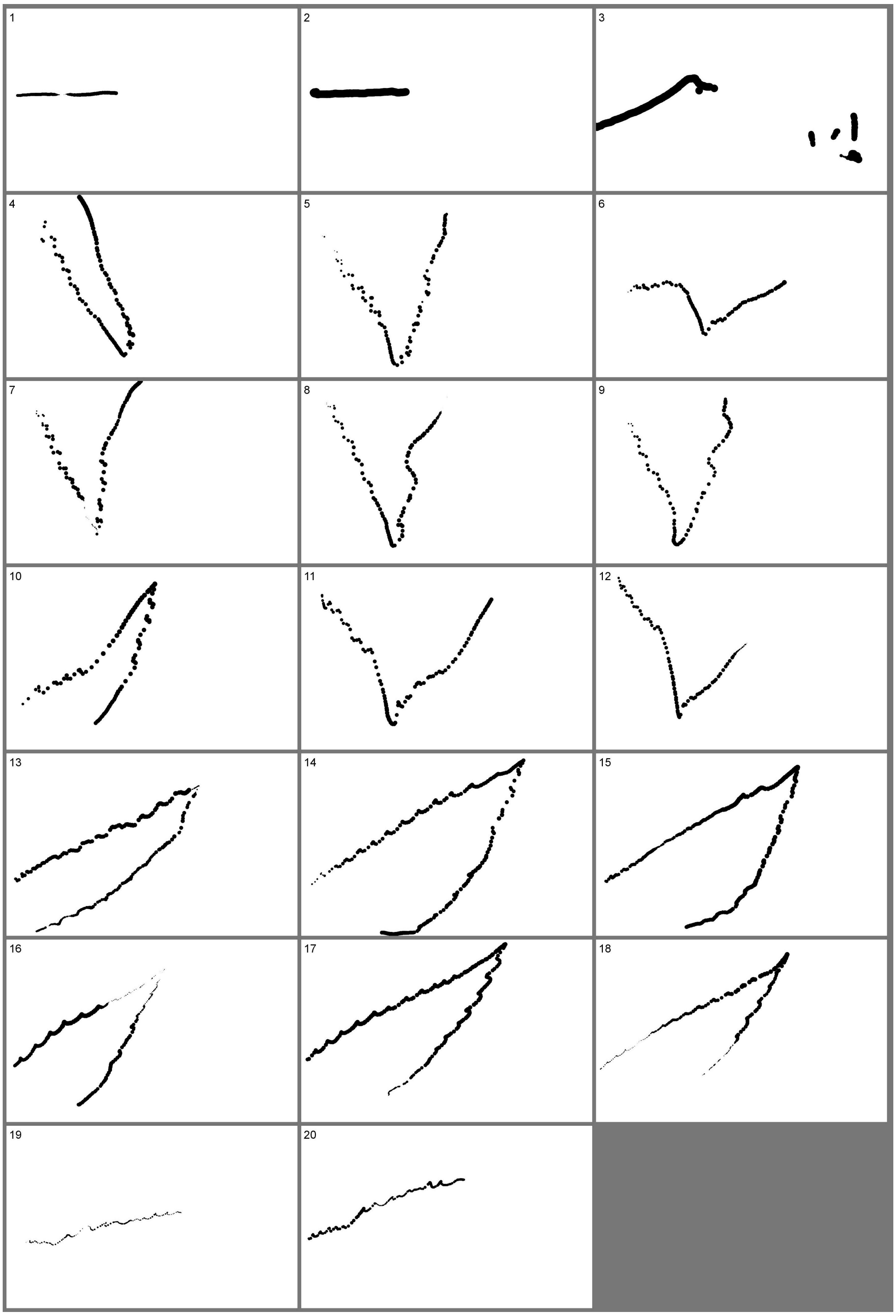


Figure 1.2.: Drawings of two participants representing several sounds and pieces of music. The first set of 20 drawings were sketched by a musician, the second by a non-musician. Drawings 1 to 18 represent sequences of pure tones varying in pitch, loudness and tempo. Drawings 19 and 20 represent the beginning of Chopin's Prelude in B minor, performed by Martha Argerich in 1975 (19) and by Alfred Cortot in 1926 (20) (Küssner, 2013).

In Chapter 3, the results of an empirical study, in which the influence of specific musical styles (*heroic* and *lyric*) on music-induced dance movement was investigated, are presented. In addition, corporeal articulations were associated with specific linguistic, metaphorical descriptions which people used to describe the expressive qualities they perceived in the music. Results showed that the physical appearance of body movement performed in response to music can be successfully linked to the musical style itself as well as to linguistic descriptions of the underlying expressive qualities of the music.

1.2.2.3. Empathy

Empathy is the competence to share another person's affectations and emotions as if they were one's own (Berthoz & Jorland, 2004). Applied to music perception, this is the ability to identify with the emotional expressivity of a piece of music, as if sharing it with the music itself (Leman, 2008). From the perspective of embodied music cognition, empathy can be interpreted as corporeal imitation of emotional intentionality; music expressing joy or sadness can for instance be replicated through movements of the body. Aristotle (335 BC/2013) believed that imitation triggers a sense of pleasure. By extension, it follows that in an empathetic musical experience pleasure arises from the feeling of identification with and attunement of the self to the music.

A study by Burger, Saarikallio, Luck, Thompson and Toiviainen (2013), for example, investigated how music-induced, quasi-spontaneous movement is influenced by the emotional content of music. The dance movements of 60 individuals were recorded, and from those data, movement features were extracted and analyzed. The emotional content (happiness, anger, sadness, and tenderness) of the stimuli was also assessed in a perceptual experiment. Results of the study revealed characteristic movement features for each emotion, suggesting that body movements reflect or imitate the emotional qualities of music. Movement to happy music was characterized by body rotation and complexity, whereas for angry music, movements were found to be non-fluid and without rotation. Sad music was embodied in simple movements and tender music in fluid movements of low acceleration and a forward-bent torso. In addition, both the particular dance movements and the emotion-specific non-verbal behavior were similar for professional musicians and dancers.

1.2.3. Conclusion

Music not only moves us, but it also makes us move. Several types of musical gesture can be distinguished, namely sound-producing gestures, sound-facilitating gestures, communicative gestures, and sound-accompanying gestures. Only sound-accompanying gestures are taken into account in this dissertation as we are particularly interested in how people dance to music. When performing these sound-facilitating gestures, three levels of interaction can take place: entrainment, attuning, and/or empathy. The assumption is that these manifestations of corporeal articulation rely on different levels of the sensorimotor system and action/perception couplings, as well as on different levels of emotional processing. Entrainment can be seen as relatively passive; something that the subject largely undergoes, such as a sensation, since it is an aspect of the ideomotor principle which states that body movement is the result of resonances. By contrast, empathy brings the emotion system into play, implying commitment to, identification with, and participation in the expressed emotional content of the music. Finally, attunement lies somewhere between the two. It also requires participation, but necessitates less involvement than empathy (Leman, 2008). The actions of a person resonate with particular properties of the music, for example when he/she dances or sings to music. However, we believe that several levels of imitation and intentional involvement with music can occur at the same time; therefore, entrainment, attuning, and empathy can coexist.

1.3. Human emotions and music-induced movement

Not only the characteristics of the music, but also emotions can influence the gestures of people dancing to music. In this section, the theory behind the influence of emotion on movement will be discussed. First, we briefly explain what emotions are. Second, several classificatory models of emotion are described and finally, we shed light on how emotions can be communicated through bodily movement.

1.3.1. Defining emotions

In a general sense, emotions can be described as subjective, conscious experiences that are essentially characterized by psychophysiological expressions, biological reactions, and mental states. They are believed to play a role in all critical transactions with our environment (Gaulin & McBurney, 2003), and concern responses to internal or external events that have a particular significance for the organism (Fox, 2008). They are shaped by temperament, personality, disposition, motivation, and so on, but are also believed to have an impact on these traits as well. In addition, emotions are influenced by hormones and neurotransmitters. Emotions guide, direct, and sometimes even disrupt actions (Campos, Campos, & Barrett, 1989; Izard, 1991; Sroufe, 1996). Plutchik (1980) proposed a chain of events for emotion, one which is frequently used in research today (see Fig. 1.3.).

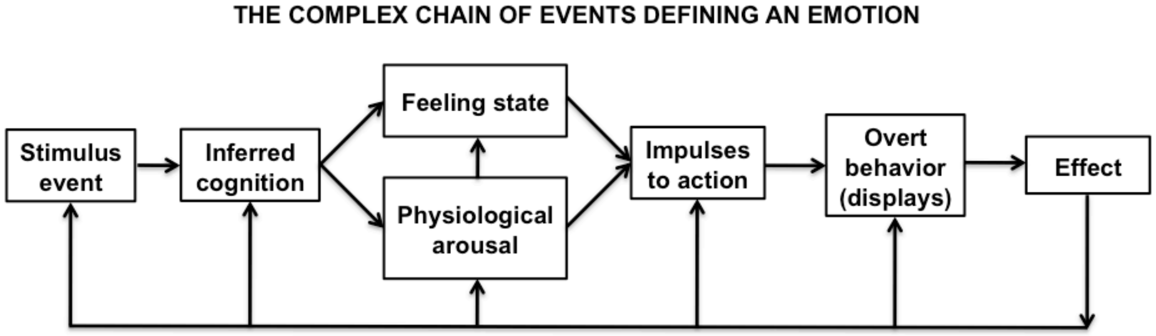


Figure 1.3.: Plutchik's (1980) causal model for emotion.

As shown, the feelings experienced and behavior can loop back and influence the ongoing cognitive processes (or even the affective stimulus). Importantly, here, emotion is conceptualized as a complex process; mechanisms such as perception, recognition, appraisal, or judgment are part of virtually every emotion theory (Sroufe, 1996).

The ubiquity of potential stimulus events and human behaviors means that emotions can effect all dimensions of our life. They are of the utmost importance to our relationships with friends, family, and so on. In addition, they prove to be significant for our psychological well-being, cognitive functioning, moral sensitivity and other important developmental processes (Sroufe, 1996). The basis for considering those emotions that concern us here is set out below.

1.3.2. Emotion classification

A huge body of research has explored the impact of emotions on all kinds of human activities and processes, and this has led to the establishment of an abundance of different emotion theories and concepts. Generally speaking, two contrasting approaches can be distinguished in the field of emotion classification. The first approach incorporates the idea that emotions are discrete, fundamentally different constructs; the second one asserts that emotions can be characterized on dimensional axes. The most important models arising from these two viewpoints are discussed below.

1.3.2.1. Basic/discrete model of emotion

One of the most dominant models in emotion research, especially in relation with music, is the *basic emotions model*, often also referred to as the *discrete emotions model* (Eerola & Vuoskoski, 2011; Juslin & Sloboda, 2010; Zentner & Eerola, 2009). It proposes that the array of human affective phenomena arises out of a handful of basic emotions (Buck, 1988; Ekman, 1992; Izard, 1971, 1972, 2007; Tomkins, 1984). The idea that at least some emotions have distinctive features is traditionally traced back to Darwin (1872/2009), who described several facial, physiological and behavioral processes related to different emotions in humans as well as in animals. Moreover, Darwin laid out principles intended to explain the purpose of such processes and how they evolved (Colombetti, 2009). In the same spirit, Izard (2007) considered basic emotions as “those emotions that have been characterized as having evolutionarily old neurobiological substrates, as well as an evolved feeling component and capacity for expressive and other behavioral actions of evolutionary origin’’ (p. 261).

Various studies have been conducted in the past in order to determine the nature of the specific basic emotions. For example, Tomkins (1962, 1963), who was strongly influenced by Darwin, stated that only a limited number of pan-cultural basic emotions or *affect programs* exist: surprise, interest, joy, rage, fear, disgust, shame and anguish. Some years later, emotion theorists Izard and Ekman independently conducted a series of cross-cultural studies to test Tomkins’ theory and reported various similarities in how people across the world produce and recognize the expression of at least six emotion (Colombetti, 2009). According to Izard (1971, 1972) the basic emotions were surprise, interest, joy, anger, fear, disgust, shame, contempt, distress, and guilt. Ekman, on the other hand, believed that only six basic emotions occur, namely surprise, happiness, anger, fear, disgust, and sadness. According to him, each of these stands for a *family* of related emotions and incorporates specific characteristics that can be expressed to varying degrees (Ekman, 1972). Izard's and Ekman's emotion theories are both frequently used in emotion research today.

1.3.2.2. Dimensional models of emotion

Dimensional models conceptualize human emotions by situating them in two or three dimensions. In contrast to basic emotion theories, which suggest that different emotions arise from discrete neural systems, these models propose that a common and interconnected neurophysiological system is responsible for all affective states (Posner, Russell, & Peterson, 2005). Several dimensional models of emotion have been developed. The three most dominant models are discussed below: the two-dimensional circumplex model, the positive activation - negative activation (PANA) model, and the vector model.

The two-dimensional circumplex model This model, first developed by Russell (1980), proposes that all affective states arise from two independent neurophysiological systems: one related to *valence* (pleasure-displeasure continuum) and the other to *arousal* (activation-deactivation continuum). In other words, all emotions can be understood to have varying degrees of valence on the one hand, and arousal on the other (Posner et al., 2005; Russell, 1980). Thayer (1989) developed a similar model, although he claimed that the two affective axes constitute distinct types of arousal: *energetic* and *tense*. According to Thayer's multidimensional model of activation, valence can be explained in terms of varying combinations of energetic and tense arousal. The two-dimensional circumplex model is employed most often in contemporary research where a dimensional model is used. Figure 1.4 depicts Russell's and Thayer's models of emotion.

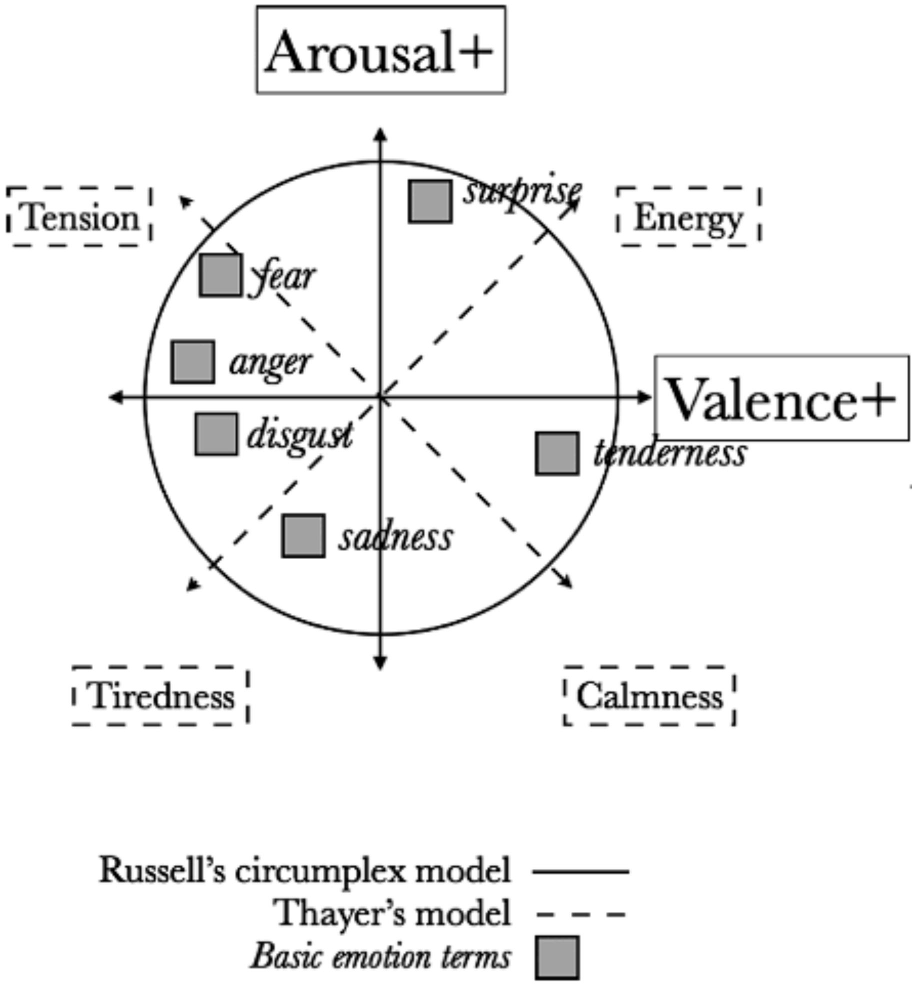


Fig. 1.4.: Schematic diagram of the two-dimensional circumplex models of Russel and Thayer, with common basic emotion categories overlaid (Schimmack & Grob, 2000).

The positive activation - negative activation (PANA) model The PANA model is commonly understood as a 45-degree rotation of the circumplex model defined by two primary axes reflecting two basic behavioral systems. *Positive activation* (PA) is anchored at one end by mood terms like active, elated, and excited and at the other by drowsy, dull, and sluggish. The other axis, *negative activation* (NA), is anchored by labels such as distressed, fearful, and nervous at one end and by calm, at rest, and relaxed at the other (Watson & Tellegen, 1985; Watson, Wiese, Vaidya, & Tellegen, 1999).

The vector model This model holds that there is an underlying dimension of arousal and a binary choice of valence that determines direction. This results in two vectors, both starting at zero arousal and neutral valence, proceeding as straight lines, one in a positive-, and one in a negative-valence direction (Rubin & Talarico, 2009).

1.3.3. Communication of emotions

Successfully communicating one's emotional state is an effective strategy to avoid risk or spend additional energy (i.e., a frown can prevent a fight), to aid one's relatives and friends (i.e., a scream can prompt them to run for cover), or to elicit supportive behavior (i.e., a smile can bring on a helping hand) (Campos et al., 1989). By extension, since emotions signal information regarding the safeness or dangerousness of certain situations, adequate communication of emotions is crucial to our survival (Ekman, 1992).

Darwin (1872/2009) stated that the importance of communicating emotions precedes the evolution of verbal abilities, and according to him, both humans and animals are capable of displaying emotions through motor behavior. Experimental research has confirmed that emotions can be recognized from facial expressions, which have distinct and universal expressive characteristics, signaling positive and negative feelings, attitudes and intentions (Ekman, 1972; Likowski et al., 2001; Lundqvist & Dimberg, 1995; Moody, McIntosh, Mann, & Weisser, 2007). In addition, emotion can be communicated bodily (App, McIntosh, Reed, & Hertenstein, 2011; Buck, 1984). Previous studies have unveiled the presence of emotional content in movements of the trunk (de Meijer, 1989), the arms (de Meijer, 1989; Pollick, Paterson, Bruderlin, & Sanford, 2001), and the hands (Gross, Crane, & Fredrickson, 2010) for instance. Moreover, children and adults are believed to master the ability to decode emotions from full body movements (Boone & Cunningham, 1998; Dittrich, Troscianko, Lea, & Morgan, 1996; Lagerlöf & Djerf, 2000; Ross, Polson, & Grosbras, 2012; Shikanai, Sawada, & Ishii, 2013; Van Meel, Verburgh, & de Meijer, 1993). Even if movements are not fundamentally expressive, common experience tells us that often they do carry a message (Pollick et al., 2001), since emotions are multi-component response systems initiated by changes in current circumstances (Gross et al., 2010).

As an example, a particular study conducted by Ekman and Friesen (1975) played a central role in settling the dispute over whether facial expressions of emotions are universal or specific for each culture. In that study, stress-inducing films were shown to college students in the United States and in Japan. The film clips were played both in a solo condition and in a setting where another person from the same culture was present. Measurements of facial muscle movements revealed that, in the solo condition, American and Japanese participants displayed virtually identical facial expressions (see Fig. 1.5.). However, in the presence of another person, when by implication, cultural ‘rules’ concerning the management of facial appearance (display rules) apply, there was very little correspondence between American and Japanese facial expressions. It appeared that Japanese participants masked their facial expressions of unpleasant feelings more than the American students. The researchers concluded that the universal feature of the facial expression of emotions lies in the distinctive appearance of the face for each of the primary emotions, although people in different cultures tend to differ in what they have learned about managing or controlling their facial expressions.

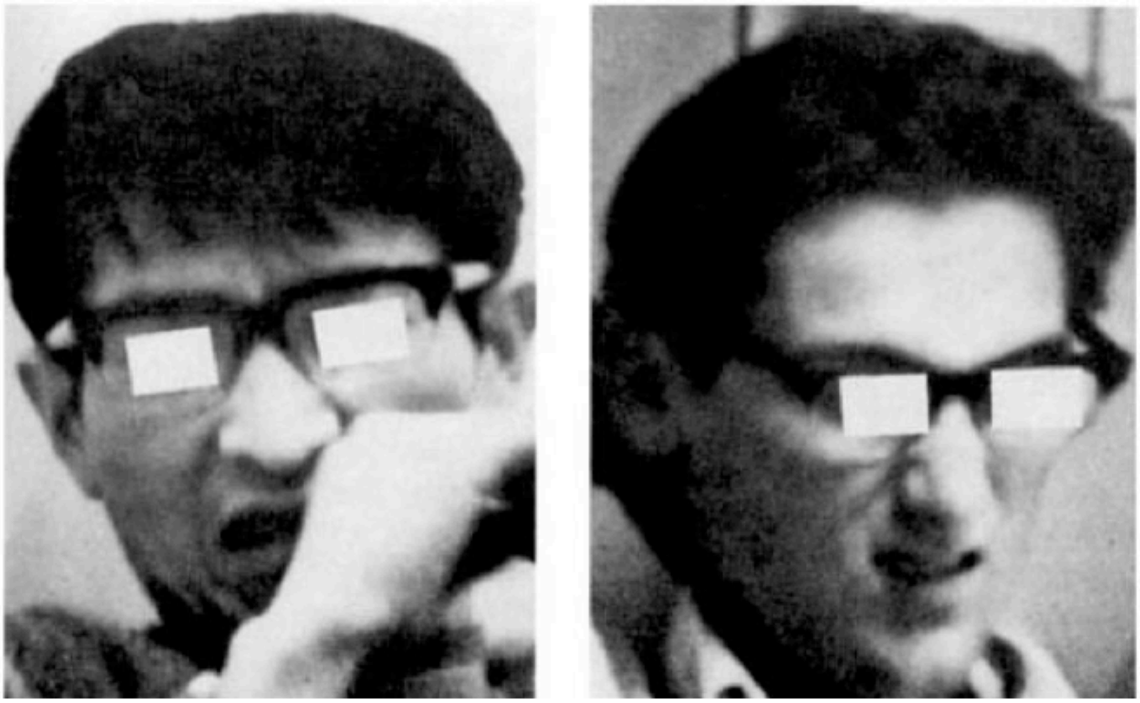


Figure 1.5.: Example of a facial expression of a Japanese (left) and American (right) participant when watching a stress-inducing film (Ekman & Friesen, 1975).

In another study, in this case on the topic of the expression of emotions through full-body movement, Lagerlöf and Djerf (2000) investigated movements of dancers portraying emotions of joy, grief, anger, and fear. Comparison of gestures across the four emotion categories uncovered distinct differences in expression of emotion. The results revealed that joy, anger, and fear were related to frequent tempo changes, whereas only few changes of pace were detected in the grief condition. Moreover, associations between the tendency for movements to project outward from the center of the body and expressions of joy and anger were observed. In other words, this study revealed that emotions of people dancing to music have a particular impact on their dance movements.

1.3.4. Conclusion

In this section, we briefly described what emotions are and discussed the three most commonly used models for their classification. Moreover, we explored the channels through which they can be communicated. It is beyond the scope of this dissertation to provide an exhaustive study on emotions. Accordingly, we merely discussed models and ideas that are of particular relevance to this dissertation and are closely linked with the two empirical studies presented in Chapters 4 and 5, which deal with the expression and recognition of basic emotions through and from dance movement.

1.4. Methodological matter

Chapters 2 to 5 are reports on four experimental studies designed to investigate aspects of the concepts and models described above. In this section issues relevant to the applied methods that arose in the course of the design and execution of those studies are discussed: why certain methodological choices have been made, and how they are supported by previous research, available theories, or merely by practical considerations.

1.4.1. Organization of the research process

Several steps were taken when we carried out our empirical studies. The order and importance of these steps can vary from one study to the next, but largely, consensus exists among most researchers that: first, the problem is identified; second, a plan of action is developed; third, data is gathered to answer the questions the researchers derived in the first phase; fourth, the data is analyzed and interpreted; and fifth, the results are shared with the rest of the world. However, the process does not end there, as problems that need to be adjusted in order to draw sound conclusions may have occurred during the process. Moreover, in reality, nearly all answers lead to new questions … Consequently, in the long term, research processes usually tend to be cyclical (see Fig. 1.6).

Figure 1.6.: Representation of the research cycle (Grady, 1998).

1.4.2. Identifying the problem

In all four studies, our empirical research kicked off with an *a priori* theory, which was applied to try to explain and/or predict real world events and behaviours. Thus, at the start of each one, a problem was identified and one or more research questions and hypotheses were drafted. Profound familiarity both with the subject under study and with previous research relating to the topic was crucial in arriving at these questions. For this reason, an extensive literature survey was executed at the start of every experiment. Each of the following four chapters contains a literature review focussed on elements indispensable to our research, retrieved from previous studies (either empirical or theoretical). Thereafter, the research questions and hypotheses which were challenged throughout the relevant study are sketched, so as to reflect and explain the decisions taken on the basis of the theoretical concepts and models at hand, the results of earlier research, and the strengths and flaws of methodological choices made in the past (either by ourselves or by others).

The main *research questions* of this research project are:

1. How do properties of musical stimuli influence dance movement (Chapt. 2 and 3)? And do these musical properties and corporeal articulations also correlate with linguistic descriptions of the musical stimulus in question (Chapt. 3)?

2. How do emotional states influence music-induced dance movement (Chapt. 4)? And can the emotional state of a dancer be recognized when perceiving merely his/her dance movement (Chapt. 5)?

The main *hypotheses* of the research project are:

1. Properties of musical stimuli influence dance movement (Chapt. 2 and 3). In addition, both musical properties and corporeal articulations are correlated with linguistic descriptions of the musical stimulus (Chapt. 3).

2. Emotional states influence music-induced dance movement (Chapt. 4). Moreover, the emotional state of a dancer can be recognized when perceiving his/her dance movement (Chapt. 5).

1.4.3. Developing a plan of action

Before the actual execution of a study, a plan of action was developed. Several questions arose, of which the most crucial ones were: Who will be the participants? How will they be protected during their participation? What will the stimuli be? And how will they be designed?

1.4.3.1. Participants

The selection of participants for the experiments was specific to the topic under scrutiny, as different studies often have different requirements with respect to the participants, for example regarding their age, background, or gender. For instance, a study on the effect of music on milk production (e.g., Albright & Arave, 1997) requires drastically different participants than a study on the effects of music on cardiovascular, cerebrovascular, and respiratory changes in musicians (e.g., Bernardi, Porta, & Sleight, 2006) (see Fig. 1.7).

Figure 1.7.: Different studies can necessitate completely different types of participants.

Moreover, factors such as ethnic origin, education, age, and so on, might influence the obtained data. Therefore, in our empirical studies, these factors were either controlled or taken into account in the data analysis. As the age of the participants could prove to be a confounding factor (Larcom & Isaacowitz, 2009), predominantly, we invited participants of the same age group: mostly young adults (with an average age between 22.75 and 27.23 years old). In the research described in Chapter 2, this was a deliberate choice. Since the aim was to create a club-like setting, participants who would typically visit dance clubs in real life were invited. For purely practical reasons (since experiments took place at the university), the other three studies tested primarily university students. Usually, we tested an equal number of males and females in order to control for gender. Often, the musical background of the participants was taken into account in the data analysis phase. Additionally, participants were selected based on their willingness to dance during the experiments.

1.4.3.2. Ethical standards

During each experiment, the rights of the participants were protected by a system of ethical protection. To meet ethical standards, each of the four studies was approved by the Ethics Committee of either the Faculty of Arts and Philosophy or the Faculty of Psychology and Pedagogical Sciences of Ghent University. In addition, participants signed a form at the start of every experiment, declaring that their participation was voluntarily; that they had received sufficient information concerning the tasks, the procedures, and the technology used; that they had the opportunity to ask questions; and that they were aware of the fact that recordings were being made, for scientific and educational purposes only. Moreover, there were no risks involved in the studies and finally, confidentiality was guaranteed.

1.4.3.3. Stimuli

In our research, theoretical hypotheses were interpreted in terms of events in the empirical world. In this process, the stimulus was one of many potential variations of an independent variable (i.e. the input or the cause of an effect). In each and every experiment, the stimulus either had a minimum of two different values or was completely absent in order to test its effect. However, the questions that came to pass were: ‘How should the stimuli be designed?’ and ‘How realistic should they be?’. There were some demands concerning this question:

1. The requirement of *fidelity* (or *validity*): The stimuli had to be equivalent to those that occur in the real world so that the results have validity outside the laboratory.

2. The requirement of *no disturbances*: Natural stimuli that might be present in an ordinary situation could have given rise to extra factors that we did not wish to examine and whose impact might have concealed certain aspects of the matter we wished to study. This variance could often be eliminated by increasing the number of experiments or by designing new stimuli that were similar to natural ones.

3. *Practical aspects*: The production of certain stimuli could have proved to be too costly or could have caused an inordinate amount of

> trouble. Thus, practical aspects with respect to our stimuli had to be taken into account.

When we designed the stimuli for the empirical studies, we tried to meet these requirements. Three different types of stimuli were used in the studies: music, guided imagery, and video.

Music In three of the studies (Chapt. 2, 3, and 4), participants were asked to move to music, and for two of those (Chapt. 2 and 4), the music was composed exclusively, in order to ensure optimal control over all musical parameters and to eliminate familiarity effects. In the other study (Chapt. 3), a Brahms piano concerto was used, rather than a 'tailor-made' recording. However, in this case, only exemplary extracts of the styles under investigation (*heroic* and *lyric*) were taken into account, while the rest of the composition was discarded. The study described in Chapter 4 also made use of classical music in order to induce specific emotional states; in that case, these pieces had proven their value in previous research on emotion induction. Besides, the stimuli designed by the researchers consisted of pieces of electronic music, which are not as challenging to compose as a classical work performed by symphonic orchestra and piano.

Guided imagery The study reported in Chapter 4 made use of guided imagery: participants were asked to imagine themselves in particular situations described in a few sentences. These scenarios concerned circumstances that one might be faced with in daily life (e.g., 'You just got a new job and it is even better than you expected.'), and thus hold their validity outside the laboratory. In order to control for extra or confounding factors, at the end of the experiment, the effectiveness of the emotion induction procedure was measured by means of an emotion rating scale.

Video The stimuli used in the study discussed in Chapter 5 consisted of video clips depicting people dancing to music. These clips were produced in a laboratory setting. However, in order to assure ecological validity, participants were allowed to move freely; they were not required to perform choreographed dance moves. Alongside this, in accordance with the subject for study, emotion induction techniques were applied, and these can only be implemented properly in a controlled environment (e.g., a laboratory setting).

1.4.4. Data collection

After the participants were selected, approval of the Ethics Committee was obtained and the stimuli were designed, data was collected. Several measuring tools were used. Aside from the specific strategies to collect data, we also had to follow procedures within particular limits when gathering information in experiments.

1.4.4.1. Measuring tools

The selection of appropriate measuring tools was important in order to gain the most valuable information from our studies. When conducting an experiment, we had to consider those methods that would achieve the most useful results, based on the topic of the study. Certain activities could either have been observed systematically, or using less-direct strategies for obtaining information.

Direct observation In the studies discussed below, situations were observed in order to draw conclusions about the topic under investigation. For instance, body movement was recorded by means of motion capture (Chapt. 2, 3 and 4) and motion sensing (Chapt. 2), while eye movement was registered using eye tracking (Chapt. 4).

Indirect methods Direct observations were always complemented with indirect measuring tools, such as questionnaires. Detailed demographic information regarding the participants' age, gender, eductation, and so on was gathered, and questions concerning the experiments (e.g., assessment of emotional state, appreciation, etc.) were asked throughout these questionnaires.

1.4.4.2. Procedure

In order to collect reliable data, a particular chain of events or procedure had to be followed. Necessarily, the specific order of the steps that had to be taken in every experiment was preserved. In order that all of the steps in the experiment are clear to the reader, the experimental procedure is described in detail in each of the following four chapters.

1.4.5. Analyzing the data and drawing conclusions

Once the data was collected, the studies could proceed to the analysis phase, in which data were inspected, cleaned, transformed, and modeled in order to isolate crucial information from which to draw conclusions. Several phases can be distinguished in the process of data analysis: data cleaning, initial analysis, and the main analysis.

The term *data cleaning* is used to denote the procedure for detecting and correcting errors. During this procedure, the data were inspected and inaccuracies were corrected. Where errors were found, the data were no longer taken into account. For instance, if the accuracy of certain measurements proved to be exceptionally poor, these particular measurements were discarded (e.g., Chapt. 2).

In the course of the *initial data analysis*, several preliminary tests were performed, although at this stage no analysis was performed that aimed to answer the original research question(s). In this phase, the quality of the data and measurements was checked using descriptive statistics and by testing assumptions of normality (Chapt. 2 to 5). In addition, the quality of the measurements was verified through analyses of homogeneity (Chapt. 2 to 4) and by means of validation tests (Chapt. 5). Occasionally, initial transformations were required, such as a Fast Fourier Transform (Chapt. 2).

The aim of the *main analysis* phase was to answer the research question. In addition, other relevant analyses, linked to the research questions and hypotheses, were performed. In the main analysis phase, the adopted approach was either exploratory or confirmatory. An *exploratory analysis* entails no clear hypothesis and enables the testing of multiple models. By contrast, in a *confirmatory analysis*, clear hypotheses about the data are tested (Adér, Mellenbergh, & Hand, 2008). Previous research demonstrates that confirmatory hypothesis testing techniques are more powerful (i.e., have a higher probability of rejecting a false null hypothesis) and have a higher probability of choosing the correct or the best hypothesis than their exploratory counterparts (Kuiper & Hoijtink, 2010). Therefore, in the studies reported in the following four chapters, the analyses performed were mostly confirmatory analyses (e.g., ANOVA, *t*-test, Wilcoxon signed-rank test, correlation test, etc.). However, if no specific hypotheses were drafted for some aspects of the data (e.g., the profile of the participants), exploratory analyses were carried out (e.g., descriptive statistics, PCA, etc.).

1.4.6. Reporting results

Since the work of a researcher is only truly rewarding if the report of the results ends up in the hands of people who are able to use them, in this dissertation, the results of our empirical research are presented as journal papers (see Chapt. 2 to 5). Some of them have already been published or are currently still under review. Some studies were also presented during conferences and summer schools, although these were published as conference papers as well.

1.4.7. Adjusting the theory and beginning again

On completion of our studies, the data could have proven to be very different from what had been expected. If this was the case, rather than discard the entire study, we might have opted to adjust the initial theory, hypothesis and/or research question. In addition, new data could have been collected. Yet, the results of the empirical studies discussed in the following chapters did not necessitate the collection of additional data or adjustment of the hypotheses. At times, even when the data confirmed the hypothesis, the study was complete, and the results were published, new questions arose from particular results. If this was the case, a new study could have been designed in order to deal with these recently developed issues. For example, the questions that emerged from the results of the study described in Chapter 4 led to the design of the study reported in Chapter 5. Thus, research is never finished, yet it embodies a cyclical process of questions leading to answers, leading to new questions …

1.4.8. Conclusion

In this section, we explored the different steps of the research process and presented the principal methods of our empirical research in order to clarify why certain methodological choices have been made. Throughout, we aimed to provide an adequate methodological introduction which should allow the reader to comprehend fully the research tools and procedures described in the following four chapters. A general overview of the topic, participants, stimuli, measuring tools, and analysis techniques of the empirical studies discussed in the following chapters, is provided in Table 1.1.

Table 1.1.: Overview of the main characteristics of the behavioral studies reported in Chapters 2 to 5.

	Chapter 2	*Chapter 3*	*Chapter 4*	*Chapter 5*
Topic	Musical properties and dance	Musical properties and dance	Emotions and dance	Emotions and dance
Participants				
Number	100	36	32	30
Average age	25.43 years	24.20 years	22.75 years	27.23 years
Sex (male/female)	50/50	20/16	16/16	15/15
Stimuli	Original music	Brahms' piano concerto no.1, op. 15	Original music, classical music, guided imagery	Video clips
Measuring tools				
Direct observation	Motion caption, motion sensing	Motion caption	Motion caption	Eye tracking
Indirect observation	Surveys	Surveys	Surveys	Surveys
Analyses				
Exploratory	Descriptive statistics	Descriptive statistics, PCA	Descriptive statistics	Descriptive statistics
Confirmatory	Friedman's ANOVA, *t*-tests	ANOVA	Wilcoxon signed-rank tests, *t*-tests	Chi-square tests, Wilcoxon signed-rank tests, Friedman's ANOVA

PART 2:

EXPERIMENTAL STUDIES ON THE EFFECTS OF MUSICAL FEATURES ON DANCE MOVEMENT

Chapter 2

The impact of the bass drum on human dance movement

Van Dyck, E., Moelants, D., Demey, M., Deweppe, A., Coussement, P., & Leman, M. (2013). The impact of the bass drum on human dance movement. *Music Perception, 30*, 349–359.

Abstract

The present study aims to gain a better insight into the connection between music and dance by examining the dynamic effects of the bass drum on a dancing audience in a club-like environment. One hundred adult participants moved freely in groups of five to a musical sequence that comprised six songs. Each song consisted of one section that was repeated three times, each time with a different sound pressure level of the bass drum. Hip and head movements were recorded using motion capture and motion sensing. The study demonstrates that people modify their bodily behavior according to the dynamic level of the bass drum when moving to contemporary dance music in a social context. Participants moved more actively and displayed a higher degree of tempo entrainment as the sound pressure level of the bass drum increased. These results indicate that the prominence of the bass drum in contemporary dance music serves not merely as a stylistic element; indeed it has a strong influence on dancing itself.

2.1. Introduction

One of the main effects of music is that it supports dance movement. Dance is movement of the human body in response to, and in interaction with music (Ulyate & Bianciardi, 2002). Dance behavior might be a product of evolutionary forces (Phillips-Silver et al., 2011) as dancing together with other human beings could increase group cohesion (Merker, Madison, & Eckerdal, 2009; Wiltermuth & Heath, 2009). It may also have a function in sexual selection (Darwin, 1872/2009), as dance attractiveness could signal phenotypic quality (Brown et al., 2005). The oldest depiction of dance dates back 20.000 years (Appenzeller, 1998), although dance is believed to be as old as the human capacities for bipedal walking and running, which are two to five million years old (Ward, 2002; Bramble & Lieberman, 2004).

It has been suggested that, while dancing, humans tend to generate ‘corporeal articulations’ in response to the auditory stimulus (Leman, 2008). Unlike linguistic description, these are believed to be capable of accurately describing or translating musical experience (Bengtsson, 1973). Just as people tend to imitate the behavior of another person in their own action-oriented ontology in order to understand it, they can mirror changes in sound energy through body movement (Leman, 2008). As imitation is believed to be a well-developed and innate human characteristic that fosters learning and yields pleasure (McKeon, 2001), corporeal imitations of an auditory stimulus are assumed to facilitate a better understanding and a more pleasurable and satisfactory experience of music. Although the precise mechanisms by which acoustical features generate an effect on body movement are little understood (Madison, Gouyon, Ullén, & Hörnström, 2011), it is known that humans tend to be capable of imitating a wide variety of structural layers in music, such as harmony, rhythm, and melody (Leman, 2008). For instance, in a study of running, Edworthy and Waring (2006) explored the effect of tempo and sound pressure level of music on a treadmill exercise. Participants had to perform exercises on a treadmill while listening to a musical stimulus that was presented either fast/loud, fast/quiet, slow/loud, slow/quiet, or was absent. The study showed that increasing the tempo, and to a lesser extent, increasing the loudness of music, tends also to increase running speed. Further to this, the effect of musical cues on corporeal articulations is also observable in more localized body areas, for example in the proclivity to tap along with the beat of the music (Repp, 2005).

Aside from corporeal articulations in response to music, joint action or global group attuning can occur, as dancing most often takes place in social contexts (Leman, 2008). Kirschner and Tomasello (2010) suggested that moving to music encourages dancers to maintain a constant audiovisual representation of the mutual intention and goal of dancing, which satisfies the intrinsic human desire to share emotions, experiences, and activities with others. De Bruyn, Leman, Moelants, and Demey (2009) sought to quantify the effect of social interaction on dance movements made both by individuals and groups of participants. Results showed that social context not only stimulates participants to entrain more closely with, and to move more actively to music, but it also increases the entrainment of the movements between the individuals. A common case of small-scale joint action is when someone is walking with a friend and suddenly becomes aware that they are not in step. As a result, he or she tries to get in step in order to be 'with' that person. On the other hand, when someone discovers that his or her footsteps are in sync with those of a total stranger, this can create a sense of intimacy that feels awkward. Therefore, he or she will try to get out of step (Gill, 2007). Joint action in large groups can be observed during pop concerts where people often synchronize dance movements. Other products of global group attuning are drum circles, where people gather to drum together with the intention of sharing rhythm and entraining their performances and movements to one another in order to form a group consciousness (Phillips-Silver, Aktipis, & Bryant, 2010).

As humans have the capacity to become attuned both to musical stimuli and to each other, there is perhaps no stronger behavior to unite humans than coordinated rhythmic movement (Phillips-Silver et al., 2010). Throughout history, both coordinated rhythmic movement and the shared feelings it evokes have proved their potency in holding groups together (McNeill, 1995). The driving force behind this phenomenon is motor entrainment, i.e., the ability to align motor actions with external rhythms (Brown, Martinez, & Parsons, 2006). In that context, Toiviainen, Luck, and Thompson (2010) showed that several levels of the metrical hierarchy of music are simultaneously embodied in the movements of dancers. Large and Jones (1999) consider entrainment where parts of the dancer match up with certain time spans in the music as a means of understanding or, as they state, 'knowing' the music. Several studies imply that the capacities to perceive and entrain to a beat or to a musical tempo rely on a network of auditory, motor, and vestibular systems (Janata & Grafton, 2003; Phillips-Silver & Trainor, 2008; Trainor, Gao, Lei, Lehtovaara, & Harris, 2009; Zatorre et al., 2007). On the other hand, there is also evidence to suggest that gestures affect beat perception, as Phillips-Silver and Trainor (2007) discovered that the human encoding of meter could be affected by passive movements of the body.

The present work is an empirical investigation into the phenomenon of motor entrainment, as it occurs in actual dance clubs. Dance clubs have become a significant part of the entertainment scene for many young adults, and attending such clubs ('clubbing') has become a common recreational activity for many young people (Williams, Beach, & Gilliver, 2011). In this dance scene, it is common practice to enhance music with loud low-frequency beats (e.g., by turning up the volume in the low-frequency domain), or the so-called 'bass drum', in order to encourage the audience to move. The significance of the bass drum in contemporary music is also manifested through the popular trend of adding components (e.g., subwoofers) to home or automobile stereo systems for the sole purpose of intensifying audio bass reproduction (McCown, Keiser, Mulhearn, & Williamson, 1997). According to Todd, Cody, and Banks (2000), a loud bass drum may affect the vestibular system and subsequently, also the sense of motion. These researchers suggested that acoustically evoked sensations of self-motion may to a certain extent account for the compulsion to expose oneself to loud bass drum sound. It has also been shown that listening to rhythms with a strong beat engages motor areas in the brain (Chen et al., 2008; Grahn & Brett, 2007). More specifically, Large and Kolen (1994) suggested that events with greater accent (e.g., intensity) could cause greater phase and period adjustments. In addition to affecting movement, a loud bass drum sound could elicit sensations of pleasure. Continuous stimuli with frequencies between about 50–800 Hz above about 90 dB may evoke a continuous response in the saccular nerve (Todd et al., 2000). When the sacculus, which is part of the vestibular system, is stimulated, sensations of pleasure arise through interaction with the limbic system. By activating the sacculus, loud music with a strong beat may be a form of vestibular stimulation. Percussive sounds are also expected to have a power distribution in the region of saccular sensitivity. Thus, the typical intensities and frequency distributions in dance clubs might be considered to be intended to stimulate the sacculus (Dibble, 1995).

Motor entrainment has been studied extensively, although only a few experiments have been executed with more than one participant at a time (Drake, Penel, & Bigand, 2000; Snyder & Krumhansl, 2001; Toiviainen et al., 2010), and consequently, they have overlooked the social aspect of entrainment, or joint action, despite the fact that motor entrainment usually takes place in social contexts (Kirschner & Tomasello, 2010; Repp & Keller, 2008). Therefore, in this study, the experiments were performed in groups of participants, in order to replicate the situation of a dance club.

This study examines the impact of the sound pressure level of the bass drum (the beat presented in the low frequency domain) on a dancing audience. In view of the fact that a loud bass drum can affect the vestibular system, and subsequently also the sense of motion (Todd et al., 2000), we expected bass drum loudness to affect human movement. As Edworthy and Waring (2006) revealed that loud music can enhance optimal exercising, we presumed that an increase in the sound pressure level of the bass drum could lead to an increase in motor activity. Moreover, the effect on tempo entrainment is considered. Large and Kolen (1994) suggested that events with greater accent could cause greater period adjustments. Therefore, we expected that an increase in bass drum loudness could improve tempo entrainment. Additionally, as the experiment was performed in groups, social interaction was presumed to have an effect on participants' movements. Consequently, we expected to uncover an effect of joint action, in the form of an increased similarity of movements between members of the same group compared to movements between members of different groups. Finally, the effect of sex is examined. As Passmore and French (2001) revealed that females are more likely to actively engage in dance activities than men, we expected female participants to display more active dance movements than male participants.

2.2. Method

2.2.1. Participants

A total of 100 adult participants (50 females, 50 males) with an average age of 25.43 years (*SD* = 8.01) took part in the study. All participants had normal hearing capacities. The majority (72 %) had received music lessons: at a music school (65 %), a conservatory (4 %) or via private music lessons (3 %). Of all participants, 85 % reported enjoying dancing (9 % danced about once a year or less; 33 % about once a month; 43 % about once a week or more), and 35 % had received dance training. All participants signed a form to declare that they participated voluntarily and that they had received sufficient information concerning the tasks, the procedures, and the technologies used. As a reward, they received a CD voucher.

2.2.2. Music

The music for the experiment consisted of a club-like mix, conceived as a concatenation of six electronic pieces (here referred to as ‘songs’), composed exclusively for this study. The choice to use new and unknown music was motivated by the intention of ensuring optimal control over all musical parameters and to exclude effects of familiarity. The composition had a fixed tempo of 128 beats per minute (BPM), which represents the most common tempo in contemporary dance music (Moelants, 2008). Every beat of the bass drum sounded identical, which means that no single one was any more stressed than the others.

The music was composed in a 4/4 meter, and in the key of A minor. The key remained unaltered throughout all six songs. The composition comprised two independent instrumental parts. One contained all the melodic material, consisted of two lead synthesizers (in the mid section of the frequency range) and had relatively simple chord progressions, similar to those used in popular house and techno records. The other instrumental part consisted of a stable basic bass drum. Each of the six songs consisted of three loops of a 16-bar core-motive (30”), different for each song (see Fig. 2.1). This motive appeared three times in the course of the stimulus, featuring three different sound pressure levels of the bass drum (bass drum levels, BDLs). The order of the different BDLs was determined in such a way that it would ensure that each possible series of levels would occur only once. When producing the mix, the reference level of the bass drum (i.e., the intermediate level, BDL 2) was determined by giving the bass drum a clear presence in the mix, resembling modern dance productions, and without affecting the global sound pressure level (SPL) of the mix. At the lower (-5 dB) level (BDL 1), the bass drum faded further into the background of the mix, whereas the higher (+5 dB) level (BDL 3) made the bass drum more prominent.

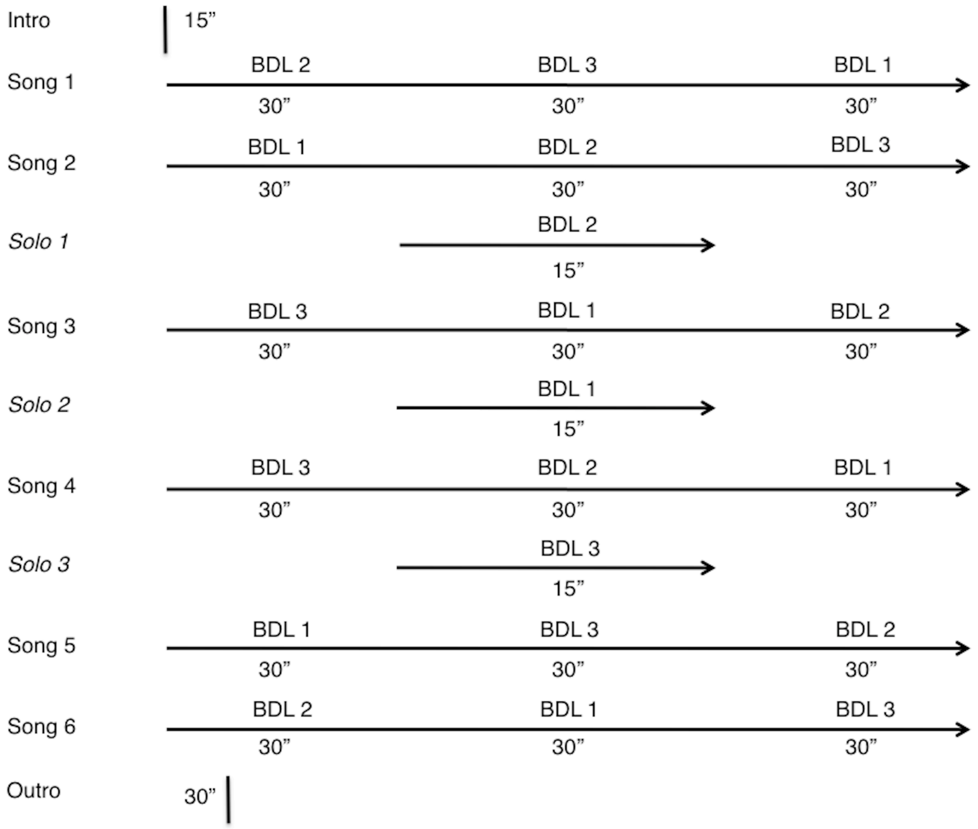


Figure 2.1.: Overview of the succession of the different BDLs in the musical stimulus.

Finally, three points in the music were chosen where the bass drum was presented without accompaniment for 15 seconds, each with a different SPL, serving as a point of reference for the analysis. These solo parts were placed between the second and third song, between the third and fourth song, and between the fourth and fifth song. Hence, the mix consisted of 21 blocks and had a length of 9 minutes and 45 seconds. Additionally, a short introduction (15”) was added to avoid a start-up-effect in the first song, whereas a fade-out (30”) was added at the end of the composition. The introduction and the fade-out were not taken into account in the analysis.

2.2.3. Apparatus

Participants were fitted with a hip bag containing a wireless Nintendo Wii Remote Controller and wore a hat with three reflective markers for position tracking with a motion capture system (Optitrack, Natural Point). Acceleration data from the remote controller were recorded at a sampling rate of 100 Hz using a Max/MSP patch, the resultant recording being synchronized with the playback of the musical stimulus. The 3D position of the head was also tracked at a sampling rate of 100 Hz. In order to be able to synchronize the audio playback and the motion capture recordings, the control of an Arduino card was incorporated in the Max/MSP patch. The Arduino card controlled IR LEDs (infrared light-emitting diodes), detected in the motion capture data as markers. The IR LEDs were switched on at the moment the audio playback was started, defining the onset in the motion capture data. The music was played through four Metro MX100 loudspeakers, placed in every corner of the dance floor just behind the curtains. The space was equipped with basic club-style lighting, including sound-sensitive light effects. The light effects responded to sound in general and did not stress the bass drum. Figure 2.2 depicts a group of participants performing the experiment in the experimental room where they were shielded from the outside world by black curtains and where colorful lighting contributed to create a club-style atmosphere.

Figure 2.2.: Group of participants performing the experiment accompanied by sound-sensitive light effects.

Mean SPL and peaks in the SPL of the music were measured by means of a Svantek SVAN 959 sound and vibration analyzer. Measurements demonstrated that the overall dB(A) level (see upper graph in Fig. 2.3.) remained below the legally permitted Belgian limit of 90 dB(A). On the authority of the National Institute for Occupational Safety and Health's (NIOSH) (http://cdc.gov/niosh/) chart of loudness and exposure time, a maximum exposure of 8 hours per day at 85 dB(A) is allowed. No direct relationship between the BDL and changes in the global dB(A) was noticeable (except during the solo parts), as shown in the upper graph of Figure 2.3. The lower graph illustrates the SPL at 63 Hz (bass drum sound).

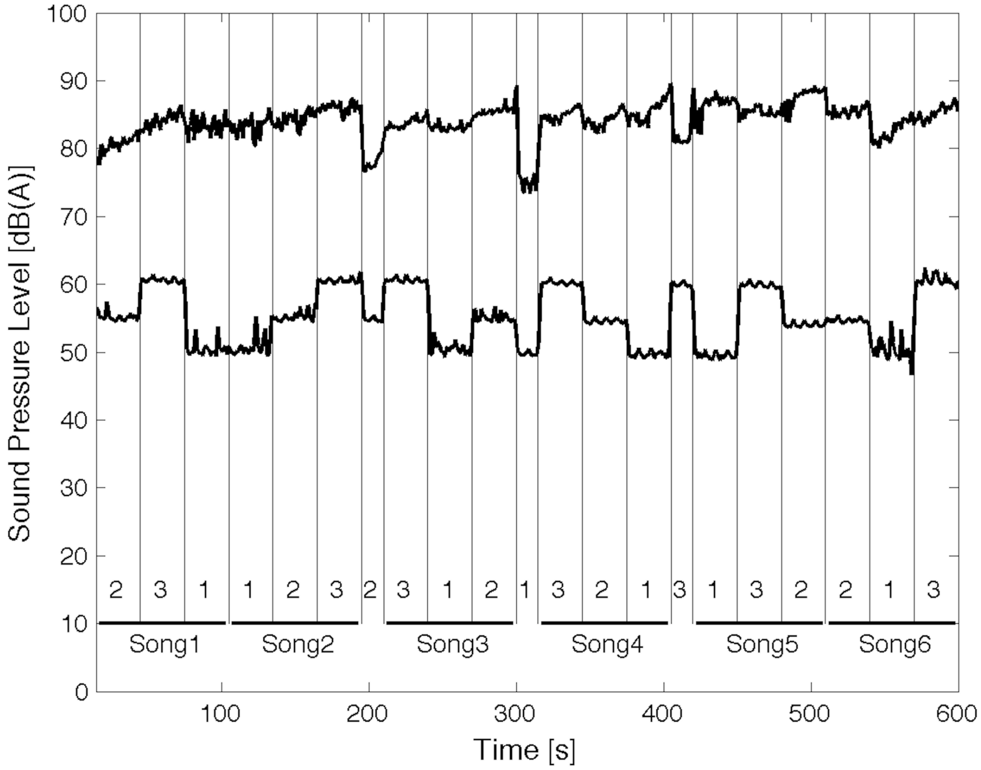


Figure 2.3.: Overview of the SPL for each song and BDL, the upper graph representing the global dB(A) level, the lower graph illustrating the dB(A) level at 63 Hz.

2.2.4. Procedure

The experimental sessions took place in the late afternoon or evening. Participants were invited in groups of five. Upon their arrival, they were offered refreshments and were asked to complete a form with questions about their personal background and their music and dance preferences and training. After having been fitted with the movement tracking equipment, participants were directed to a dance floor surrounded by black curtains. Next, they were instructed to move freely to the music. After the experiment, they were asked to complete a second questionnaire which included items concerning the participants' impressions of the experiment. Participants had to elaborate on their appreciation of the musical stimulus, the lighting effects, and the general ambience. The total duration of the experiment was about 30 minutes.

2.2.5. Data processing

The measurements aimed at extracting two parameters from the movement data, called activity count and tempo entrainment. Activity count was extracted from acceleration data. For that purpose, we measured the 3D acceleration of the hips, using the remote controller attached to the hips. Tempo entrainment was extracted from displacement data. For that aim, the 3D displacement of the head was measured, using the motion capture system. The choice of body parts was based on a pilot study where head and hips indeed proved to be the most reliable body parts for the parameters we wanted to extract. Moreover, foot, leg, and arm movements depended on the dominance of the right or left foot, leg, or arm whereas the head and hips did not display a similar lateral dominance.

2.2.5.1. Activity count

Activity count concerns a quantity commonly used in studies related to actigraphy, where motor activity is monitored. This quantity could be calculated on the basis of a digital integration of the acceleration signal. First, the acceleration was filtered using a band-pass filter between 0.5 Hz and 4 Hz. This resulted in the removal of the offset in the acceleration signal due to the constant force of the gravitation. In addition, it reduced signals that were unrelated to the actual motion of the participants. The next step concerned the rectification of the signal and summation of the samples over the time period under study. Since a 3D sensor was used to measure acceleration, activity count consisted of the mean value of the RMS over the three directions:

$$C = \frac{1}{N}\sum_{i=1}^{N}\sqrt{a_x(t_i)^2 + a_y(t_i)^2 + a_z(t_i)^2}$$

where N was the total number of samples in one BDL segment and $a_{x,y,z}$ concerned the 3D acceleration measured at time t_i. For each participant, activity count was calculated for each of the 21 segments in the music.

2.2.5.2. Tempo entrainment

In order to quantify entrainment with the tempo of the music, a frequency analysis of the positional data of each participant was performed. This analysis was carried out on the positional information in the vertical direction. The analysis was based on a Fast Fourier Transform (FFT). The input consisted of windows of data with a duration of five seconds (corresponding to 500 data points at 100 Hz sampling rate), zero padded to a total length of 6000 samples in order to achieve a resolution of 1 BPM in the frequency domain. Initially, each window of data was centered on zero to eliminate the frequency component at 0 Hz, and multiplied with a Hanning window in order to minimize higher harmonics due to disruptive changes at the boundaries of the analyzed data set (see Fig. 2.4). This analysis was repeated every 0.25 seconds to obtain a clear picture of the behavioral change of the participants. Movements from each musical fragment with different BDL were analyzed, and data obtained during transitions between these fragments were disregarded. The analysis resulted in 101 FFT calculations for each musical fragment of 30 seconds (i.e., (30”-5”)/0.25”+1) and 41 FFT calculations for the solo fragments of 15 seconds (i.e., (15”-5”)/0.25”+1). In each of the frequency spectra obtained, the highest peak was located in the range between 20 BPM and 200 BPM and its corresponding BPM value was used in the statistical analysis.

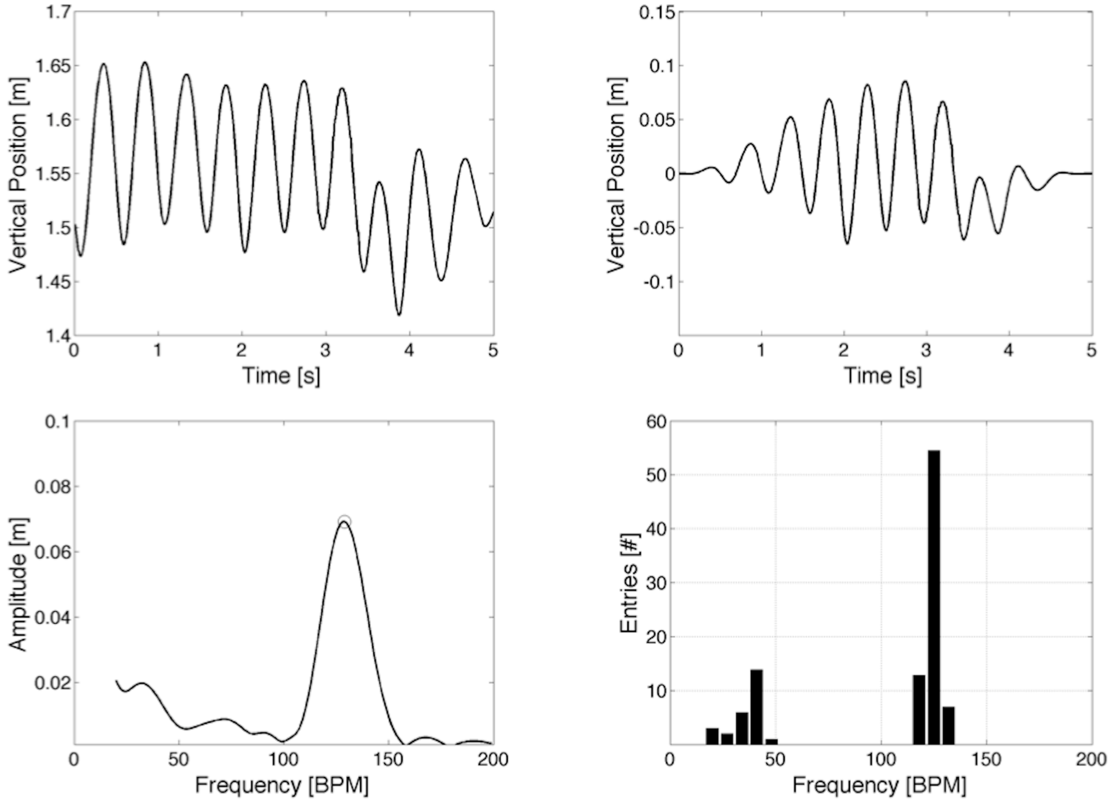


Figure 2.4.: Example FFT graphs for the tempo entrainment of one participant. The first graph represents the original input of movement data in a frame of five seconds. The second graph shows the same window after centering on zero and multiplying with a Hanning window. The third graph displays the frequency output containing the highest peak value in the range between 20 BPM and 200 BPM. The fourth graph shows the resulting histogram for a single piece of music of 30 seconds.

For each of the 21 segments in the music, the obtained BPM values found in the FFT analysis were added to a histogram with bins of 7 BPM-width, where either 128 BPM (one-beat periodicity) or 64 BPM (two-beat periodicity) was at the center of its corresponding bin. Both one-beat periodicity and two-beat periodicity were studied as adults are believed to be able to entrain to external rhythms over a great range of tempi, also at rates that are multiples or fractions of the same underlying pulse (e.g., Drake, Jones, & Baruch, 2000; Large & Palmer, 2002; Snyder & Krumhansl, 2001). Double beat was not studied as 128 BPM already proved to be quite fast. By combining the bins corresponding to 128 BPM and 64 BPM, it was possible to count the times the participants were entrained to the tempo of the music. Since there were either 101 or 41 frequency analyses performed for each musical segment of 30 seconds or 15 seconds, respectively, these counts were added and scaled to a maximum of 100, so the number represents the percentage of time during which the participants successfully entrained with the tempo of the music.

2.3. Results

Apart from the effect of the BDL on activity count and tempo entrainment, we also examined the effect of social interaction. Moreover, the effect of the participants' sex was studied.

2.3.1. Activity count

We first examined whether there was any significant effect of the six songs on activity count. A Kolmogorov-Smirnov test (KS-test) showed that the assumption of normality could not be accepted. A Friedman's ANOVA with the songs as test variables showed a significant change in activity count over the songs, $\chi^2(5) = 222.76$, $p < .05$.

Next, mean activity count over the six songs was calculated for each BDL. A Friedman's ANOVA with mean activity count as test variable was used to check the effect of the different BDLs. This test showed a significant change in activity count over the BDLs, $\chi^2(2) = 24.01$, $p < .05$. Wilcoxon tests were used to follow up this finding and a Bonferroni correction was applied. It appeared that activity count significantly increased from BDL 1 to BDL 2, $T = 3597$, $p < .0167$, $r^2 = .07$, and from BDL 1 to BDL 3, $T = 3773$, $p < .0167$, $r^2 = .09$. No significant difference was found between BDL 2 and BDL 3 (see Fig. 2.5).

When considering the 'solo bass drum' sections, activity count also changed significantly over the BDLs, $\chi^2(2) = 32.82$, $p < .05$. Activity count significantly increased from BDL 1 to BDL 2, $T = 3409$, $p < .0167$, $r^2 = .05$, from BDL 2 to BDL 3, $T = 3605$, $p < .0167$, $r^2 = .07$, and from BDL 1 to BDL 3, $T = 4149$, $p < .0167$, $r^2 = .15$ (see Fig. 2.5).

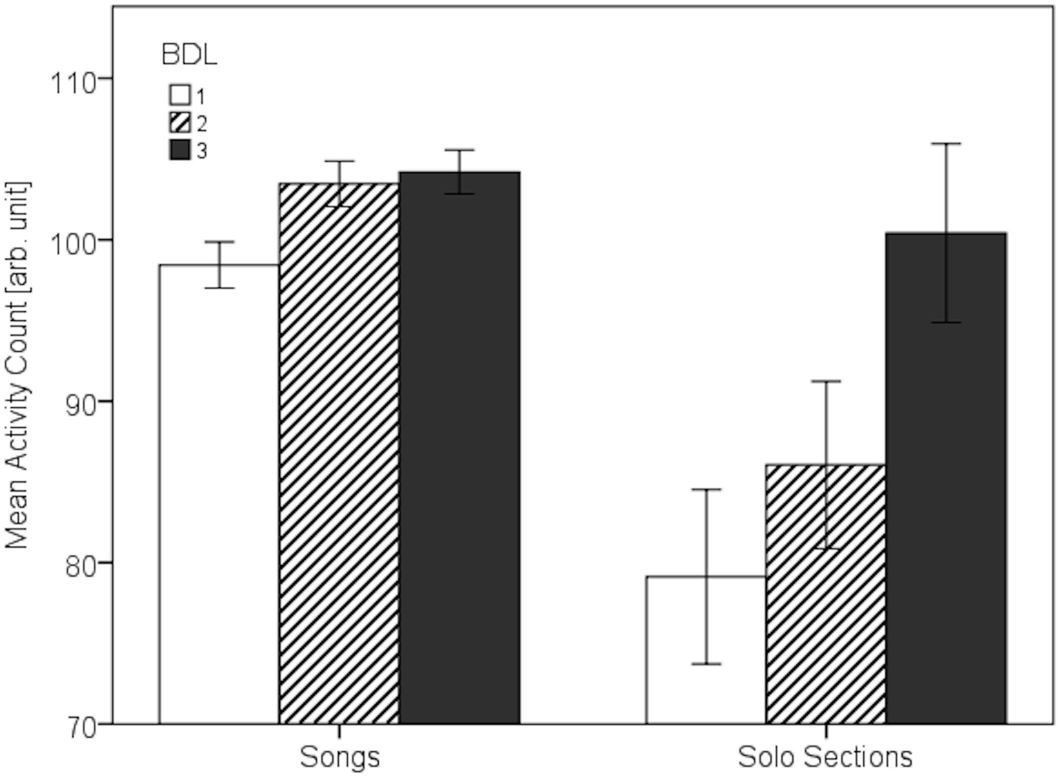


Figure 2.5.: Mean activity count for the songs and solo sections as a function of BDL. Data presented are mean ± SE.

2.3.2. Tempo entrainment

Only 14 of the 20 groups (n = 70) produced workable data sets from motion capture. The data of six groups were removed due to missing values caused either by occlusion of markers, or by participants dancing outside of the range of the camera system. Therefore, tempo entrainment data of only 70 participants is analyzed here.

Just as in the activity count analysis, we started by testing the effect of the songs on the participants' entrainment with the tempo of the music. A KS-test showed that the assumption of normality could not be accepted. A Friedman's ANOVA with the songs as test variables showed a significant change in tempo entrainment over the songs, $\chi^2(5) = 59.97$, $p < .05$.

Subsequently, mean tempo entrainment over the songs was calculated and considered in the analysis. A Friedman's ANOVA with mean tempo entrainment as test variable revealed a significant change in tempo entrainment over the BDLs,

$\chi^2(2) = 55.80$, $p < .05$. It appeared that tempo entrainment significantly increased from BDL 1 to BDL 2, $T = 1642$, $p < .0167$, $r^2 = .04$, from BDL 2 to BDL 3, $T = 2206$, $p < .0167$, $r^2 = .23$, and from BDL 1 to BDL 3, $T = 2373$, $p < .0167$, $r^2 = .31$ (see Fig. 2.6).

Also in the solo sections, a significant effect of the BDL on tempo entrainment was found, $\chi^2(2) = 10.21$, $p < .05$. Tempo entrainment significantly increased from BDL 1 to BDL 2, $T = 1678.50$, $p < .0167$, $r^2 = .06$, and from BDL 1 to BDL 3, $T = 1548$, $p < .0167$, $r^2 = .06$. No significant effect was found between BDL 2 and BDL 3 (see Fig. 2.6).

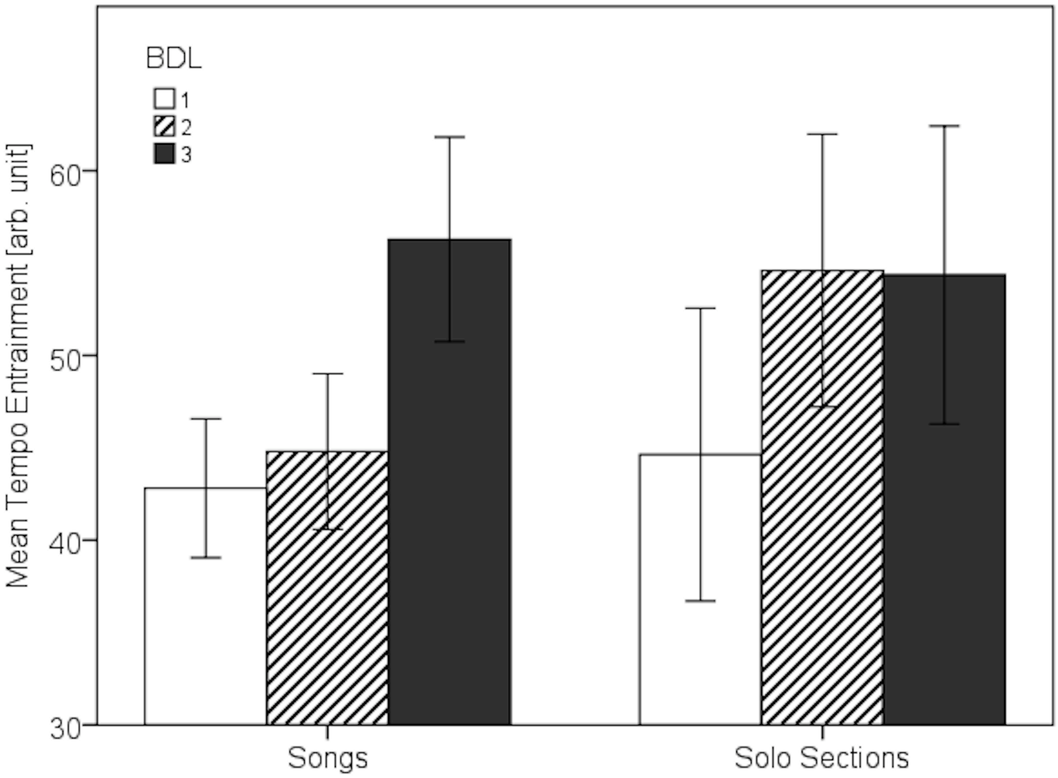


Figure 2.6.: Mean tempo entrainment for the songs and solo sections as a function of BDL. Data presented are mean ± SE.

2.3.3. Joint action

Next, the effect of joint action was examined. Based on both activity count data and tempo entrainment data for all songs (including the solo sections) and BDLs, Pearson's correlation coefficients between all participants were calculated.

Subsequently, mean Pearson's correlation coefficients between all groups were calculated for both activity count and tempo entrainment. Finally, mean coefficients of correlation within groups were compared with mean coefficients of correlation between different groups.

For both activity count and tempo entrainment, the assumptions of homogeneity of variances and normality could be accepted. Paired-samples *t*-tests with the mean coefficients of correlation within groups and the mean coefficients of correlation between different groups as test variables showed that, with regard to activity count, correlation coefficients were significantly higher within groups (M = .52, SE = .04) than between different groups (M = .20, SE = .02), $t(19) = 9.71$, $p < .05$, $r^2 = .83$. With regard to tempo entrainment, correlation coefficients were again significantly higher within groups (M = .50, SE = .05) than between different groups (M = .41, SE = .02), $t(13) = 2.73$, $p < .05$, $r^2 = .36$.

2.3.4. Sex

Finally, we examined whether there was any significant sex difference in average tempo entrainment, average activity count, or in response to the BDL. No significant difference was found concerning average tempo entrainment or concerning response to the different BDLs. Concerning activity count, a significant effect did appear. The average activity count over the songs and BDLs was calculated and used in the analysis. As the assumptions of homogeneity of variances and normality could be accepted, an independent *t*-test with the average activity count as test variable and sex as grouping variable showed that on average, female participants (M = .31, SE = .01) displayed significantly more activity than male participants (M = .26, SE = .01), $t(98) = -2.24$, $p < .05$, $r^2 = .05$.

2.4. Discussion

The present study investigated the effect of the sound pressure level of the bass drum on human dance movement. We presumed that an increase in the loudness of the bass drum could enhance tempo entrainment and activity count. In addition, a group effect and an effect of sex was expected to be uncovered. The kinematic analysis showed that participants did indeed embody the dynamic level of the bass drum. Analysis revealed that an intensification of the sound pressure level of the bass drum led to an increase in activity count. This finding is consistent with the idea that loudness generally results in more energetic movements of the listener (McNeill, 1995), a phenomenon often observed in dance clubs where DJs boost the volume of the bass drum in order to motivate the audience to move (McCown et al., 1997). It could also be linked with neuroscientific research, which emphasizes the extreme sensitivity of a particular element of the human vestibular system - the sacculus - to low-frequency and infrasound vibrations (Todd, Rosengren, & Colebatch, 2008). According to this research, sensations of pleasure are believed to emerge when the sacculus is stimulated, and it would appear that triggering the sacculus using bass sounds also results in bodily responses as participants moved more actively to an increase in the bass drum loudness.

Alongside the influence of the bass drum on activity count, an effect was revealed with respect to tempo entrainment. Participants became more closely entrained with the tempo of the music subsequent to a rise in the loudness of the bass drum. Similar findings have been reported by Burger, Thompson, Saarikallio, Luck, and Toiviainen (2010), suggesting that music with a clear rhythmic structure in the low frequency range encourages participants to move ‘on the spot’, whereas structures in this frequency range which are not so clear tend to prompt locomotion, perhaps as if dancers were ‘looking for the beat’. Our finding is also in accordance with the idea that events with greater accent could cause greater period adjustments (Large & Kolen, 1994). Additionally, an increase in the sound pressure level of the bass drum obviously facilitates beat perception, consequently, tempo perception; thus, it could facilitate tempo entrainment. It is worthwhile considering the overall level of audibility of the bass drum: it seems likely that, at particularly loud or soft overall levels, increases in bass drum volume might not lead to significant changes in bodily behavior, whereas at intermediate overall levels, the effects of variations in bass drum loudness on body movement might be more distinct. This is an issue worthy of further investigation.

Another interesting observation concerned joint action, as a group effect could be uncovered. Participants of the same group correlated stronger with each other than with participants of other groups. This finding could suggest that dancing in a group could have a positive influence on social bonding and behavioral coherency in groups of people, and therefore could facilitate group cooperation and mutual understanding (Freeman, 2000; Richman, 1987). However, this is a matter of some speculation and would benefit from further study.

With regard to sex, a general effect was uncovered as female participants moved more actively than their male counterparts. This observation could be explained by a study of Passmore and French (2001), which revealed that women are more likely to actively engage in dance activities than men. Moreover, Sanderson (2001) suggested that this difference in attitude to dance is already established during childhood. In her study, opinions were sought from a total of 1668 girls and boys, aged between 11 and 16 years, using questionnaires which included dance attitude scales. Results showed that girls display more positive attitudes to dance than boys. Risner (2009) argued that the tendency of (particularly Western) men to display less positive attitudes to dance and to be less 'willing' to dance than women, is due to the fact that the dominant Western paradigm positions dance as a predominantly female activity and art form. Therefore, males who dance (whether gay or straight) are always in danger of being stigmatized as effeminate.

An issue that was not considered in this study was that of personality, despite its being believed to play a role in the preference for loud bass sounds in music (McCown et al., 1997). Both psychoticism and extraversion are presumed to be positively related to the preference for enhanced bass. However, the data collected in this study did not allow any detailed investigation of the potential effects of personality.

This study aimed at creating an ecological setting through the employment of club-style lighting and contemporary dance music. The music was composed especially for this particular study, in order to ensure full control over every parameter in the music. Inevitably, it could be argued that the stimulus was in some way 'artificial'. However, some ecological validity of the composition was ensured as it was created by both an experienced modern dance music composer and producer. Moreover, participants' assessments of the music proved to be particularly positive and besides, implementing existing music could have caused confounding effects due to familiarity.

A social condition was created, by studying the effect of the bass drum dynamics on groups of five participants, as motor entrainment generally occurs in social contexts (Kirschner & Tomasello, 2010; Repp & Keller, 2008). Future work might investigate the effect of the sound pressure level of the bass drum both on larger groups of participants, for example in an actual dance venue, and on participants dancing alone, for instance in front of a mirror or without any means of monitoring their movements. In such conditions, the level of the bass drum might still be expected to affect participants' movements. However, whether the sound pressure level of the bass drum could affect movements of a single participant and of large groups of participants should be investigated in further studies.

To our knowledge, this study is pioneering in examining the excessive bass drum sound, which is so essential for popular dance music. As the sound pressure level of the bass drum increased, activity count and tempo entrainment increased as well. This suggests a strong causal effect of bass drum loudness on movement. These findings demonstrate that, in addition to its function as a stylistic element, the bass drum has a strong impact on dancing itself.

Chapter 3

The coupling of action and perception in musical meaning formation

Maes, P.-J., Van Dyck, E., Lesaffre, M., Kroonenberg, P.M., & Leman, M. (In press). The coupling of action and perception in musical meaning formation. *Music Perception*.

Abstract

The embodied perspective on music cognition has stressed the central role of the body and body movements in musical meaning formation processes. In the presented study, we investigate by means of a behavioral experiment how free body movements in response to music (*action*) can be linked to specific linguistic, metaphorical descriptions people use to describe the expressive qualities they perceive in the music (*perception*). We introduce a dimensional model based on the Effort-Shape theory of Laban in order to target musical expressiveness from an embodied perspective. Also, we investigate whether a coupling between action and perception is dependent on the musical background of the participants (i.e., musically trained versus musically untrained). The results show that the physical appearance of the movements performed in response to the music are reliably linked to linguistic descriptions of musical expressiveness in terms of the underlying quality. Moreover, this result is found to be independent of the participants' musical background.

3.1. Introduction

Metaphoric linguistic expressions are ubiquitous when people speak about music in the context of Western music tradition (Cox, 2011; Guck, 1994). Generally spoken, a metaphorical construct (e.g., 'life is a journey') elucidates an abstract idea (e.g., 'life') by connecting it to a related concrete, sensory-motor experience (e.g., 'journey'). In that sense, embodied, sensory-motor experiences are considered to play an important role in the use and understanding of metaphors (Crawford, 2009; Gibbs, Costa Lima, & Francozo, 2004). In the context of music, research has indicated that a substantial part of musical metaphors relate to people's experience of physical motion and space (Cox, 2011; Larson, 2012). Moreover, in the general paradigm of embodied music cognition, related theories have been developed explaining how people perceive and understand music, at least partly, in terms of music-induced body movement: the motor model of musical expressiveness (Leman, 2008), the motor-mimetic theory (Godøy, 2003), and the mimetic hypothesis (Cox, 2011), for instance. In the present study, we elaborate on the idea that the embodied experience of music is an important factor in people's understanding and employment of musical metaphors.

When listening to music, people often respond by making body movements reflecting certain aspects of the melodic and rhythmical contours inherent to the music, or of the gestures from which the music originated (Godøy, 2010). The performance of music-induced movements may instigate a sense of imagined participation with the production of the sound. This idea of imagined participation is addressed in a broad range of musicological studies with different terminology: imagined activity (Maus, 1988), active imagination (Scruton, 1997), kinesthetic empathy (Mead, 1999), simulated control (Leman, 2008), and imaginary agency (Levinson, 2006), for example. What all of these accounts have in common is their reference to a direct, sensory-motor engagement with music, to how music literally 'moves' people, and to how people feel immersed into, and resonate with, the physical sound energy. In this study, our aim was to investigate to what extent this form of embodied, sensory-motor engagement with music can be related to the use of musical metaphors. More in particular, an experiment is presented that aimed at exploring to what extent physical and expressive properties of music-induced movements (i.e., *action*) are reflected in the linguistic metaphors used by people to describe the expressive qualities they recognize in the music (i.e., *perception*).

To bridge low-level physical movement properties with high-level expressive linguistic concepts, the Effort-Shape model that originated in the Laban movement analysis (LMA) method (Laban, 1947, 1966/2011) has been applied in the current study. This model proved to be particularly appropriate as it provides an integrated conceptual system connecting a set of physical movement properties with expressive qualities. Spatial aspects as well as aspects related to Effort are thereby taken into account. The Effort-Shape model has been applied in previous studies investigating expressive movement responses to music (Camurri, Mazzarino, Ricchetti, Timmers, & Volpe, 2004; Maes, Leman, Lesaffre, Demey, & Moelants, 2010). However, no previous attempts were made to apply the model in order to provide a more profound view on the coupling between free movement responses to music and linguistic metaphors used to describe the same musical stimulus.

The experiment that was conducted, consisted of two parts. In one part, people were asked to perform free body movements in response to music (i.e., *motor-attuning part*). These body movement responses were recorded with an optical motion tracking system. In the other part, people were asked to associate a set of 24 bipolar adjectives with the musical stimulus while passively listening to the music (i.e., *self-report part*). The selected stimulus consisted of the beginning of the first movement of Johannes Brahms' First Piano Concerto. Instead of employing different, shorter extracts of music, we opted for one continuous piece of music in which contrasts in musical material are an inherent part of the composition; a typical feature of Late Romantic music. The rationale behind this choice is threefold. First, listening to a continuous piece of music is assumed to create a more ecological valid listening situation in which the listeners could immerse themselves in the music. Second, it allowed us to investigate whether the extremities in musical material were reflected in body movement responses and musical metaphors. Third, the contrasts in musical material were selected in order to reflect the opposing polarities used to structure the Effort-Shape model. Based on these contrasts in musical material, we defined two musical styles, a *heroic style* and a *lyric style*. Both were identified in three separate passages in the music. Participants were asked to rate each of these six different passages based on the set of 24 bipolar adjectives scales. Although participants were asked to move continuously for the duration of the complete length of the musical composition, the movement analysis only considered movement data that was recorded throughout these six specific passages.

Generally spoken, three main research questions were at stake in the current study. First, we wanted to investigate whether the contrasts in musical material were reflected in both participants' movement responses to the music and their ratings of the music. Second, we wanted to investigate possible dissimilarities between the different participants and check whether these differences were correlated with their musical background (i.e., *musically trained* versus *musically untrained*). Third, we aimed at investigating possible correlations between participants' movement responses and the musical metaphors they attributed to the music.

3.2. Method

3.2.1. Participants

We invited 36 people to participate in the experiment. The participants were students enrolled in a broad range of academic disciplines at Ghent University. They received no compensation for participating in the study. Two distinct groups of participants were systematically recruited on the basis of their musical background. A first group (i.e., *musically trained group*) was composed of 18 participants (10 male, 8 female) with an average age of 23.8 years (*SD* = 3.7). They reported to have received music education with a mean number of 9.7 years (*SD* = 5.4). In addition, they all played a musical instrument. Moreover, we asked how familiar participants were with the type of music used in the experiment. This question was rated on a five-point Likert scale, with 1 as 'not at all familiar', 3 as 'somewhat familiar', and 5 as 'extremely familiar'. The mean rating of the participants in the musically trained group was 4.17 (*SD* = 0.38). A second group (i.e., *musically untrained group*) was composed of 18 participants (10 male, 8 female) with a mean age of 24.6 years (*SD* = 4.8). They reported not to have received music education (except for the obligatory courses in primary and secondary school). Moreover, they did not play a musical instrument. Their ratings of 'musical familiarity' resulted in a mean of 1.67 (*SD* = 0.48).

As we considered it to be a factor which could have influenced the experimental outcome, we also tested the level of introversion/extraversion of each participant. In order to do so, we used a Dutch translation of the Big Five Inventory test (Denissen, Geenen, Van Aken, Gosling, & Potter, 2008) which provides, for the measure introversion/extraversion, a score from 1 to 5, with 1 equaling 'very introvert' and 5 equaling 'very extravert'. A statistical *t*-test indicated that there was no significant difference between the scores on extraversion/introversion between the musically trained group (*M* = 3.49, *SD* = 0.62) and the musically untrained group (*M* = 3.51, *SD* = 0.67), *t*(34) = -.10, *p* = .92. Thus, both groups were particularly homogeneous with regard to the factor extraversion/introversion.

3.2.2. Materials

3.2.2.1. Musical stimulus

The musical stimulus that was used in this experiment consisted of a segment of Johannes Brahms' First Piano Concerto, Opus 15 in D minor. More in particular, we employed 5 minutes of the first 6 minutes and 10 seconds of the Maestoso movement. The recording used in the experiment was a performance of Krystian Zimmerman accompanied by the Berlin Philharmonic Orchestra, conducted by Simon Rattle. This specific musical composition is characterized by passages articulating extreme contrasts in physical acoustic energy. Based on this quality, we defined two contrasting categories with regard to musical style which structure the main outline of the composition, namely a *heroic* and *lyric* style category. In the first 6 minutes and 10 seconds of the Maestoso movement, three heroic passages are alternated with three lyric passages (see Fig. 3.1). As the first lyric passage is relatively long compared to the other lyric sections, a part (with a duration of 1 minute and 10 seconds) of that passage was removed from the audio recording. Consequently, the musical stimulus used in the experiment had a total duration of 5 minutes. In view of the fact that fragments of equal duration were required for both the movement and self-report analysis, six fragments with a duration of 30 seconds each were defined and were taken into account in the analysis. Other than what the labels heroic and lyric might suggest, the categories were not defined in terms of expressive content but in terms of physical acoustic properties extracted from the musical signal. The acoustic properties that were obtained from the audio signal encompassed an energy feature (i.e., amplitude) and spectrum properties (i.e., irregularity, spectral flatness, spectral sharpness, and spectral variance). These qualities were extracted using the VAMP libXtract plugin (Bullock, 2007, 2009) hosted in Sonic Visualizer (Cannam, Landone, & Sandler, 2010). The specific details of the extraction process are explained more thourougly in Bullock (2009). For each of the acoustic properties, differences between the two styles were tested statistically by means of Mann-Whitney tests. Results showed that the levels of amplitude, irregularity, spectral sharpness, and spectral variance in the heroic fragments were significantly higher compared to the levels of these acoustic properties in the lyric fragments ($p < .001$). In contrast, levels of spectral flatness were significantly higher in the lyric fragments compared to the heroic fragments ($p < .001$).

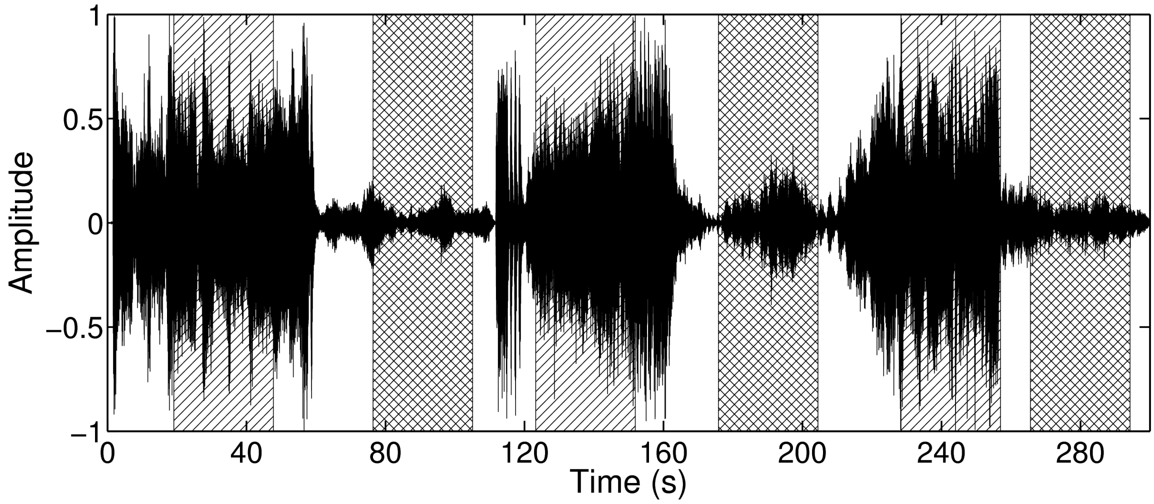


Figure 3.1.: Waveform of the musical stimulus used in the experiment (i.e., 5 minutes of the First Movement of Brahms' First Piano Concerto). The hatched regions indicate the three heroic fragments, the cross-hatched regions mark the three lyric fragments.

3.2.2.2. Effort-Shape model

The Effort-Shape model is part of the more general LMA method (Laban, 1947, 1966/2011). The model is especially relevant in the light of our study as it connects the physical appearance of body movements to aspects of subjective experience, such as expressiveness, emotion, intention, and so on. In addition, it enables the integration of linguistic metaphors that relate to these physical appearances and subjective experiences. As the name implies, the model consists of two main components, namely *Effort* and *Shape*. Effort relates to the subtle, dynamic qualities of movement expression while Shape reflects the changes of body shape. Both components are further subdivided into different categories. The Effort component is divided into four categories: *weight effort*, *time effort*, *flow effort*, and *space effort*. Each category is structured around two opposite qualities: weight effort relates to the qualities *strong-light*, time effort to *sudden-sustained*, flow effort to *bound-free*, and space effort to *direct-indirect*. The Shape component is divided into three categories structured around the polarities *spreading-enclosing*, *rising-descending*, and *advancing-retreating*. The last Shape category was not included in the analysis of the current study as it did not prove to be a relevant feature when considering hand gestures.

The principal objective of this study was to add relevant movement features and linguistic metaphors to the Effort-Shape model that reflect the different categories and the opposite qualities around which they are structured (see Table 3.1). This approach allowed us to examine the way in which contrasts in musical material are reflected in corresponding differences in movement behavior and conceptualization. Moreover, it enabled us to investigate how movement properties and linguistic adjectives, attributed to a musical stimulus, correlate with each other in terms of the qualities they express.

The complete model can be described as follows. The weight effort category is related to the movement feature *acceleration* and the bipolar indicators *heavy-light*, *vigorous-frail, rough-delicate*, and *hard-soft*. The time effort category is related to the movement feature *impulsiveness* and the bipolar indicators *fast-slow*, *nervous-tranquil*, *energetic-easeful*, and *active-passive*. The flow effort category is related to the movement feature *smoothness* and the bipolar indicators *rigid-fluent*, *anxious-secure*, *worried-carefree*, and *serious-playful*. The space effort category is related to the movement feature *Directness Index (DI)* and the bipolar indicators *compact-airy*, *dense-diffuse*, *regular-chaotic*, and *balanced-unbalanced*. The space spreading-enclosing category is related to the movement feature *size* (cf. contraction index) and the bipolar indicators *big-small*, *broad-narrow*, *thick-thin*, and *exalting-serene*. The space rising-descending category is related to the movement feature *height* and the bipolar indicators *high-low*, *vertical-horizontal*, *dominant-humble*, and *bright-muted*.

Table 3.1.: Expressive model based on Laban's Effort-Shape theory. Linguistic labels and movement characteristics highlighted in grey were associated with the heroic fragments, the others were linked with the lyric passages.

EFFORT CATEGORIES								SHAPE CATEGORIES			
WEIGHT		**TIME**		**FLOW**		**SPACE**		**Spreading-Enclosing**		**Rising-Descending**	
Strong	**Light**	**Sudden**	**Sustained**	**Bound**	**Free**	**Direct**	**Indirect**				
LINGUISTIC LABELS											
heavy	light	fast	slow	rigid	fluent	compact	airy	big	small	high	low
vigorous	frail	nervous	tranquil	anxious	secure	dense	diffuse	broad	narrow	vertical	horizontal
rough	delicate	energetic	soothing	worried	carefree	regular	chaotic	thick	thin	dominant	humble
hard	soft	active	passive	serious	playful	balanced	unbalanced	exalting	serene	bright	muted
MOVEMENT FEATURES											
Acceleration		**Impulsiveness**		**Smoothness**		**Directness Index (DI)**		**Size**		**Height**	
high	low	high	low	low	high	straight	indirect	big	small	high	low
		Jerk									
		high	low								

3.2.2.3. Motor-attuning part: movement data acquisition

In our study, we focused on hand gestures. This choice was motivated by previous research that emphasized the privileged role of the hands in music-induced gestures (Godøy, 2010). Three-dimensional movements of both left and right hands were captured with an OPTITRACK infrared optical system consisting of 12 synchronized cameras, using ARENA motion capture software (http://www.naturalpoint.com). Participants were equipped with a motion capture jacket. A default human upper body skeleton model provided in the ARENA software was constructed from 19 infrared reflecting markers that were attached to the jacket in a predefined manner: four markers for the hips and three markers for the chest, upper arms, and hands. Afterwards, the performances of all participants were exported into Biovision Hierarchy (BVH) files.

Employing the motion capture toolbox (http://www.cs.man.ac.uk/~neill/mocap) for MATLAB, complemented with own algorithms, the three-dimensional position (and displacement) of both hands in reference to the body-center (i.e., center of the hips) was calculated, independent of how a participant was positioned or orientated in the motion capture space. The selection and calculation of the individual movement features (i.e., acceleration, impulsiveness, smoothness, jerk, DI, size, and height) was grounded on results of previous studies applying the Effort-Shape model in the context of human movement behavior (Camurri et al., 2004; Petersen, 2008; Van Dyck, Maes, Hargreaves, Lesaffre, & Leman, 2013). A full description of the different features and the procedures to calculate these properties is presented in the study of Van Dyck et al. (2013). Accordingly, for each of the six fragments (i.e., three lyric and three heroic) we obtained a single-value measure for each of the seven movement features per subject (N = 36). For the statistical analysis, these measures were averaged over the three fragments per musical style (heroic/lyric). As a result, we ended up with seven 36×2 (i.e., participants×styles) matrices, which were used in the actual analysis (see Sect. 3.3.1).

3.2.2.4. Self-report part: questionnaire

The questionnaire was based on the semantic differential method (Osgood, Suci, & Tannenbaum, 1957). This method is generally employed to assess people's perspectives concerning all sorts of concepts, objects, events, and so on. It has also proved to be an adequate tool to rate people's emotional experience of musical fragments (e.g., Fujihara & Tagashira, 1984; Murakami & Kroonenberg, 2003; Nielzén & Cesarec, 1981; O'Briant & Wilbanks, 1978; Senju & Ohgushi, 1987; Swanwick, 1973; White & Butler, 1968). The method is based on a set of scales consisting of bipolar (opposite) adjective pairs placed each at one end of a continuous rating scale (generally by means of a seven-point rating scale, although also five-point and nine-point scales are often used). Respondents are required to tick one of the points in between each bipolar adjective pair, indicating the level of association (cf. *intensity*) of a particular concept, object, event, and so on, with the particular adjectives (cf. *direction*). In this study, a 24-item, nine-point semantic differential list was used to rate the six musical fragments. A nine-point scale was chosen in order to enable the inclusion of subtle nuances between different respondents. Each category of the Effort-Shape model was described by four bipolar adjective indicators (see Table 3.1). They were selected from the LMA effort bank (http://www.lmaeffortbank.com) and the Hevner adjective circle, which employs adjectives that are supposed to reflect the main feelings that can be evoked in humans by listening to music (Hevner, 1936). While the participants rated the six musical fragments, they listened to the corresponding music. The questionnaire, which was made with Qualtrics (www.qualtrics.com), was presented on a MacBook Pro.

3.2.3. Procedure

Participants were tested individually in a laboratory setting. Prior to the actual execution of the experiment, an explanation of the procedures they had to run through and the tasks they had to carry out was given to every single participant. Subsequently, the participant was equipped with the motion capture jacket which was calibrated next. The actual experiment consisted of two separate parts (i.e., *a motor-attuning part* and *a self-report part*). The order in which both parts were executed was randomized to exclude possible effects due to a specific order. Both parts took place in the motion capture space; an octagonal space with a diameter of 6.50 meters enclosed by black curtains, separating the participant from the experimenters. Prior to the execution of the motor-attuning part of the experiment, the participant received the following task: 'Translate your experience of the music into free full-body movement. Try to become absorbed in the music and express your feelings in a bodily fashion. There is no good or wrong way to execute this task.' In order to perform this task, the participant could use the space marked by a round carpet with a diameter of 4 meters. Furthermore, the lights in the room were dimmed, as the pilot study had indicated that this made the participants feel more comfortable and less constrained to execute their task. The music was played through a stereo setup constructed by two Behringer B2031A Truth Active Studio Monitors at a predefined, pleasant sounding volume level. During the self-report part of the experiment, the participant filled out the questionnaire in the same laboratory setting. Again, the lights were dimmed and the music was played in the same way as during the motor-attuning part. From start to end, the complete experiment lasted for about one hour. Afterwards, the participant was offered refreshments while the experimenters explained the purpose of the experiment.

3.3. Results

3.3.1. Motor-attuning task: movement analysis

The statistical analysis of the seven 36×2 matrices representing the general measures of all movement features (see Sect. 3.2.2.3) was conceived as a 2×2 mixed factorial design. The two independent variables consisted of the between-subjects factor ‘musical background’ (with two levels: musically trained and musically untrained) and the within-subjects factor ‘musical style’ (with two levels: heroic and lyric). The dependent variable, ‘movement response’, was constituted by multiple dependent measures related to the different movement features that were taken into account (i.e., acceleration, impulsiveness, jerk, smoothness, DI, size, and height). Multiple univariate analyses or ANOVAs were applied on each of the dependent variables (cf. Huberty & Morris, 1989; Park & Schutz, 2006).

The assumptions of normality, homogeneity of variance and sphericity could be accepted for all features. All effects are reported as significant at $p < .001$. There was a significant main effect of musical style on acceleration ($F[1,34] = 163.17$, $r = .91$), impulsiveness ($F[1,34] = 190.53$, $r = .92$), jerk ($F[1,34] = 170.27$, $r = .91$), smoothness error (or negative smoothness) ($F[1,34] = 134.81$, $r = .89$), DI ($F[1,34] = 129.14$, $r = .89$), size ($F[1,34] = 135.80$, $r = .89$), and height ($F[1,34] = 83.04$, $r = .84$). These results reveal a higher level of DI in the lyric condition compared to the heroic condition and a higher level of acceleration, impulsiveness, jerk, smoothness error, size and height in the heroic condition compared to the lyric condition.

No significant main effect of musical background was found on acceleration (*F*[1,34] = 1.88, *r* = .23), impulsiveness (*F*[1,34] = 2.13, *r* = .24), jerk (*F*[1,34] = 1.79, *r* = .22), smoothness error (*F*[1,34] = 1.76, *r* = .22), or DI (*F*[1,34] = 2.81, *r* = .28), indicating that, generally, levels for these features were similar in the musically trained group and the musically untrained group. However, a significant main effect of musical background was found on size (*F*[1,34] = 4.50, *p* < .05, *r* = .34), and height (*F*[1,34] = 5.95, *p* < .05, *r* = .39), revealing a higher level of size and height for the musically trained group than for the musically untrained group.

There was no significant interaction effect between the musical style and the musical background on acceleration (*F*[1,34] = 1.61, *r* = .21), impulsiveness (*F*[1,34] = 1.04, *r* = .17), jerk (*F*[1,34] = 1.83, *r* = .23), smoothness error (*F*[1,34] = 1.88, *r* = .23), DI (*F*[1,34] = 1.40, *r* = .20), size (*F*[1,34] < 1, *r* = .17), or height (*F*[1,34] < 1, *r* = .03). All results are reported in Figure 3.2.

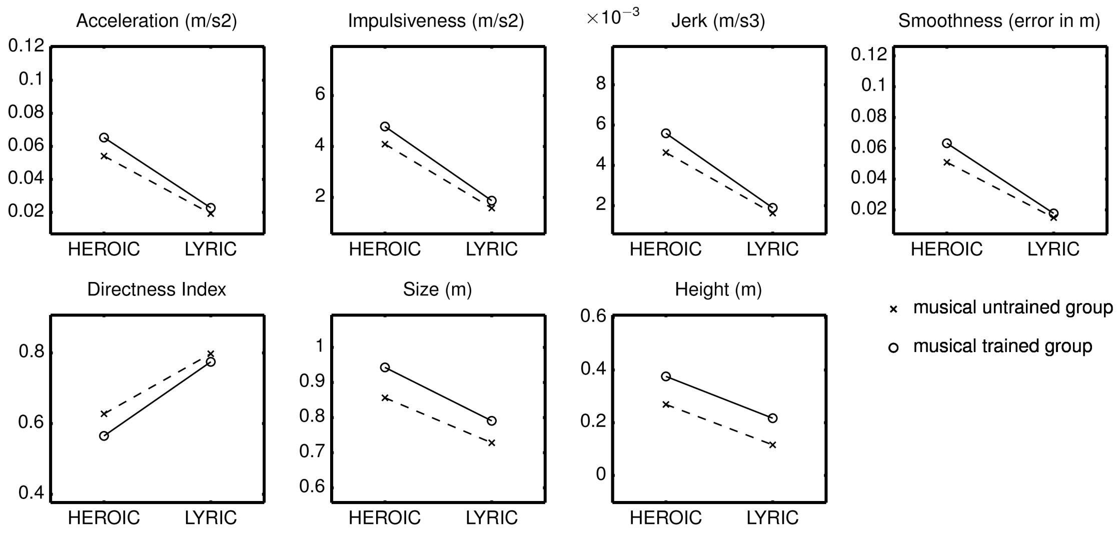


Figure 3.2.: Representation of the means over all subjects (N=36), per group (musically trained/musically untrained), per condition (heroic/lyric) for all seven movement features.

3.3.2. Self-report task: semantic differential scale analysis

A three-mode principal component analysis (PCA) was performed in order to unveil relationships between the participants (musically trained/musically untrained), the 24 semantic differential scales, and the music fragments (heroic/lyric) (Kroonenberg, 1985, 2008; Smilde, Bro, Geladi, & Wiley, 2004;

Tucker, 1966). A standard, two-mode PCA would have proved to be inadequate as one of the modes (i.e., the participants) needed to be averaged, thereby implicitly assuming that the participants did not have a different attitude towards the relations between the music fragments and the scales. However, a three-mode PCA did enable us to unravel underlying components in all three modes, to investigate the relationship between them, and to assess possible individual differences. A 2×2×2 model (fragments×scales×participants) with 2 components for each of the modes was constructed, which had a fit of 62 % to the data, which is more than adequate for interpretation. The first components of the three modes which accounted for 61 %, 58 %, and 59 % respectively, while the second components explained 1 %, 4 %, and 3 % respectively. In the scope of this experiment, we questioned (1) the participants' global consensus regarding the characterization of the musical fragments in terms of the semantic differential scales, and (2) the individual differences with respect to this characterization.

3.3.2.1. Consensus among participants

The first issue can be addressed by investigating the component coefficients of the musical fragments together with those of the semantic differential scales. Both can be projected into a single space, generally referred to as a joint biplot representation (Kroonenberg, 2008, p. 273; Murakami & Kroonenberg, 2003, p. 260). In a three-mode PCA, these joint biplots can be constructed for each component of the third mode (in this case: the participants). Figure 3.3. (upper part) displays the participants' consensus about the characterization of the music fragments in terms of the semantic differential scales. Given that the heroic fragments and the lyric fragments are located at opposite ends of the graphs, it is clear that, overall, they received scores in opposite ends of the scales. Nearly all semantic differential scales display strong contrasts between the heroic fragments and the lyric fragments as they project appropriately on the first axis, as do the fragments. However, more subtle differences were revealed as well, especially between the three lyric fragments. For instance, the third lyric fragment was especially noted as light, carefree, secure, and playful, while this was only to a lesser extent the case for the first lyric fragment. In addition, the first and third heroic fragments were rated in a highly similar way and their characteristics could almost exclusively be described by the scales which correspond to the first axis. The second heroic fragment was described as bigger and more energetic than the other two heroic fragments, although these differences are less evident than those between the lyric fragments.

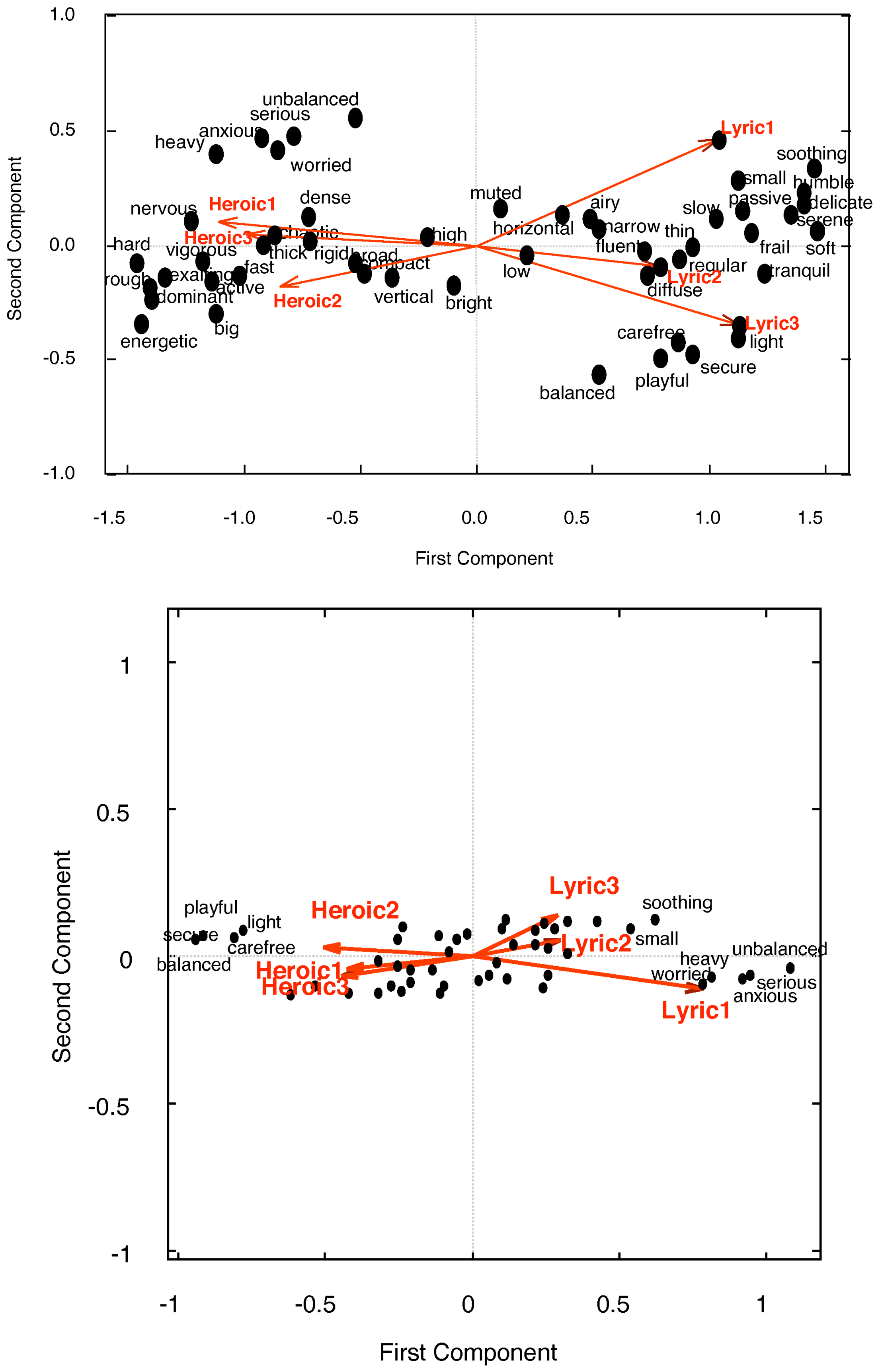


Figure 3.3.: Joint biplot for music fragments and scales representing the consensus (i.e., upper part) and the qualitative individual differences (i.e., lower part).

The size of the coefficients on the first component demonstrates the extent to which the participants agreed with the consensus judgment of the relations between fragments and scales. Figure 3.4 shows that all participants scored positively on the first component. Consequently, the consensus configuration corresponds largely with their judgments. Alternatively, the configuration could be perceived as larger for participants with a large coefficient on the first component and smaller for those with a smaller coefficient on the same component. Moreover, when examining Figure 3.4, it is nearly self-evident that there is no systematic grouping of the participants based on their musical background.

3.3.2.2. Individual differences between participants

Figure 3.3 (lower part) shows that certain fragments received substantially different judgments from different participants. On its own, the biplot contains the judgments of participants with a positive coefficient on the second participant component (see Fig. 3.4) and also with a zero coefficient on the first component. However, none of the participants displayed a zero coefficient on the first component, which means that for all participants the two joint biplots should be linearly combined (coefficient on the first component × Consensus Plot + coefficient on the second component × Individual Difference Plot) to get a correct representation of their complete judgments of the relations between fragments and scales. Figure 3.4 can be seen as a revised version of the consensus configuration for participants with a substantial coefficient on the second component. To get a view of the shape of the biplot for participants with a negative coefficient, the positions of the fragments should be mirrored with respect to the origin.

Especially for the three musically untrained participants with highly positive coefficients on the second component, the heroic fragments were rated as more playful, secure, and balanced than one would assume when regarding the first biplot. In other words, they associated characteristics with lyric fragments as well as with heroic fragments. At the same time, particularly for these participants, the first lyric fragment was rated as more unbalanced, anxious, and serious than one would deduce from the consensus configuration. For the musically trained participant with the lowest coefficient, these relations are reversed. The second component in this biplot is of little importance with regard to the description of the considerable individual differences.

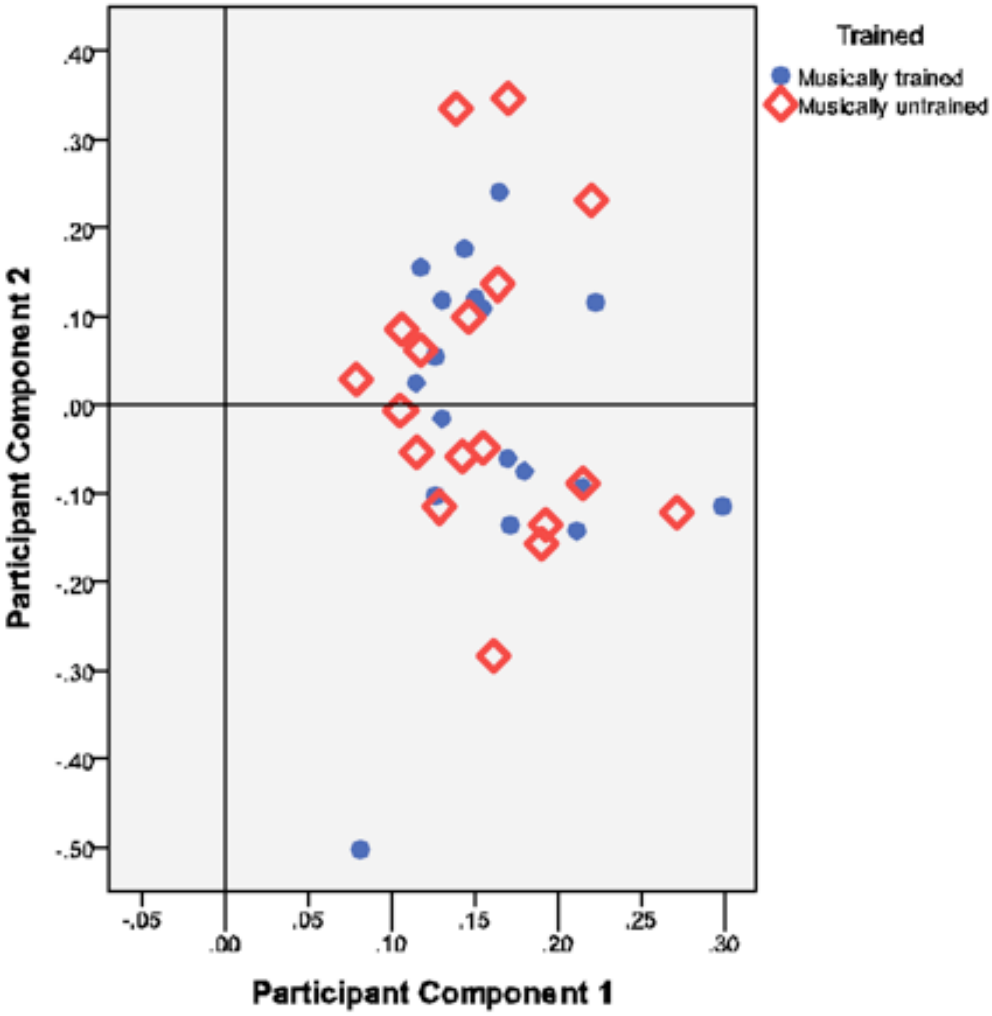


Figure 3.4.: Visualization of the participants' space.

3.3.3. Correlation analysis

Key to this study was the question whether the two behavioral responses under consideration (i.e., body movements and expressive concepts associated with the music) correlated with each other in terms of expressiveness. For this purpose, we introduced an expressive model grounded on Laban's Effort-Shape theory. Based on the previous results, in Table 3.1, linguistic concepts and movement characteristics associated with the heroic fragments are highlighted in grey. The others were associated with the lyric fragments. As observed, the polarities of the movement features correlated consistently with the polarities of the semantic differential scales that were attributed to the respective music styles. The findings of this qualitative approach suggest a correlation between movement characteristics and linguistic labels associated with the music.

To quantify this correlation, we applied a PCA on 30 items (7 movement features and 23 metaphors) with promax rotation. One metaphor (i.e., bright) was removed from the analysis as the KMO value for this item was .35 while Kaiser (1974) recommends a bare minimum of .50. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = .89, and all KMO values for individual items were higher than .58. Bartlett's test of sphericity $\chi^2(435) = 3042.83$ ($p < .001$) indicated that correlations between items were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Five components had eigenvalues over Kaiser's criterion of 1 and in combination explained 80.78 % of the variance. However, 57.54 % of the variance could be explained by the first component, which consisted of the majority of the movement features and metaphors, while the other four components only contributed to a minor extent to the total variance. Therefore, we can decide that movement features and metaphors are sufficiently correlated.

3.4. Discussion

The results of this particular study showed that participants exhibited contrasting repertoires of body movements when moving to heroic and lyric fragments of the First Movement of Brahms' First Piano Concerto. Compared to movements performed in response to the lyric style, the heroic style evoked body movements which displayed higher levels of acceleration, jerk, impulsiveness, size, and height. In contrast, the lyric style elicited more direct movements with higher levels of smoothness. In addition, a main effect of the musical background (i.e., musically trained/musically untrained) on the size and height of the movements was unveiled. This effect could be explained by the fact that musically trained participants might feel less inhibited to move to music in an experimental setting compared to participants who did not receive any musical training. In a post-questionnaire, the participants were asked to rate the degree to which they felt constrained to move during the experiment. Their perceived freedom of movement was rated on a five-point Likert scale, with 1 as 'totally disagree', 3 as 'neutral', and 5 as 'totally agree'. The median of the musically trained group was 4, while the median of the musically untrained group was 2. Thus, it seems plausible that, due to the fact that participants in the musically untrained group felt more inhibited to move to the music, their gestures were less pronounced which resulted in smaller and less elevated body movements. Further, the results of the movement analysis did not reveal a significant interaction effect between musical style and participants' musical background. This means that the observed contrasts in movement responses with regard to the heroic and lyric fragments proved to be rather homogeneous for both the musically trained and musically untrained group. This is in accordance with findings of previous research demonstrating the general ability of people to translate acoustic properties of sound and music into specific body movements (Caramiaux, Bevilacqua, & Schnell, 2010; Godøy, 2010; Kozak, Nymoen, & Godøy, 2012; Küssner, 2013; Leman et al., 2009). However, a study by Küssner (2013) regarding the representation of sounds and music by means of drawing unveiled that, although attunement proved to be a common phenomenon, musicians tended to produce more detailed drawings compared to non-musicians. Yet, in our study, the obtained data did not include exceptionally detailed movement information, since rather general measures of expressive movement behavior (up to the level of individual gesture segments) were considered. Data over large time scales were thereby reduced to single-value measures. In this way, specific dynamic processes over time were cancelled out. However, in future studies, a functional data analysis (FDA) could provide a valuable alternative as it can model data drawn from continuous processes. This approach could facilitate the disclosure of underlying processes and might provide more fine-tuned means to investigate consistency and diversity of movement behavior in response to music.

The results of the analysis of the semantic differential scales revealed an association between heroic and lyric fragments with opposite adjectives, in terms of expressive quality. Moreover, a general consensus of responses among participants, (both musically trained and untrained) was unveiled. This finding could be related with previous studies on musical expertise which report that emotional responses to music are generally stable and are only to a minor extent influenced by musical expertise (Bigand & Poulin-Charronnat, 2006; Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005). This could be explained by the fact that in different daily-life contexts (e.g., film, television, etc.), people are confronted with music similar to the excerpts used in the experiment. This might enable the development of a specific attitude of the listener towards the expressive characteristics of music.

One of the objectives of the study was to investigate whether the behavioral responses (i.e., the body movements and linguistic labels associated with the music) corresponded with each other. Up to now, only few studies explicitly addressed the relation between music-induced movement and the description of musical expressivity (Maes et al., 2010; Sievers, Polansky, Casey, & Wheatley, 2013). Therefore, in this study, we introduced a dimensional model that enabled the comparison of movement features and linguistic labels based on their underlying expressive qualities. These qualities were defined in terms of the taxonomy applied in Laban’s Effort-Shape theory. The results of the movement analysis revealed that the polarities of the movement features correlated with the polarities of the semantic differential scales, in relation to the different musical styles. When considering the semantic differential scales, the model particularly proved its strength with regard to the categories weight, time, flow, and spreading-enclosing. For the category rising-descending, a tendency towards correlation was still observed, although in this case, the correlation proved to be substantially weaker. The space category correlated negatively with the labels compact and dense. Hence, it could be argued that these two labels were not perfectly suited for that particular category. However, overall, the findings of our study indicate that movements and linguistic labels reflect highly similar expressive qualities. In other words, the behavioral results clearly show that body movements correlated with linguistic labels. This provides a strong basis of support in favor of our experimental hypothesis which stated that linguistic descriptions of music share common ground with bodily responses to music and sounds. Possibly, this connection between music-induced movement and cross-domain associations of music explicated in linguistic descriptions could be explained by a grounded, modal view on cognition and emotion (Barsalou, 2008; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012). Previous research has shown that, when people passively listen to music, sensory, motor (Bangert et al., 2006; Chen et al., 2008; Haueisen & Knösche, 2001), and introspective (Alluri et al., 2011; Chapin, Jantzen, Kelso, Steinberg, & Large, 2010) brain areas are activated. In addition, the processing of both action-related and abstract concepts, as well as concepts related to emotional states, are also believed to require the involvement of sensory (e.g., sight and hearing), motor (e.g., movement and proprioception), and introspective (e.g., mental states including affects, intentions, and meta-cognition) brain areas (e.g., Aziz-Zadeh & Damasio, 2008; Citron, 2012; Moseley, Carota, Hauk, Mohr, & Pulvermuller, 2012). In other words, both music perception and the processing of concepts create, what Barsalou (1999) calls, ‘perceptual symbols’ (i.e., neural networks distributed over sensory, motor, and introspective brain areas). Therefore, it seems plausible that, if perceptual symbols partially overlap, one perceptual symbol gets associated with the other. Our study suggests that this overlap can occur, at least partially, in motor-related processing areas.

A particularly interesting finding concerned the distinct similarities between movement responses of different groups of participants. All the more because it was shown that the exhibited repertoires of body movements could be related to a vocabulary of expressive qualities and concepts. This suggests that the human body (and the movements it produces), can function as a non-verbal means to communicate musical meaning, but also to convey emotion and intentionality in general. Further, this finding provides support for the idea that the human body functions as a mediator, transforming purely subjective phenomena (e.g., feelings, intentions, and ideas) into physical phenomena (e.g., sight and hearing) and vice versa. Moreover, it indicates that the human body plays an important, although not exclusive, role in the process of musical meaning formation.

In this study, it was shown that people's engagement with music is structured around a dynamic contrast between opposite qualities related to expressive gestures. For the purpose of this particular study, the beginning of the First Movement of Brahms' First Piano Concerto was ideally suited as it covers all categories and opposing qualities within each category of Laban's Effort-Shape model. However, the introduced method (including the Effort-Shape model), the semantic differential scales, and the various algorithms for the extraction of expressive movement features could be applied to other musical stimuli as well. Moreover, future studies could investigate whether the Effort-Shape model could be used to annotate people's personal descriptions and imagery of the expressive qualities of music.

Based on the findings of this study, it is tempting to conclude that linguistic descriptions of music (i.e., *perception*) are mediated through our embodied understanding of music and sounds (i.e., *action*). However, only limited conclusions could be drawn with regard to the relationship between action and perception. The finding that a correlation between both exists, does not imply that it is a causal one. However, previous research claims that the use of metaphors is rooted in, and structured by, embodied experiences (Crawford, 2009; Gibbs et al., 2004). This idea suggests that music-induced movement may shape people's interpretation and understanding of the expressive properties of music and sounds. A recent study by Maes and Leman (2013) seems to support this idea. In this study, two groups of children were trained (i.e., conditioned) to perform choreographies in response to a 'neutral' musical stimulus. One group performed a happy choreography while the other completed a sad one. Afterwards, the children's perception of musical expressiveness in terms of valence and arousal was assessed. The results suggested that the expressive qualities of their dance movements influenced their perception of musical expressiveness significantly. In addition, some studies examined the effect of body movement on the perception of other musical properties, such as pitch (Repp & Knoblich, 2009), meter (Phillips-Silver & Trainor, 2005, 2007), and musical preference (Sedlmeier, Weigelt, & Walther, 2011). Complemented with the results of this study, one might suggest that motor processes are a substantial, although not exclusive, part of people's engagement with music. Moreover, this result provides an argument for the development of methodologies in music education that support an active engagement with music.

3.5. Conclusion

In this study, participants performed two tasks. First, they translated expressive qualities of a musical stimulus into corresponding body movements. Second, they reported on the perceived associations between the music and specific linguistic labels. The results of this study showed that contrasts in musical style (heroic/lyric) were reflected in participants' movement responses to the musical stimulus. In addition, the results uncovered associations between linguistic labels and musical styles. Moreover, correlations between movement features (i.e., *action*) and linguistic labels (i.e., *perception*), based on their underlying expressive qualities, were unveiled. Possibly, this connection between music-induced movement and linguistic descriptions could be explained by means of a grounded, modal view on cognition and emotion. However, more research should be conducted in order to expose causal relationships between action and perception in processes of musical meaning formation.

PART 3:

EXPERIMENTAL STUDIES ON THE EFFECTS OF HUMAN EMOTIONS ON DANCE MOVEMENT

Chapter 4

Expressing induced emotions through free dance movement

Van Dyck, E., Maes, P.-J., Hargreaves, J., Lesaffre, M., & Leman, M. (2013). Expressing induced emotions through free dance movement. *Journal of Nonverbal Behavior, 37*, 175–190.

Abstract

The aim of this study was to examine the effect of two basic emotions, happiness and sadness, on dance movement. A total of 32 adult participants were induced to feel emotional states of either happiness or sadness and then danced intuitively to an emotionally neutral piece of music, composed specifically for the experiment. Based on an Effort-Shape analysis of corporeal articulation, full body movement was captured and seven different movement cues were examined, in order to explore whether differences in dance movements between the happy and sad condition existed. Results revealed that in the happy condition, participants moved faster, with more acceleration, and made more expanded and more impulsive movements than in the sad condition. Results are discussed with respect to possible consequences for future research on human movement.

4.1. Introduction

Dance is believed to facilitate the expression of a great variety of emotions in a non-verbal way (Levy, 1988). Moreover, both experienced dancers and individuals without a background in dance have been shown to be quite skillful in their ability to decode emotions from dance movement (Brownlow, Dixon, Egbert, & Radcliffe, 1997; Dittrich et al., 1996). In a study by Brownlow et al. (1997), for example, point-light display videos of happy and sad performances by several dancers were judged by experienced and novice dancers. Results showed that all participants succeeded in determining whether dancers performed the happy or sad dance, regardless of their level of experience in dance.

The ability to recognize emotional meaning from dance movement is believed to be present from childhood onwards. In a study by Boone and Cunningham (1998), a selection of videos of dancers expressing emotions of happiness, sadness, anger, and fear was presented to children (aged either four, five and eight) and adults. Results revealed that children as young as five were able to decode information relating to the emotions expressed by the movements of the dancers.

Alongside these findings, recent research has started to classify the types of dance movements prompted by emotions and attempted to explain how dance might be modified by emotions (Brownlow et al., 1997; Camurri, Lagerlöf, & Volpe, 2003; Camurri et al., 2004; Lagerlöf & Djerf, 2000; Walk & Homan, 1984). In an experiment by Lagerlöf and Djerf (2000), movement cues were extracted from recordings of dancers portraying emotions of joy, grief, anger, and fear. Comparison of the cues across those four emotion categories revealed distinct differences in expression of emotion. The results suggested that joy, anger, and fear were related to frequent tempo changes; contrastingly, there were few changes of pace in the grief condition. Moreover, an association between the tendency for movements to project outward from the center of the body and emotions of joy and anger was observed. In a similar study by Camurri et al. (2003, 2004), using automated recognition techniques to track the important emotion recognition cues, the researchers were able to show that the duration of grief performances was remarkably longer than those for other emotions. Furthermore, movements were more contracted in the grief and fear conditions than in the joy condition. Finally, a main effect for Quantity of Motion (QoM) (a measure of the total amount of detected motion, involving velocity and force) was revealed, as performances for joy received significant higher mean scores than those for grief. In the light of all this previous research, emotional content is generally assumed to be a characteristic that can be detected from dance movement, as it was shown that particular mood states can be positively associated with distinct movement features.

Most previous research in this area has tended to take actors' portrayals of emotion as the subject for study. Studies of corporeally expressed emotion in dance (Brownlow et al., 1997; Camurri et al., 2003, 2004; Dittrich et al., 1996; Lagerlöf & Djerf, 2000; Walk & Homan, 1984) and also in other types of movement (Atkinson, Dittrich, Gemmell, & Young, 2004; Boone & Cunningham, 1998; de Meijer, 1989; Montepare, Koff, Zaitchik, & Albert, 1999; Pollick et al., 2001; Wallbott, 1998), have been, in this way, more limited in their scope. In Lagerlöf and Djerf (2000) and Camurri et al. (2003, 2004), for example, 'acting' dancers were asked to perform the same choreography repeatedly, each time expressing a different basic emotion. This sort of experimental design arises from the assumption that actors are supposed experts in displaying emotion using the body and face (as well as the voice), such that they can intensify and/or distil the specific qualities of an emotional signal expressed using the body (Gross et al., 2010). However, several studies have revealed that not all actors generate equally recognizable, emotionally expressive corporeal articulations (Gross et al., 2010; Montepare, Goldstein, & Clausen, 1987; Wallbott, 1998). Rather than continuing to pursue the study of acted, portrayed emotions, we believe that emotion induction techniques could be applied in this area of research. An important argument for this assumption is that induced emotions are supposedly equivalent to naturally occurring emotions (Jallais & Gilet, 2010). For our study, therefore, an emotion induction procedure consisting of guided imagery and emotion-supporting music was used, with the intention of inducing emotional states either of happiness or sadness. These basic (or discrete) emotions were chosen in order to enable comparison between the results of this study and the findings of previous research (Scherer, 2004), which mainly focused on basic emotions.

A second concern of ours regarding the experimental design in earlier work is the restrictions on dance movement, imposed 'artificially', using choreography (Brownlow et al., 1997; Camurri et al., 2003, 2004; Lagerlöf & Djerf, 2000). We believe that allowing participants to move freely facilitates better expression of emotion, hence this approach can prove to be a far more ecologically-valid means of studying the relation between emotions and dance movement cues. Further, in order to achieve results whose validity was not 'tainted' by any effects of familiarity with the music, participants were asked to move intuitively to an 'emotionally neutral' stimulus, designed specifically for this study.

To summarize, this study examined the effect of induced emotions (happiness and sadness) on free dance movement in the belief that this is a more ecologically-valid approach than those used in previous studies of expressive movement. Indeed, it has been proposed that free dance inheres cues from the underlying principle of natural emotional expression through movement (Boone & Cunningham, 1998; Stevens, Malloch, Hazsard-Morris, & McKechnie, 2002) and we believe that this approach will offer new insights into the bodily expression of emotions. In order to explore potential differences in corporeal articulations between the two conditions, several movement cues were examined, chosen on the basis of Laban's Effort-Shape Theory (Laban, 1950; Dell, 1977). Moreover, the selection of movement features was also grounded on the range of movement cues applied in previous studies regarding expressive dance movement (e.g., Camurri et al., 2003, 2004; Lagerlöf & Djerf, 2000). The literature on professional dancers using posed choreography led us to predict that participants' movements would be faster, more accelerated, more impulsive, and that their limbs would project higher and further out from the body center when happiness had been induced than when sadness had. In addition, we expected to unveil a more pronounced effect of smoothness of motion, and that the trajectories followed by the body parts would not be as direct in the sad condition as in the happy. Finally, we expected to see an effect of emotional state on movements of the entire body.

4.2. Method

4.2.1. Participants

A total of 32 adult participants (16 females, 16 males) took part in the study. As it is believed that the duration of negative emotional states decreases with age (Larcom and Isaacowitz, 2009), only participants between 20 and 30 years of age were included in the experiment. The average age of the participants was 22.75 years (*SD* = 3.12). The majority (75 %) had received musical training, and of those, the average time spent in musical training was 8.96 years (*SD* = 3.18). Only a minority (34.38 %) had trained in dance and spent, on average, 3.91 years (*SD* = 2.74) in dance training. However, 87.50 % of participants reported that dancing is an activity that forms a part of their lives, with varying degrees of frequency (46.88 % danced about once a month; 21.88 % danced about once a week; 18.77 % danced more than once a week). The test group comprised predominantly Belgian university students (91 %). They received no compensation for participating in the study.

4.2.2. Design

The experiment was conceived as a repeated-measures (within-subjects) strategy to evaluate changes in movement characteristics. The design encompassed 'induced emotion' as independent variable (with two levels: 'happiness' and 'sadness') and 'body movement' as dependent variable (a detailed explanation of which movement parameters were considered, is provided in Sect. 4.3). Each participant was exposed to both levels of the independent variable and measured on the dependent variable during each exposure.

4.2.3. Materials and stimuli

4.2.3.1. Emotion induction procedure

Emotion induction procedures aim to alter the participant's emotional state in an artificial and controlled way (Mayer, Allen, & Beauregard, 1995). Since multiple inductions are believed to contribute cumulatively to the emotional response (Bower, 1981; Clark, 1983; Coan & Allen, 2007), the emotion induction procedure that was designed for this particular study used a combined method. Foreground attention was manipulated by guided imagery, which consisted of a series of sentences describing particular situations in which the participants were asked to imagine themselves (Ahsen, 1989). As they read the sentences, emotion-supporting music was played in the background. A wide range of studies have stressed the vast power of music to evoke emotions in listeners (e.g., Dowling & Harwood, 1986; Huron, 2006; Juslin & Sloboda, 2010; Lundqvist, Carlsson, Hilmersson, & Juslin, 2009; Meyer, 1956; Thayer, 1989, 1996) and music has demonstrated to be an effective means of emotion induction in a laboratory setting (Västfjäll, 2002; Westermann, Spies, Stahl, & Hesse, 1996). Moreover, associations between emotions and particular musical characteristics are well established, especially for happiness and sadness (Gabrielsson & Juslin, 2003; Juslin & Laukka, 2004). The combination of music and guided imagery is therefore believed to lead to a controlled, specific, and effective induction (Clark, 1983; Pignatiello, Camp, & Rasar, 1986; Mayer, Gayle, Meehan, & Haarman, 1990).

A series of eight guided imagery vignettes was projected on a screen in both the happy and the sad conditions. These were Dutch translations of those developed by Mayer et al. (1995), for example: 'you just got a new job and it is even better than you expected' (happy condition), and 'a pet you were really fond of has died' (sad condition). Prior to their use in the experiment, 20 judges had rated the 16 vignettes, presented in random order, using a five-point Likert scale (ranging from '1 = not' to '5 = a lot' according to the emotions 'happiness' and 'sadness'). The validity of the translations was confirmed as all happy emotion induction vignettes were rated near 5 (*M* = 4.75, *SD* = .44) for happiness and near 1 (*M* = 1.15, *SD* = .37) for sadness and conversely, all sad emotion induction vignettes were rated near 5 (*M* = 4.60, *SD* = .60) for sadness and near 1 (*M* = 1.30, *SD* = .57) for happiness. During the experiment, the vignettes were projected on a Sanyo PLC XU-105 projector screen.

The four pieces of music (two for the happy induction and two for the sad induction) used to accompany the vignettes were all non-vocal classical compositions drawn from prior designed emotion induction procedures (cf. Bower & Mayer, 1989; Mayer et al., 1995). In the happy condition, the Mazurka from Coppelia by Delibes and Bach's Brandenburg Concerto No. 2 were used, while the music in the sad condition consisted of the theme from Schindler's List by John Williams and Prelude Opus 28 No. 6 by Chopin. Just as for the vignettes, 20 judges had rated the pieces of music, presented in random order, on a five-point Likert scale, and similarly, the musical compositions intended to induce happiness were rated near 5 (*M* = 4.65, *SD* = .59) for happiness and near 1 (*M* = 1.25, *SD* = .44) for sadness, those intended to induce sadness were rated near 5 (*M* = 4.55, *SD* = .61) for sadness and near 1 (*M* = 1.35, *SD* = .59) for happiness. During the experiment, the music was played through four Altec 1218A speakers.

4.2.3.2. Assessment of emotional experience

The effectiveness of the emotion induction procedure was measured using a shortened version of the Differential Emotions Scale (cf. Izard, Dougherty, Bloxom, & Kotch, 1974; Lundqvist et al., 2009). Clear instructions so that listeners should focus on induced emotions were administered, as listeners may find it difficult to discriminate between felt emotions and perceived emotions (Kivy, 1990; Scherer & Zentner, 2001). Thus, participants were asked to report 'to what extent each of the described feelings match the emotion they currently experience', using separate unipolar rating scales. Sadness was represented by Dutch translations of the words 'sad' (*triest*), 'blue' (*droevig*) and 'downhearted' (*neerslachtig*) while happiness was represented by Dutch translations of the words 'cheerful' (*vrolijk*), 'happy' (*gelukkig*) and 'joyful' (*blij*). Below each word was a five-point Likert scale with each number accompanied by a verbal description ('1 = Not at all', '2 =

Slightly', '3 = Moderately', '4 = Very', '5 = Extremely').

Smith (2000) emphasizes that participants might provide what they believe to be the 'expected' or 'correct' response in an attempt to please the experimenter, rather than one that actually reflects their experience. Therefore, a total of 14 other feelings were also named on the list (e.g., 'relaxed', 'sleepy', and 'awake') to disguise the underlying nature of the experiment. Moreover, they were told that the questionnaire merely served as a control instrument. During the experiment, the questionnaires were filled out on a MacBook Air laptop.

4.2.3.3. Musical stimulus for dance movement

A professional composer designed the music that accompanied the dance movements of the participants with the intention of providing music that could be danced to intuitively. As far as possible, this music was also intended not to arouse the participants to the extent that it led to heightened emotion, or to a marked change in the valence or potency of the emotion induction procedure. Alongside the potential for controlling compositional intent, another argument in favor of using original music for this study was to overcome the effects of familiarity, which might increase the intensity of emotional responses to music (Ali & Peynircioglu, 2010; Peretz, Gaudreau, & Bonnel, 1998).

The neutrality of the music was justified by characteristics of the tempo, harmony, timbre and style. Music with a fast tempo and major mode is generally experienced as 'happy', whereas music with a slow tempo and minor mode is mainly understood as 'sad' (Hunter, Schellenberg, & Schimmack, 2010). Accordingly, the harmony alternated between major and minor chords and the tempo was mid-paced, set at 120 BPM. Moreover, according to a long-term study of dance music tempi by Moelants (2008), a tempo of around 120 BPM represents the most common tempo in contemporary dance music and is believed to stimulate movement. The timbres were chosen in such a way that they would be heard as complementary, and importantly, not 'harsh-sounding' (Hailstone et al., 2009): Mellotron flute, Mellotron strings, Rhodes electric piano, a clavichord sound with a phaser effect, and a drum kit. No vocals were used, so that lyrics could not have any influence at all. Regarding music style, the intention was to produce a stimulus that was ecologically valid: the stimulus had to sound like modern dance music that the participants might encounter in 'everyday life' settings, particularly those that might involve dancing. Thus, with a view to striking a balance between not arousing the participants excessively on one hand, and not arousing them sufficiently on the other (thus, perhaps, leading to boredom), the style of the music was intended as ‘middle of the road’ rock/pop, with an emphasis on the drumbeat, so that participants could move intuitively to the rhythm, as they might do in a dance club.

Before the actual experiment, the neutrality of the music was ratified by the same 20 judges who had been asked to rate the happy and sad pieces of music. In this process, the five musical compositions were presented, in random order, during the same rating session. The judges rated the musical stimulus on a five-point Likert scale (ranging from ‘1 = not’ to ‘5 = a lot’ according to the emotions ‘happiness’ and ‘sadness’). The music was rated near 3 for both happiness (M = 3.15, SD = .45) and sadness (M = 3.10, SD = .67). During the experiment, the musical stimulus was played back from a Max/MSP patch, where the recording of the motion capture data was synchronized with the music.

4.2.4. Procedure

Participants were tested individually in a laboratory room with dimmed lighting. Black curtains surrounded the test area so that participants would be shielded from outside influences. The experiments took place in the early morning in order to control for possible shifts in emotional state due to time of the day (Hill & Hill, 1991; Thayer, Newman, & McClain, 1994). Each participant performed the experiment on two separate occasions, always with an intervening period of at least three days between experimental conditions, as was necessitated by the combination of the emotion induction procedure and the experimental design. To avoid possible effects due to any specific order, half of the participants performed the experiment in the sad condition first; the other half started with the happy condition.

Upon arrival, the participant was equipped with a suit required to facilitate motion capturing and subsequently, the body markers were calibrated (see Fig. 4.1). Next, all further instructions were given to enable the participant to continue the rest of the procedure by himself/herself without intervention of the experimenter.

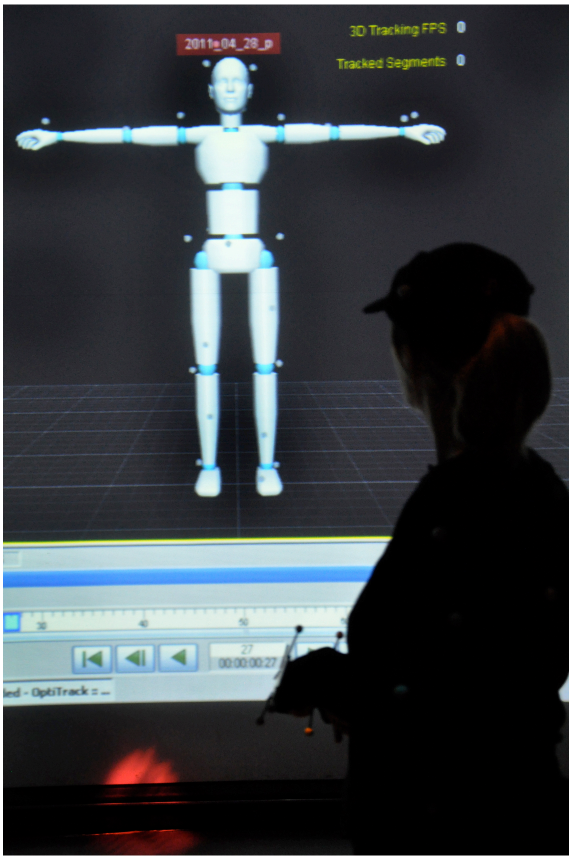


Figure 4.1.: Calibration of the body markers.

Each of the two experimental sessions consisted of four parts, namely the filling out of the emotion rating scale questionnaire, the emotion induction procedure, the performing of the dance task, and the filling out of the emotion rating scale questionnaire for a second time. Firstly, the participant was asked to take a seat in the experimenting room and fill out an emotion rating scale questionnaire on a laptop. Secondly, the emotion induction procedure started automatically when the questionnaire was filled out. At the very start of both the happy and sad emotion induction procedure, only music was presented. After 10 seconds, the guided imagery vignettes started to accompany the musical composition at 30-second intervals (cf. Mayer et al., 1995). When the first piece of music ended, the second (alternate) piece faded in. At the end of all eight vignettes, the music faded out. Both the happy and sad emotion induction procedures lasted 4 minutes and 30 seconds. The participant had been instructed to read the sentences that would appear on the projector screen, to listen to the music that would simultaneously play through the speakers, and to try to imagine to be in the same situation as described in the sentences. Thirdly, after the emotion induction procedure had ended, a final sentence appeared instructing the participant to stand up and to take place at the center of the motion capture space. Next, music started to play automatically and the participant executed the task (s)he had received beforehand, namely to 'move in any way (s)he wanted' to the music. Finally, when the music had stopped, the participant had to take a seat again, reopen the laptop and fill out the same emotion rating scale once more.

Afterwards, the participant received a beverage and a snack and was thanked for taking part in the study. Before departure, participants in the sad condition had the opportunity to listen to cheerful music in order to improve their emotional state.

4.3. Movement Data Analysis

Since the primary aim of the experiment was to compare participants' physical movements to music with contrasting emotional implications, we used a three-dimensional optical motion capture system to record their full body movements. From this data, we extracted an objective set of movement features that could function as comparative measures between conditions.

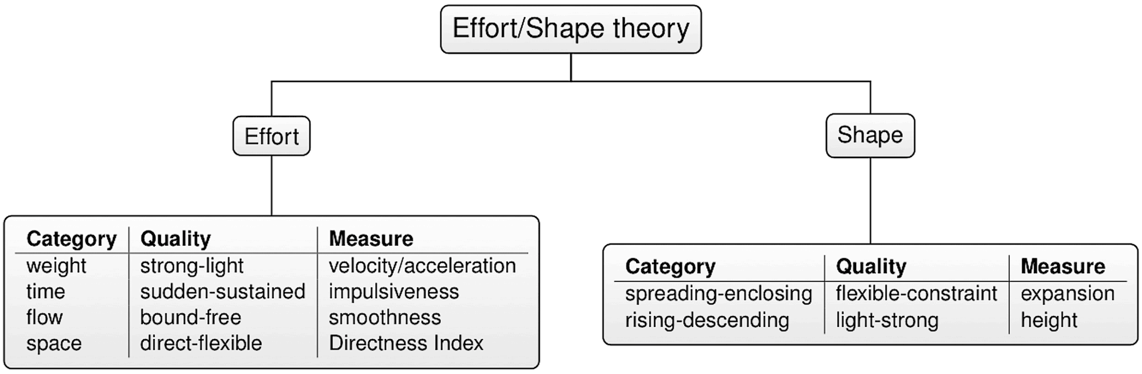
4.3.1. Movement data acquisition

Full body movement was captured at a sampling rate of 100 Hz using an OptiTrack infrared optical system consisting of 12 synchronized cameras with related ARENA motion capture software. Participants were equipped with a special suit to which 34 infrared reflecting markers were attached, consisting of a jacket, trousers, and cap. A default human skeleton model provided within the ARENA software was constructed from the markers, whose placement on the suit was determined in a predefined manner: four markers for the hips, three each for the head, chest, upper arms, hands, and two each for the thighs, shins, and feet. Afterwards, the performances of all participants were exported into BVH files. Using the MATLAB motion capture toolbox (http://www.cs.man.ac.uk/~neill/mocap/) complemented by our own algorithms, the three-dimensional position and displacement of seven body parts in relation to the body-center (i.e., the pelvis) was calculated independent of the position or orientation of a participant in the motion capture space. The following seven body parts were considered: head, chest, arms, hands, hips, legs, and feet.

4.3.2. Extraction of objective movement features

The selection of objective movement features from the raw data was based on the Effort-Shape theory introduced by dance artist and theorist Rudolf Laban (1947, 1966/2011). Of particular relevance to our study, Laban developed an integrated terminology for describing objective movement features, which he related to qualitative aspects of subjective human experiences. The Effort-Shape theory as a whole is far more extensive than our purposes require; our study merely focused on the terminological system, using it to derive labels for the objective movement features that, effectively, serve to define the dance performances of our participants. Moreover, as previous studies regarding expressive movement (Camurri et al., 2003, 2004; Lagerlöf and Djerf, 2000) have used comparable movement features, it enables comparison with previously acquired results.

As the name implies, the terminological system consists of two main components, namely *Effort* and *Shape*. Effort relates to the dynamics (i.e., quality of energy) of body movements while Shape relates to the correlated changes in corporeal form of the movements. Both components are subdivided into categories, each of which is structured around two opposite polarities. The Effort component has four categories: *weight effort* (strong-light), *time effort* (sudden-sustained), *flow effort* (bound-free) and *space effort* (direct-indirect). The Shape component can also be divided into several subcategories, of which the most relevant to this study are the polarities *spreading-enclosing* (flexible-constrained) and *rising-descending* (light-strong). We defined seven movement features corresponding to these categories: *velocity* and *acceleration* (weight effort), *impulsiveness* (time effort), *smoothness* (flow effort), *Directness Index (DI)* (space effort), *expansion* (spreading-enclosing), and *height* (rising-descending) (see Fig. 4.2).



Category	Quality	Measure
weight	strong-light	velocity/acceleration
time	sudden-sustained	impulsiveness
flow	bound-free	smoothness
space	direct-flexible	Directness Index

Category	Quality	Measure
spreading-enclosing	flexible-constraint	expansion
rising-descending	light-strong	height

Figure 4.2.: Laban's movement analysis model (1966/2011).

Velocity was calculated as the first derivative of distance with respect to time while acceleration was calculated as the second derivative of distance. Expansion was represented by the distance between joints of the upper limbs (i.e., hand and elbows) and the body center. Height was calculated as the position coordinate along the vertical axis.

Calculations of DI, impulsiveness and smoothness were based on the division of the raw data into discrete motion segments. This segmentation process resembled methods presented in previous research, which took the velocity profile (i.e., bell-shaped curves) as the basis for defining the boundaries of each segment (Camurri, 2003, 2004; Leman et al., 2009) (see Fig. 4.3). The boundaries of each motion segment were determined by local minima in the velocity signal (i.e., points in time where the acceleration value is zero), which in turn indicate a transition from a decrease to an increase of movement velocity. Accordingly, each segment was defined by a single increase and subsequent decrease in movement velocity. Due to this methodological approach, a number of small, insignificant motion segments (in terms of duration and covered distance) occurred. Therefore, we attributed a weight to each segment defined by the multiplication of their respective duration and the (Euclidean) distance covered by the three-dimensional spatial trajectory. In our study, we calculated the movement features described below using only a specific subset containing the 10 most significant motion segments (i.e., the segments to which the highest weights were attributed) for each 30 seconds in the movement performance. These were considered as being most representative of the complete movement performance in that time interval. Accordingly, we avoided that small, insignificant movement segments had a disturbing effect on the final result. For each performance of a participant, this segmentation method was executed for all body parts.

DI (Camurri et al., 2003, 2004) was calculated as the proportion between (1) the Euclidean distance of the straight trajectory between the position occupied by a body part at the beginning and end of a given segment, and (2) the distance covered in reality (i.e., the sum of distances from sample to sample) (see Fig. 4.4).

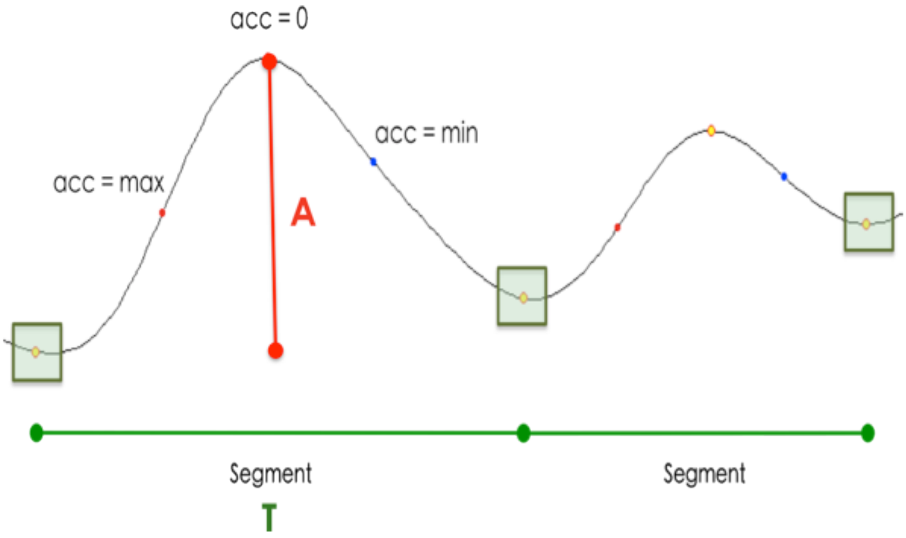


Figure 4.3.: Representation of a bell-shaped velocity curve.

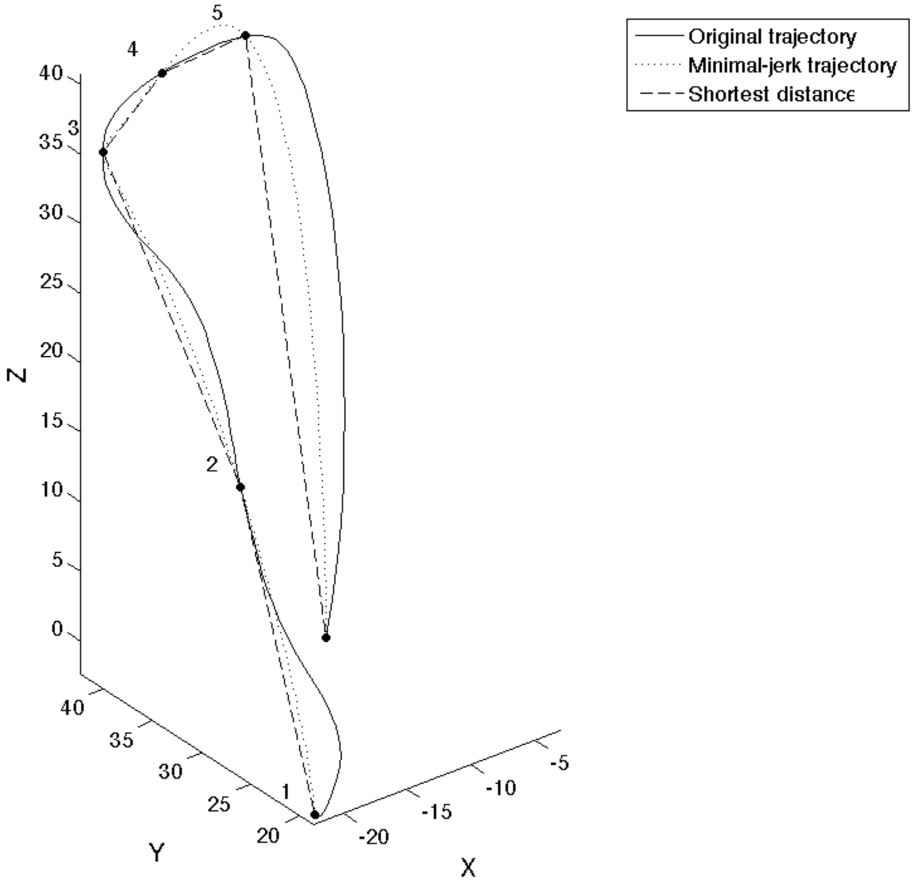


Figure 4.4.: Representation of DI and smoothness. The straight line refers to the distance covered in reality while the dashed line represents the Euclidean distance of the straight trajectory of a joint between the beginning and the ending of a segment, marked by the numbers. The dotted line illustrates the minimum-jerk trajectory.

Impulsiveness was calculated as the amplitude range of the velocity curve divided by the duration of a motion segment. Our measure of smoothness originated in the constrained minimum-jerk model presented by Todorov and Jordan (1998). Based on the algorithms presented in their study, the minimum-jerk trajectory of each motion segment (i.e., considered as the smoothest trajectory) can be computed (see Fig. 4.4). Accordingly, the sample-to-sample distances between the minimal-jerk trajectory and the actual trajectory covered by a specific body part provided a measure of smoothness. For each of these seven movement features, the mean was calculated over all samples or motion segments, per subject and condition. This provided results for each movement feature of each participant in each of the two conditions.

4.4. Results

To investigate the effect of the emotion induction procedure, the scores given by participants on the emotion rating scales before and after the dance session were analyzed and seven movement features were tested for dissimilarities between the happy and sad condition.

4.4.1. Emotion rating scale

Wilcoxon signed-rank tests revealed that before the experimental sessions started, both in the happy and in the sad condition, scores for happiness (*Mdn* = 3.67) were significantly higher than scores for sadness (*Mdn* = 1.33), $Z(31) = -6.92$, $p < .001$. However, after the happy emotion induction procedure, scores for happiness (*Mdn* = 4.00) were significantly higher than at the start of the experiment (*Mdn* = 3.50), $Z(31) = -2.56$, $p < .05$. In addition, scores for sadness were significantly higher after the sad emotion induction procedure (*Mdn* = 1.83) than at the beginning of the experiment (*Mdn* = 1.33), $Z(31) = -2.92$, $p < .01$. Moreover, scores for happiness were significantly higher after the happy emotion induction procedure (*Mdn* = 4.00) than after the sad emotion induction procedure (*Mdn* = 3.33), $Z(31) = -2.85$, $p < .01$, whereas scores for sadness were significantly higher after the sad emotion induction procedure (*Mdn* = 1.83) than after the happy counterpart (*Mdn* = 1.00), $Z(31) = -3.45$, $p < .001$.

To summarize, analyses of the scores on the emotion rating scales showed that the intended effect of the emotion induction procedure was obtained.

4.4.2. Movement features

All seven movement features for each of the seven body parts were tested separately in order to search for differences between the happy and sad condition, for a total of 49 significance tests. First, the differences between scores were calculated and tested for normality by means of KS-tests. If the assumptions of homogeneity of variances and normality could be accepted, dependent *t*-tests, with the scores for the two conditions as variables, were performed. If these assumptions could not be accepted, Wilcoxon signed-rank tests were executed. Significant results are reported in Table 4.1.

Table 4.1.: M and SE of the movement feature as a function of emotion condition and body part are reported for the paired-samples t-test. Mdn of the movement feature as a function of emotion condition is reported for the Wilcoxon signed-rank test. Only significant effects are shown.

	Happy condition	Sad condition	*t*	*Z*	*df*	*p*
Impulsiveness						
Chest	7.91	6.81		-2.00	31	<.05
Arms	13.61	12.58		-2.09	31	<.05
Hands	26.18 (2.00)	23.15 (2.05)	2.61		31	<.05
Hips	2.18	1.79		-2.30	31	<.05
Velocity						
Arms	36.15 (2.76)	31.78 (3.11)	2.05		31	<.05
Hands	80.70 (6.31)	69.86 (6.41)	2.58		31	<.05
Acceleration						
Head	1.74	1.52		-2.39	31	<.05
Hands	3.95 (0.29)	3.42 (0.31)	2.42		31	<.05
Hips	0.19	0.16		-1.98	31	<.05
Feet	4.45	4.27		-2.34	31	<.05
Expansion						
Hands	37.47 (1.11)	35.68 (1.02)	2.41		31	<.05

In summary, the conditions were shown to have significant effects upon four features: impulsiveness, velocity, acceleration, and expansion. By comparison with the sad condition, in the happy condition chest, arm, hand and hip movement proved to be more impulsive; movement of the arms and hands was faster; head, hand, hip, and foot movement accelerated to a greater extent; and finally, hand movement proved to be more expanded. No effects were uncovered for DI, smoothness, and height. We also tested to see if there was a significant effect of the order of the conditions, but no such effect was discovered for any of the body parts and any of the features.

4.5. Discussion

The overall goal of this study was to investigate the effect of induced emotions on unchoreographed dance movement. It has been suggested that each individual emotion has its own meaning, and may, therefore, influence behavior in its own unique way (e.g., Boone & Cunningham, 1998; Camurri et al., 2004; Dittrich et al., 1996; Gross et al., 2010; Lagerlöf & Djerf, 2002; Van Meel et al., 1993; Wallbott, 1998). Thus, in hypothesizing, we sought to identify differences between corporeal articulations in happy and sad conditions. Our results suggest several effects of emotional state on movement in dance, all of which accord with earlier research. Firstly, participants displayed significantly faster and more accelerated body movement in the happy condition than in the sad one. This resonates with findings of Camurri et al. (2003), which revealed that dance performances portraying joy received significantly higher mean scores for QoM than those portraying grief. QoM is a measure of the overall amount of detected motion, involving velocity and force, hence, this finding accords with our results, which take into account velocity and acceleration. Further, our study also exposed an impulsiveness effect as movements were more impulsive in the happy condition than in the sad condition. Results with similar implications were reported by Lagerlöf and Djerf (2000), whose study of expressive dance movement unveiled a relationship between joy and frequent tempo changes. Finally, our data uncovered an effect of induced emotion on expansion: movements were significantly more expanded in the happy condition than in the sad condition. Again, this finding is in line with Camurri et al. (2003), who found that dancers displayed a higher level of contraction when portraying grief than when they were portraying joy. Lagerlöf and Djerf (2000) also revealed a correlation between greater levels of joy and the tendency for movements to reach out further from the center of the body. No significant effects were revealed for DI, smoothness, and height, despite the fact that findings of previous studies (e.g., Camurri et al., 2003; Lagerlöf & Djerf, 2000) suggest that these features could have proved to be influenced by the induced emotional state of the dancers. Nevertheless, the results of this study suggest that the emotional state of the participants does not affect the directness of the trajectories of the body parts, the height of the projection of the limbs, or the smoothness of the body movements.

The effects of the emotion induction procedure on full body movement in this particular study have more general implications with respect to the application of theories of embodied cognition to emotion (Leman, 2008) as our results imply that not merely the perception of emotion (Niedenthal, 2007) and the portrayal of emotion (Camurri et al., 2003; Lagerlöf & Djerf, 2000), but also the induction of emotion, involves the embodiment of the implied emotion. Hence, we believe that emotion induction techniques could be successfully applied to future research regarding emotions and movement.

One could argue that only a relatively small number of body parts have been influenced by the emotional state of the participants. However, the amount of significant results did exceed the number that would be expected by chance alone. Moreover, significant results tended to cluster in meaningful groups rather than being distributed across all the body parts.

Remarkably, more significant differences were obtained for the hands than for any other body part. This is consistent with the belief that the hands have a privileged role in music-related gestures (Godøy, 2010), and it accords with the more general cognitive phenomenon that hand movement is closely linked with the expression of emotions (Goldin-Meadow, 2003). It has been proven that hand movements are frequently used to convey emotion; further, human observers' attention has been shown to focus on this body region spontaneously when attempting to grasp the emotional state of another person (Glowinski et al., 2011; McNeill, 1992). Moreover, one of the first functions of spontaneous hand movement in early infancy is believed to be emotional (Trevarthen, 1986).

Previous studies, conducted from a more cultural-ethnographical viewpoint, have demonstrated the significance of hand movement in dance customs of other cultures, especially in Asian traditions. A distinctive feature of classical Indian dances, for example, is the use of *hastas*, or expressive hand gestures, used to communicate both with the audience and with other dancers (Hariharan, Acharya, & Mitra, 2011). Hand positions and gestures are also important in Balinese and

Javanese dances where long, generally artificial (often gold or silver), fingernails accentuate the movements of the hands (Barba & Savarese, 1991), but also play a significant role in the traditional Khmer dances of Cambodia and classical Thai dances (Wee, 2002).

This predominance of the hands in emotionally expressive movement is facilitated by the many biomechanical degrees of freedom enabled by the jointed lever system of arms and hands. In addition, the cerebral programming of the combinations of rotation about the many joints is, from birth, extremely refined and informed by many sensitive receptors. Hands can be projected from the body with high velocity to transmit large forces, moved with perfect temporal and spatial precision of guidance in an extensive reaching field, and accurately rotated in any direction (Trevarthen, Delafield-Butt, & Schögler, 2009). This freedom of movement could account for the significance of hand movement in our results, given that this study dealt primarily with inexperienced dancers; a lack of control over other parts of the body might be ascribed to a lack of dance skill, although the easy control that most people have over their hands perhaps predisposes them to express emotion manually. A novel study comparing dance movements of professional and novice dancers might investigate this possible effect of dance experience more thoroughly. Notwithstanding, we believe that future studies should pay sufficient attention to hand and arm movement when analyzing emotionally expressive movements.

In this study, the use of free dance movement was deliberately chosen in order to explore the effect of emotion on kinematics, and our results suggest that it can indeed serve as an adequate alternative to choreography in research on movement and emotion. Removing the constraints of a prescribed 'dance routine', however fixed or skilled, has the advantage of opening participation in the study to people without a professional background in dance, thus enabling researchers to address a far broader group of potential participants. In addition, as participants are granted the freedom to move intuitively, arguably, they might feel less inhibited, and therefore, they might move in a less restrictive fashion. There are inevitable issues surrounding the ecological validity of the experimental design. Given that participants wore a motion capture suit and were instructed to move to the music, the question could rise whether participants were truly able to move intuitively, authentically, and freely. Some levels of freedom were indeed impossible to obtain, as this was not a real-life setting, but an experimental one in which accurate kinematic data needed to be obtained. To counteract this as far as possible, we ensured that the motion capture suit was non-intrusive to the participants' mobility before the experiment started. In addition, the participants were instructed to move in whatever way they wanted, and the openness of this instruction lead to a wide variety of individual interpretations: some participants moved very actively whereas others made hardly any movements at all. Therefore, in our study, free movement should be understood as unprepared, unchoreographed movement with as few restrictions as possible, within the predetermined, inescapable limits of the motion capture mechanism.

Another deliberate choice in our experimental setup was the absence of a neutral control condition. As we learned from the self-reported emotional state that participants reported overall happy emotional states before any induction took place, incorporating a neutral emotional state would perhaps have created a too artificial situation, without any ecological parallel. However, Jallais and Gilet (2010) stated that induced emotions are supposed to be equivalent to naturally occurring emotions. Moreover, measures other than self-reports could have been applied in assessing the participants' emotional state. For example, physiological signals, such as heart pulse and blood oxygenation, have been found to be reliable in differentiating between emotions (Jaimovich, Coghlan, & Knapp, 2012). Yet, for this physically demanding experiment such measures would probably have proved unreliable as participants were dancing just prior to the emotion induction assessment; probably, increases in heart rate speed, skin conductance, and so on, might have been a result of the physical exertion involved in the experiment, and only to a much lesser extent due to the emotion induction procedure.

A limitation of our study is that it relies on the discrete emotions model, which proposes that the entire array of human affective phenomena arises out of a handful of basic emotions, such as sadness, happiness, fear, anger and disgust (Buck, 1988; Ekman, 1992; Izard, 1971, 1972, 2007; Tomkins, 1984). Scherer (2003, 2004) has pointed out that so small a number of primary basic emotions seems ill-suited to describe the extraordinary richness of the effects of emotion induction. Two alternatives for studying the effect of emotions on dance movement might be the dimensional model, which distinguishes between several dimensions of feelings (e.g., valence, arousal, etc.), or the eclectic approach, in which appropriate verbal affect labels are used by researchers within the bounds of their own specific study (Eerola & Vuoskoski, 2011; Juslin & Sloboda, 2010; Scherer, 2004; Zentner & Eerola, 2009). However, both of these models have attendant disadvantages; the dimensional model has a low degree of resolution and differentiation while a crucial drawback of the eclectic approach is that it renders the comparison of data from different studies impossible (Scherer, 2004).

For these reasons, we preferred the discrete emotions model for this particular study.

Another criticism which could be leveled at our study might be that the music participants moved to was composed specifically for this particular study. This decision was taken in order to ensure optimal control over the musical parameters. Inevitably, it could be argued that the stimulus was in some way artificial, although the ecological validity of the composition was ensured as an experienced composer created it. Moreover, assessments of the music in a pilot study justified its neutrality and besides, implementing existing music could have caused other confounding effects due to participants' familiarity with the stimulus (Ali & Peynircioglu, 2010; Peretz et al., 1998).

In summary, in our controlled experimental study, dance movements of Western, primarily amateur dancers moving freely to Western tonal music were analyzed, and such studies, regarding the effect of emotions on dance movement, are relatively rare. Our results are consistent with reports by others, but they also go beyond earlier research, showing that a combined emotion induction technique comprising guided imagery and music is an adequate tool for studying emotionally expressive movement. Moreover, this study shows that free dance movement serves as an excellent means of studying the effect of emotions on kinematics. Alongside these findings, our data supports the notion that hand movement plays a prominent role in the expression of emotions.

Chapter 5

Recognizing emotions of happiness and sadness from dance movement

Van Dyck, E., Vansteenkiste, P., Lenoir, M., Lesaffre, M., & Leman, M. (Submitted). Recognizing emotions of happiness and sadness from dance movement.

Abstract

Recent research revealed that emotional content can be successfully decoded from human dance movement. Most previous studies made use of videos of actors or dancers portraying emotions through choreography. The current study applies emotion induction techniques and free movement in order to examine the recognition of emotional content from dance. Observers (N = 30) watched a set of silent videos showing depersonalized avatars of dancers moving to an emotionally neutral musical stimulus after emotions of either sadness or happiness had been induced. After every film clip, the observers were asked to make forced-choices concerning the emotional state of the dancers. Results revealed that observers were able to identify the emotional state of the dancers. Moreover, emotions were more often recognized for female dancers than for their male counterparts. In addition, the results of this study unveiled that observers primarily focus on movements of the chest when decoding emotional information from dance movement. The findings of our study show that not merely portrayed emotions, but also induced emotions can be successfully recognized from free dance movement.

5.1. Introduction

Emotions color all aspects of our daily life. They are essential to our social relationships, psychological well being, cognitive functioning, moral sensitivity and other important developmental processes (Sroufe, 1996). Moreover, as they serve as signals that convey information about the friendliness or dangerousness of our environment, the communication and recognition of emotions has proved to be crucial to our survival (Ekman, 1992). In daily life, emotions can be communicated through speech prosody (McCann & Peppé, 2003) and voice quality (Gobl & Ní Chasaide, 2003; Laukkanen, Vilkman, Alku, & Oksanen, 1997). However, they can also be transmitted through nonverbal and nonvocal communication channels. Theories of embodied cognition suggest that perceiving, experiencing and thinking about emotions involves embodiment, or interaction with the body, of the relevant emotions in one's self (Niedenthal, 2007). Charles Darwin (1872/2009) himself introduced the idea that both humans and animals are capable of displaying emotions through motor behavior (especially posture). Recent research confirmed that emotions can for instance be recognized from facial expressions, which have distinct and universal expressive characteristics, signaling positive and negative feelings, attitudes and intentions (Ekman, 1972; Likowski et al., 2001; Lundqvist & Dimberg, 1995; Moody et al., 2007). Other studies have shown how emotions may successfully be recognized from bodily expression, especially from particular parts of the body such as the trunk (de Meijer, 1989), the arms (de Meijer, 1989; Pollick et al., 2001), and the hands (Gross et al., 2010). In addition, both children and adults are believed to master the ability to decode emotions from full body movements (Boone & Cunningham, 1998; Dittrich et al., 1996; Lagerlöf & Djerf, 2000; Ross et al., 2012; Shikanai et al., 2013; Van Meel et al., 1993).

An interesting type of full body movement, in particular with regard to emotion research, is dance, which is one of the oldest forms of cultural expressions (Sachs, 1937). Moreover, dance is believed to facilitate the expression of several different emotions in a non-verbal way (Levy, 1988). The ability to successfully decode emotions from dance movement is already present from early childhood onwards, as children as young as about five years old have proved to be able to recognize emotional meaning from dance. In addition, they have demonstrated to be capable of decoding the intensity of the emotions expressed by dancers when observing videos of adults moving expressively to music (Boone & Cunningham, 1998). Some previous studies have used point-light displays, in which the body is represented by a small number of illuminated dots, positioned in such a way as to highlight the motion of the main body parts (e.g., Atkinson et al., 2004; Brownlow et al., 1997; Dittrich et al., 1996; Pollick et al., 2001; Ross et al., 2012), while others addressed the issue of emotion recognition using full-light displays (e.g., Atkinson et al., 2004; Boone & Cunningham, 1998; Lagerlöf & Djerf, 2000; Ross et al., 2012; Shikanai et al., 2013). Emotion recognition by adults has proven to be more accurate from full-light than from point-light displays, which suggests a benefit from having the full complexity of the movements available (Ross et al., 2012). Therefore, in the current study, videos of full-body movements of dancers are used instead of point-light displays.

Most previous research concerning emotion recognition from dance movement has used videos of actors or dancers portraying basic emotions such as happiness, sadness, fear, disgust and anger (e.g., Atkinson et al., 2004; Boone & Cunningham, 1998; Camurri et al., 2003; de Meijer, 1989; Lagerlöf & Djerf, 2000; Montepare et al., 1999). The assumption underlying the selection of emotions presented through acting in previous studies is that actors are typically believed to be experts in displaying emotional information corporeally (Gross et al., 2010). However, one might argue that their actions are exaggerated and should rather be regarded as symbolic portrayals of the emotions at issue (Ross et al., 2012). Moreover, a number of studies have revealed that not all actors generate equally identifiable, emotionally expressive dance movements (Gross et al., 2010; Montepare et al., 1987; Wallbott, 1998). Therefore, instead of considering emotions portrayed through acting, the current study applies emotion induction techniques in order to examine the recognition of emotions from dance movement by observers.

In addition, contrary to previous studies, which have made use of choreography to study expressive dance movements (e.g., Brownlow et al., 1997; Camurri et al., 2003; Montepare et al., 1999; Wallbott, 1998), the dancers in this study were able to move freely as we believe that this facilitates more accurate expression of emotion. Moreover, this method could prove to be a more ecologically valid approach for studying emotion recognition from dance movement.

In a previous study by Van Dyck, Maes, Hargreaves, Lesaffre, & Leman. (2013) which examined the impact of induced emotions (happiness and sadness) on dance movements of participants dancing freely to emotionally neutral music by measuring and analyzing the kinematics of the movements, evidence of the effect of emotion induction on dance movement was indeed provided. In the current study, we examine whether observers are also able to decode induced emotions from free dance movement. We expect that observers are capable of distinguishing between happy and sad dances. We also presume that female observers perform better in the recognition task than their male counterparts, as women are believed to be superior in understanding others' emotions (Eisenberg & Lennon, 1983; Hampson, van Anders, & Mullin, 2006; McClure, 2000). In addition, as women generally experience and express emotions more intensely than do men (Donges, Kersting, & Suslow, 2012), we expect the observers to have a higher success rate when judging the emotional state of female than of male dancers.

Van Dyck et al. (2013) showed that movements of participants who danced after being induced to feel emotional states of happiness proved to be faster, more accelerated, more expanded and more impulsive than after sad emotion induction. Thus, we presume that observers will label the kinematics of the dances in a similar way. While the recognition of emotions from dancers’ movements has received considerable attention, little is known about visual search patterns people use to gather information on which this recognition is built. Therefore, in this study, we use the behavioral method of eye tracking to examine where observers direct their focus. As Van Dyck et al. (2013) revealed that the differences between the emotion conditions were primarily detectable from hand movement, we expect observers to primarily focus on the gestures of the dancers’ hands.

5.2. Method

5.2.1. Ethics statement

The study was approved by the Ethics Committee of the Faculty of Arts and Philosophy of Ghent University. In addition, all participants signed a form to declare that they participated voluntarily, that they had received sufficient information concerning the tasks, the procedures, and the technologies used, that they had the opportunity to ask questions, and that they were aware of the fact that recordings of eye movements were made, for scientific and educational purposes only.

5.2.2. Observers

The sample of observers concerned a non-random selection. The selection criterion was scientific and was based on the condition of being aged between 20 and 35 years of age, as it is known that emotion recognition is not fully matured until early teenage years and it is believed that the duration of negative emotional states decreases with age (Larcom & Isaacowitz, 2009).

Thirty adult observers (15 females, 15 males) took part in the study. The average age of the observers was 27.23 years (*SD* = 3.43). The majority (60 %) had received musical training, and of those, the average time spent in musical training was 6.23 years (*SD* = 6.70). More than half of the participants (56.70 %) had also trained in dance and spent, on average, 2.67 years (*SD* = 4.02) in dance training. In addition, 90 % of the participants reported that dancing is an activity that forms a part of their lives, with varying degrees of frequency (13.30 % danced about once a year; 63.30 % danced about once a month; 10 % danced about once a week; 3.30 % danced more than once a week). The participants received no compensation for participating in the study.

5.2.3. Stimuli

Sixteen video clips were used in this study. The video clips were recorded with motion capture cameras in a previous study (Van Dyck et al., 2013), in which the effect of induced emotions on the kinematics of dance movements was studied. In that particular study, the participants were induced to feel emotional states of either happiness or sadness and then danced intuitively to an emotionally neutral piece of music. Each participant performed the dance both in the happy and sad condition. For the current study, silent video clips showing depersonalized avatars were created from the movement data of the non-expert dancers.

Each of the 16 video clips consisted of a pair of two dance performances, one of a dancer in the happy condition and one of the same dancer in the sad condition (see Fig. 5.1). Three series of video clips were prepared, each time with randomized order of the clips. Moreover, the order of the emotion conditions (whether happy and sad dances were presented on the left or right side in the video clips) was randomized. In addition, video clips were counterbalanced for identity (and therefore also for sex) of the dancers. Half of the dancers were female and all emotional states were presented an equal number of times on the left and on the right side of the screen. All video clips were edited to exactly 10 seconds in length. Three practice clips preceded the 16 clips to be rated. The video clips were presented on a 22-inch computer monitor. The distance between the monitor and the participants was about 27.60 inch and the stimuli occupied approximately 37.8° of the field of view.

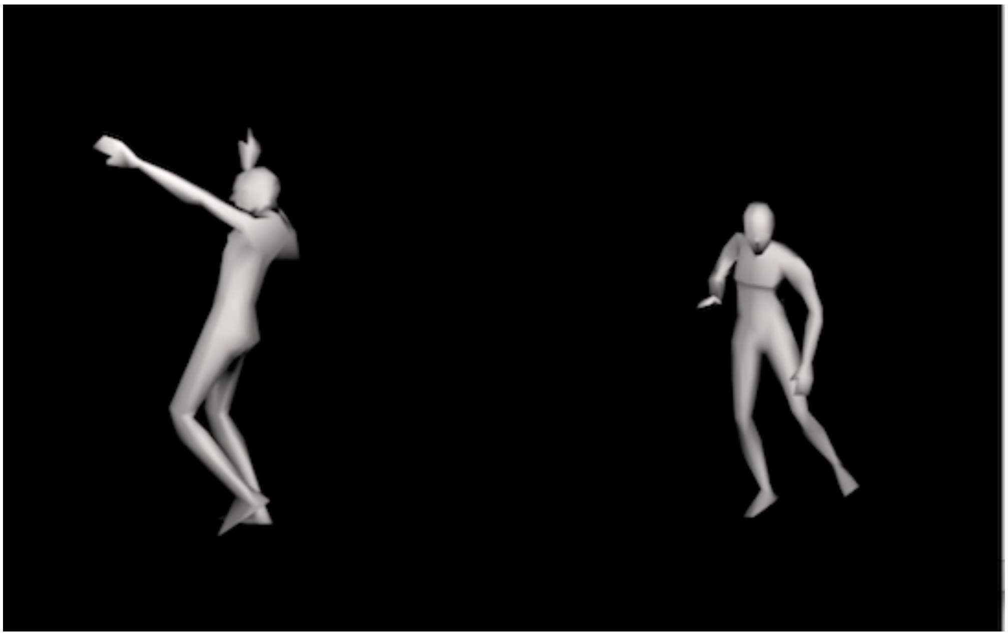


Figure 5.1.: Example of a video clip presenting a pair of dance performances of the same dancer; one in the happy condition and one in the sad condition.

5.2.4. Eye tracking

The behavioral method of eye tracking was chosen as it concerns an unobtrusive strategy to gather information with regard to the specific focus of the observers. It consists of a more implicit measure of what is guiding the gazer's motivation than for instance self-reports, and offers quantitative evidence of the observer's visual and attention processes. In addition, eye movements are the result of the interaction between cognitive and perceptual processes. Therefore, we believe that eye tracking can serve as an adequate tool to investigate the process of emotion recognition.

Eye movements were recorded using a Remote Eye tracking Device (RED) by SensoMotoric Instruments, which operated at 120Hz. A five-point calibration was used and two validations were performed during the experiment. To calculate the time participants watched the different regions of the body, dynamic Areas Of

Interest (AOIs) were coded on the video clips using BeGaze 3.2 (SMI). Once the AOIs were coded, the dwell-time percentages (percentage of time the eyes were directed towards the AOIs) were retrieved. Since we were dealing with moving stimuli, the coding of the AOIs was very time-consuming. Therefore only two clips were coded in detail, with following AOIs : head, chest, hips, arms, hands, legs, and feet. The other videos were analyzed using more general AOIs, being head, upper, and lower body.

5.2.5. Procedure

Observers were asked to watch the three practice clips and 16 dance videos and to fill out a short questionnaire after each video. In the questionnaire, they were asked about the perceived emotional state of each dance performance. The observers were aware of the fact that the same dancer, in one excerpt feeling happy, in the other feeling sad, executed each pair of dance performances. Moreover, the observers were asked to rate each dance performance concerning its kinematic properties. They rated their impressions with regard to the features *velocity*, *acceleration*, *impulsiveness*, and *expansion* on a five-point Likert scale (‘1 = Not at all’, ‘2 = Slightly’, ‘3 = Moderately’, ‘4 = Very’, ‘5 = Extremely’). At the end of the experiment, the observers were asked to fill out a second questionnaire, which contained questions concerning their music and dance background.

5.3. Results

5.3.1. Emotion recognition

A one-sample chi-square test revealed that, overall, observers were able to recognize the correct emotion from the dance movements, χ^2 (1) = 255.21, $p < .001$. In addition, the effect of the order of the videos and the order of the emotions (presented either left or right), but also of the sex of the dancers and the observers was examined. No significant associations between the order of the videos, χ^2 (2) = .64, $p = .89$, the order of the emotions, χ^2 (1) = 2.15, $p = .14$, or the sex of the observers, χ^2 (1) = 1.44, $p = .23$, could be found. However, there was a significant association between the sex of the dancers and the results of the emotion recognition task, χ^2 (1) = 29.91, $p < .001$. The emotional state of female dancers proved to be more often recognized in comparison to the emotional state of male dancers.

5.3.2. Kinematic features

In order to check whether observers associated particular kinematic features with specific emotional states, rating data for the different motion features were compared between the two emotion conditions by means of Wilcoxon signed-rank tests. However, no significant differences were found between the happy and sad performances for either velocity, $Z(479) = -0.39$, $p = .70$, acceleration, $Z(479) = -0.39$, $p = .70$, impulsiveness, $Z(479) = -0.94$, $p = .35$, or expansion, $Z(479) = -0.88$, $p = .38$.

5.3.3. Eye tracking

Validation tests showed an average accuracy of 0.37° ($SD = 0.12$) and the average tracking ratio (% of time eye movement was actually measured) was 89.90 % ($SD = 3.70$). Eye tracking data of all participants proved to be accurate enough in order to be analyzed statistically.

Firstly, the two video clips containing the more detailed AOIs were analyzed. A KS-test showed that the assumption of normality could not be accepted. A Friedman's ANOVA with the AOIs as test variables unveiled a significant difference in mean dwell time between the different AOIs, $\chi^2(6) = 110.64$, $p < .05$. Wilcoxon tests were used to follow up this finding. A Bonferroni correction was applied and so all effects are reported at a .0024 level of significance. The mean dwell time was significantly higher for the chest than for the head, $Z(29) = -3.12$, arms, $Z(29) = -4.78$, hands, $Z(29) = 4.78$, hips, $Z(29) = -4.78$, legs, $Z(29) = -4.78$, and feet, $Z(29) = -4.78$. In addition, mean dwell time was significantly higher for the head than for the arms, $Z(29) = -3.08$, hands, $Z(29) = -3.64$, legs, $Z(29) = -3.57$, and feet, $Z(29) = -4.37$. Finally, mean dwell time was significantly lower for the feet than for the arms, $Z(29) = -4.78$, hands, $Z(29) = -4.46$, hips, $Z(29) = -4.11$, and legs, $Z(29) = -3.18$. An overview of the mean dwell time for the different AOIs is presented in Figure 5.2.

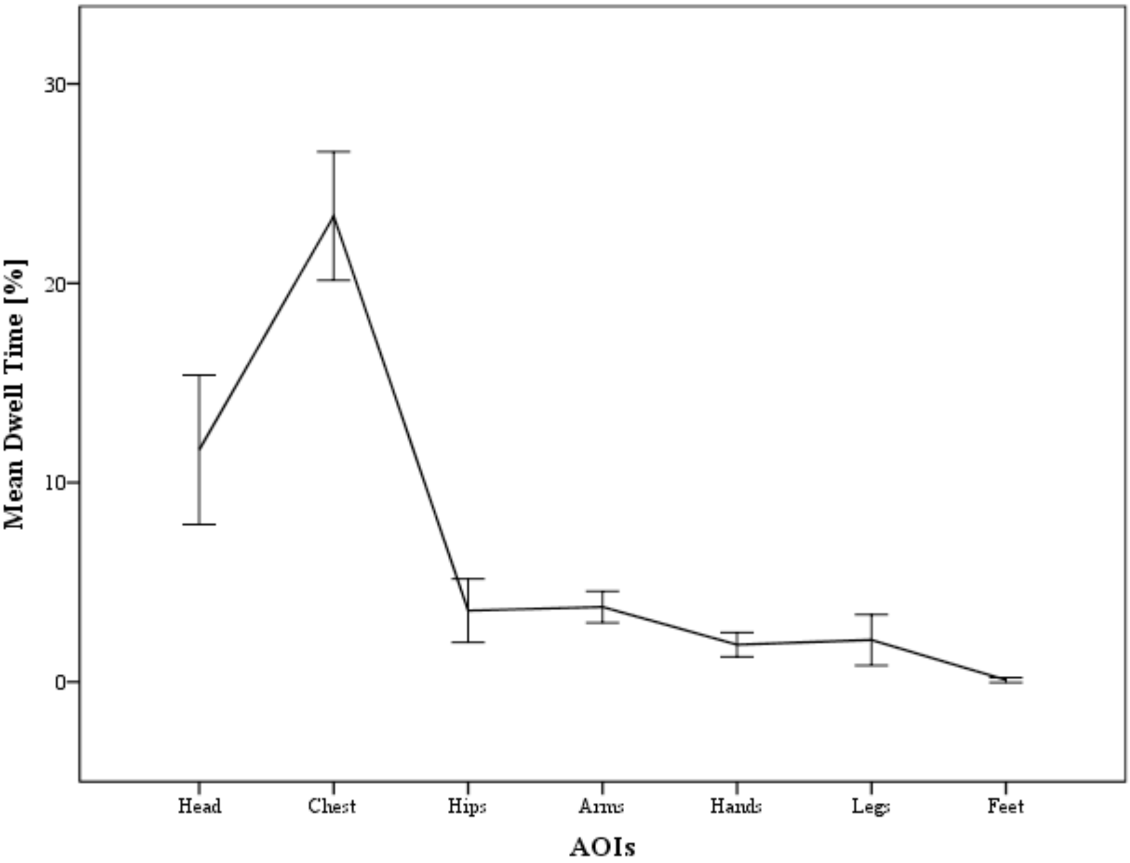


Figure 5.2.: Mean dwell time for the AOIs. Data presented are mean ± SE.

Based upon these observations, we analyzed the other clips using more general AOIs. A KS-test showed that the assumption of normality could not be accepted. A Friedman's ANOVA with the AOIs as test variables showed a significant difference in mean dwell time between the different AOIs, $\chi^2(2) = 38.47$, $p < .001$. Wilcoxon tests were used to follow up this finding. A Bonferroni correction was applied and so all effects are reported at a .0003 level of significance. It appeared that the mean dwell time was significantly higher for the upper body than for the head, $Z(29) = -4.47$, and lower body, $Z(29) = -4.78$. An overview of the mean dwell time for the more general AOIs is presented in Figure 5.3.

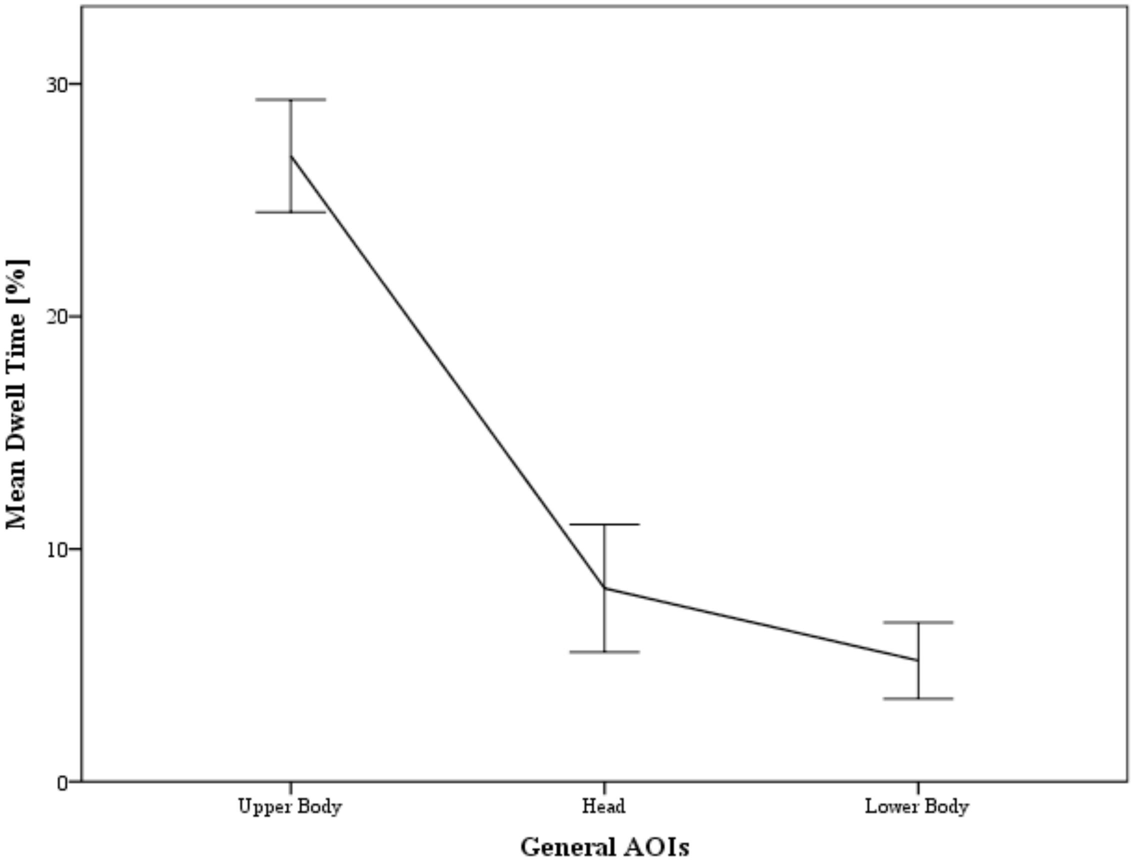


Figure 5.3.: Mean dwell time for the more general AOIs. Data presented are mean ± SE.

5.4. Discussion

In this experiment, it was investigated whether observers are able to decode emotional content from corporeal articulations of dancers moving to an emotionally neutral piece of music after emotions of either happiness or sadness had been induced. The results revealed that observers were indeed capable of successfully recognizing the intended emotion from the dance movements. This resonates with findings of previous research on emotion recognition from dance movement using portrayed emotions. Boone and Cunningham (1998), Montepare et al. (1999), and Shikanai et al. (2013), for example, showed that emotions such as happiness, sadness and anger expressed in dance could be accurately identified by observers. Therefore, our results are in accordance with findings of previous studies, but also extend them by showing that in addition to portrayed, or ‘acted’, emotions, induced emotions of happiness and sadness can also be decoded from unchoreographed dance movements by observers.

As it is well-documented that women are better at understanding and considering the feelings and needs of others compared to men (Eisenberg & Lennon, 1983; Hampson et al., 2006; McClure, 2000), we presumed female observers to recognize the induced emotions more often than their male counterparts. However, our results did not support this premise and apparently this finding is not all that unique. A similar study by Ross et al. (2012) regarding emotion recognition from body movements of actors portraying emotions of happiness, sadness, fear, and anger, for instance, did not reveal any sex effects with regard to the observers either.

On the other hand, in the current study, a significant association with recognition accuracy was unveiled regarding the sex of the dancers, as the emotional state was more often recognized for female dancers than when male dancers were being observed. This suggests that women are more proficient in expressing their personal feelings in a corporeal manner compared to men. This is in accordance with a fairly substantial body of research, which has demonstrated that women are more emotional, and both experience and express emotions more intensely than men (Donges et al., 2012; Kring & Gordon, 1998).

By capturing and analyzing the kinematics of the movements of participants dancing to an emotionally neutral stimulus, Van Dyck et al. (2013) unveiled that, after happy emotion induction, movements proved to be faster, more accelerated, more expanded and more impulsive than after sad emotion induction. Likewise, similar findings were reported in previous studies regarding the effect of portrayed emotions of joy, grief, anger, and fear on dance movement. Both Camurri et al. (2003) and Lagerlöf and Djerf (2000) showed that the duration of grief performances was remarkably longer and consisted of a smaller amount of tempo changes compared to performances in other emotion conditions. In addition, movements were more contracted in the grief and fear conditions than in the joy condition. Finally, Camurri et al. (2003) revealed a main effect for QoM (a measure of the total amount of detected motion, involving velocity and force), as performances in the joy condition received higher mean scores than those in the grief condition. However, in the current study, which relied on video data of the study of Van Dyck et al. (2013), no significant differences between the emotional states were unveiled with regard to observers' designation of kinematic properties. This could be due to the choice of the specific kinematic labels (e.g., acceleration, expansion, etc.), which might have proved to be too abstract for the observers to fully comprehend. Another explanation could be found in the short duration (10 seconds) of the film clips, which might not have enabled thorough examination of the kinematic characteristics of the dance movements. A novel study with a new set of kinematic properties comparing dance clips of different lengths might investigate the significance of the specific labels and the duration of dance stimuli more thoroughly.

As the hands are generally believed to have a privileged role in music-related gestures (Godøy, 2010), and as Van Dyck et al. (2013) obtained more significant differences for the hands than for any other body part, we expected that observers would mainly focus on the gestures of the dancers' hands. However, eye tracking data from the current study unveiled a specific focus of the observers on the chest area, and to a lesser extent also on the head. Although this finding did not fit our expectations, several explanations arise from the data. First, most of our body movements tend to start from the more proximal segments and develop towards the more distal limbs (Chapman, 2008). This implies that information on changes in movement direction or acceleration might be readily seen in the trunk and shoulder area first. Second, even though the observers' general focus is on the chest area, gestural information concerning other body parts is not necessarily disregarded as the participants are still capable of perceiving movements of other parts of the body, in relation to the chest. In this specific experimental set-up, most of the movements of the arms and legs were still within the useful field of view when focusing on the chest. The reported gaze behavior therefore suggests that dancers' emotions were analyzed using an extended visual span and parafoveal processing. This visual strategy has been described in fields such as sports (e.g., Charness, Reingold, Pomplun, & Stampe, 2001; Gegenfurtner, Lehtinen, & Säljö, 2011) and radiology (e.g., Kundel, Nodine, Conant, & Weinstein, 2007) and has been labeled as 'the holistic model of image perception'. This visual strategy suggests that observers do not pay attention to the head, the hands, the hips, and so on, as separate parts of the body, but rather see the human body as one entity. Our finding with regard to the focus on the chest, and in addition to the head, accords with previous research on emotions and body posture as several studies have emphasized the importance of the posture and position of the torso and head, as indicators for emotional content. Schouwstra and Hoogstraten (1995), for instance, used stick drawings of armless figures and varied the positions of the head and spine. Their study revealed that upright postures were judged more positively, and forward-leaning postures more negatively. In addition, an unpublished study by Inouye (1998), which required participants to pose a wooden artist's doll, suggested that basic emotions could be represented in terms of sagittal movement, spinal flexion, open/closed and forwards/backwards reaching, and facial orientation towards or away from the eliciting stimulus.

Previous research revealed that, even though emotion recognition is not fully matured until early teenage years (Herba, Landau, Russell, Ecker, & Phillips, 2006; Tonks, Williams, Frampton, Yates, & Slater, 2007), children as young as about five years old perform above chance in successfully perceiving emotional information from body language (Boone & Cunningham, 1998; Ross et al., 2012). Moreover, they are capable of decoding the intensity of the emotions expressed by dancers when observing videos of dancers moving to music (Boone & Cunningham, 1998). As it is believed that the duration of negative emotional states decreases with age (Larcom & Isaacowitz, 2009), the current study only considered a specific age group (all participants were between 24 and 34 years of age). However, a future study could investigate whether also children or observers in other age groups are capable of successfully recognizing induced emotions from free dance movements.

In this study, the use of free dance movement was deliberately chosen because of its ecological validity and our results suggest that it can indeed serve as a suitable alternative to choreography in research on emotion recognition. Participants were allowed to move intuitively, so they might have felt less inhibited and as a result moved in a less restricted manner. Additionally, the removal of the limitations of a prescribed dance routine has the advantage of opening participation in the study to people without a professional background in dance, thus enabling researchers to address a far broader group of potential dancers in future studies regarding emotion recognition.

5.5. Conclusion

In summary, this experimental study examined whether observers are able to decode induced emotions from free dance movement. Our results are in tune with results of similar studies, but they also extend previous research, showing that, in addition to portrayed emotions, also induced emotions can be perceived from unchoreographed dance movement by adult observers. Moreover, this study shows that female dancers are better at communicating emotional meaning corporeally than their male counterparts. Finally, the results of this study unveiled that observers generally focus on movements of the chest, and to a lesser extent of the head, when decoding emotional information from dance movement.

PART 4:

GENERAL DISCUSSION AND CONCLUSION

Chapter 6

Discussion and conclusion

The theoretical roots of the research presented above lie in the notion of embodied music cognition, which implies that musical intentions, meanings, and significations (*mind*) on the one hand, and musical sound and other types of energy that afford human action (*matter*) on the other, are mediated through the body (Leman, 2008). This idea also accords with the notion of action-perception coupling, which considers perception and action processes to be intertwined: perception leads to action; conversely, action leads to perception. Thus, (music) perception is as a phenomenon that cannot be considered to be detached from the body with which it interacts. Moreover, action and perception processes also interlink with other factors, such as the emotional state of the perceiver/actor. Emotions routinely affect how and what we perceive, but they can also influence the way in which we act. Thus, not only can emotions be affected through the perception of music; they can also shape (and even be shaped by) dance movement. In other words, music perception, movement, and emotion are thoroughly interconnected. Moreover, out of this network, conceptualizations about music and narrative accounts of musical aesthetics and experience can be created (Barsalou, 2008).

The variability in music-induced dance movement can be shaped by characteristics other than the emotional state of the dancers, for example, their age, gender, musical/dance background, as well as their neurological, musculatory, and skeletal qualities. Besides variances in musical features and subject-specific characteristics, contextual factors can also affect dance movement: the time of day, environmental qualities, the attendance of other dancers, and so on; each of these qualities could prove to influence the corporeal articulations of dancers. However, in this doctoral dissertation, we focused specifically on emotions and musical features (and in addition also on linguistic descriptions of music, see Chapt. 3) when considering music-induced dance movement. Contextual characteristics and subject-specific properties besides emotion were either controlled in the course of the experiments or taken into account in data analysis. Since we believe in the need to validate the embodiment approach empirically, this research aimed to examine this field through several experimental studies. In the past, embodied music cognition has rarely been studied empirically in association with emotion theories, as cognitive approaches have mostly been applied with regard to emotion expression and perception. Here, however, we tried to understand more about the way emotions can be expressed bodily, and how they can be perceived from movements of the body. Thus, in this doctoral dissertation, we approached music perception, emotion, and movement as firmly entangled components while trying to gain deeper inside in these concepts by means of empirical research.

6.1. Overview

First, the theoretical framework on which the behavioral studies were based, was presented. Second, four empirical studies were discussed; two on the influence of musical features on dance movement and two on the effect of emotions on dance. The overarching research question for this dissertation was: *How and to what extent do musical features and emotional states influence music-induced dance movement?*

In PART 1, a theoretical framework for this dissertation, describing the theoretical background on the relations between mind, body, and music; between music and dance movement; and between emotion and movement, was set out. In addition, the methodological approach behind the empirical studies was discussed.

Next, in PART 2, two empirical studies on the influence of musical features on dance movement were reported. In the first empirical study presented in this dissertation (see Chapt. 2), the impact of the sound pressure level of the bass drum on dance movement was investigated. Results revealed that the dancers modified their bodily behavior according to the dynamic level of the bass drum when they moved to music in a social context: as the sound pressure level of the bass drum increased, they danced more actively and displayed a higher degree of tempo entrainment. In general, this study demonstrated the significance of the bass drum in contemporary dance music; in addition to its function as a stylistic signifier, the bass drum proved to have a strong impact on dancing itself. In a second study, presented in Chapter 3, the influence of musical style (*heroic* vs. *lyric*) on dance movement was examined. In addition, the relationship between people's linguistic, metaphorical descriptions of perceived musical expressiveness and their corporeal articulations was investigated. The results of this study showed that the physical appearance of freely-performed body movement in response to music is linked to the linguistic description of musical expressiveness.

In PART 3, two empirical studies on the expression and perception of emotion in music-induced dance movement were considered. The first of these, discussed in Chapter 4, examined the influence of emotion on dance. Emotional states of either happiness or sadness were induced before participants danced intuitively to an 'emotionally neutral' piece of music. Results showed that participants' dance movements in the happy condition differed from those in the sad condition. In the former condition, movements were faster, more accelerated, more expansive, and more impulsive than in the latter. In a final study (see Chapt. 5), the extent to which the emotional content of dance movement could be decoded by observers was investigated. Observers watched a set of silent videos showing depersonalized avatars of the dancers in the previous study, and were asked to make forced-choices concerning the emotional state of the dancers. Results showed that observers were able to identify the emotional state of the dancers. The findings reported in Chapters 4 and 5 reveal that not only portrayed emotions, but also induced emotions can be successfully recognized from free dance movement.

Overall, the empirical studies showed that emotions and musical features can indeed influence dance movement and that emotions expressed in dance can be successfully recognized from the movements of the dancers.

6.2. General discussion

6.2.1. Contributions

A large body of previous research examined the influence of specific musical features, and also, to a lesser extent, that of particular emotions, on motor processes and body movements. We believe that our research is a valuable contribution to this field, as our approach differs from earlier research, incorporating novel strategies in comparison to other studies. First, we conceive music, body movement, and emotions as thoroughly intertwined rather than as distinct variables. Further original features of our approach concern the employment of free dance movement, induced emotion, fair numbers of participants, and ecologically-valid environments.

6.2.1.1 Free dance movement

Generally, earlier studies on the topic of dance movement have tended to provide the participants with instructions as to the particular types of movement they were to make, according to a prespecified scheme (e.g., Brownlow et al., 1997; Camurri et al., 2003, 2004; Dittrich et al., 1996; Lagerlöf & Djerf, 2000; Walk & Homan, 1984). These restrictions were imposed artificially, typically in the form of choreography. We believe that allowing participants to move freely to music, has several advantages over choreography. First, we believe that this approach is a far more ecologically-valid means of studying the relationships between musical features and emotions on the one hand, and between musical features and dance movement cues on the other. Second, removing the constraints of a prescribed dance routine, however fixed or skilled, has the advantage of opening participation in the study to people without a vocational background in dance, thus enabling researchers to address a far broader group of potential participants. In addition, as participants are granted the freedom to move intuitively, arguably, they might feel less inhibited than otherwise, and therefore, they might move in a less restrictive fashion. Finally, we believe that the use of free dance movement facilitates better expression of emotion, as participants are given a freer rein in their choice how to express a given emotion. The results of our empirical studies suggest that free dance movement can indeed serve as an adequate alternative to choreography in research on the influence of musical features and emotions on dance movement.

6.2.1.2 Induced emotion

Most previous research on emotions and (dance) movement took actors' portrayals of emotion as the subject for study. As such, these studies of corporeally expressed emotion have been more limited in their scope (e.g., Brownlow et al., 1997; Camurri et al., 2003, 2004; Dittrich et al., 1996; Lagerlöf & Djerf, 2000; Walk & Homan, 1984). The use of 'portrayed' emotions arises from the assumption that actors are experts in displaying emotion using the face and body (as well as the voice), capable of expressing and intensifying the specific qualities of an emotional signal by means of corporeal articulations (Gross et al., 2010). Nevertheless, a large body of studies has revealed that not all actors generate equally recognizable, emotionally expressive body movements (e.g., Gross et al., 2010; Montepare, Goldstein, & Clausen, 1987; Wallbott, 1998). Thus, rather than study acted, portrayed emotions, we applied emotion induction techniques in the relevant studies, as induced emotions are supposedly equivalent to those that occur spontaneously (Jallais & Gilet, 2010). The results of the studies reported in Chapters 4 and 5 revealed that not only portrayed emotions, but also induced emotions can be successfully expressed through and recognized from free dance movement.

6.2.1.3 Original stimuli

Typically, previous studies on (dance) movement have used existing music as stimuli for the corporeal articulations of the participants, the exceptions being cases in which mere sounds or other auditory stimuli were used (e.g., Brown, Martinez, & Parsons, 2006; Burger, Saarikallio, Luck, Thompson, & Toiviainen, 2013; Edworthy & Waring, 2006). In most of our studies (see Chapt. 2, 4, and 5), however, the musical stimulus was composed especially for that particular experiment. The decision to use original music was made in order to ensure optimal control over every parameter in the music. Inevitably, it could be argued that the musical stimuli were in some way 'artificial' on this account. However, the ecological validity of the compositions was ensured, as the pieces were created by experienced composers and producers. Moreover, generally, participants' assessments of the music proved to be particularly positive and besides, implementing existing music could have caused confounding effects due to participants' familiarity with the stimulus (Ali & Peynircioglu, 2010; Peretz et al., 1998).

Nonetheless, in one study (see Chapt. 3), a Brahms piano concerto was used, for practical reasons: our aim was to investigate the effects of stylistic characteristics typical of symphonic music, and so we chose to employ an existing rather than design and commission our own classical concerto. Besides, the stimuli designed by the researchers for the other studies consisted of electronic music pieces, which are not as challenging and costly to compose as a classical work performed by symphonic orchestra and piano.

6.2.1.4. Fair numbers of participants

The majority of research on dance movement has tended to employ only small numbers of dancers (e.g., 1 dancer: Brownlow et al., 1997; 2 dancers: Dittrich et al., 1996; 5 dancers: Camurri et al., 2003; 6 dancers: Shikanai et al., 2013; 18 dancers: Toiviainen, 2010), even though the results obtained when testing a larger group of participants are generally more reliable. In addition, there is evidence that there can be considerable variation in dancers' ability to encode emotion (e.g., Wallbott & Scherer, 1986). Moreover, having only a small number of dancers further restricts the total number of stimuli from which a suitable test set could be selected (Atkinson et al., 2004). Therefore, in the empirical studies reported in the previous four chapters, we tried to test larger populations: 100 participants (Chapt. 2), 36 participants (Chapt. 3), 32 participants (Chapt. 4), and 30 participants (Chapt. 5).

6.2.1.5. Ecological environment

Previous studies have often disregarded ecological considerations and on many occasions, dance experiments have been performed by single individuals in clean laboratory settings, with researchers closely watching every move, and in some cases no music or mere sounds were played to accompany the dance movements (e.g., Brownlow et al., 1997; Camurri et al., 2003, 2004; Dittrich et al., 1996). In our studies we tried to create ecological environments similar to real life dance settings, in order to make the participants feel more at ease and less inhibited.

The experiments were executed in a room at IPEM instead of an actual dance venue, because the recording of body movements entailed the use of 12 synchronized cameras positioned at predetermined spots. However, when we designed the settings for the dance sessions, we tried to ensure their ecological validity in any way we could. For the tests discussed in Chapters 2, 3, and 4, the participants were at all times shielded from the outside world by black curtains. Furthermore, the lights in the room were dimmed as pilot studies had indicated that this made the participants feel more comfortable and less constricted. In the study described in Chapter 2, club-style lighting was used which contributed to create a club-like atmosphere.

Although motor entrainment has been studied extensively, only a few experiments have been carried out using more than one participant at a time (Drake, Penel, & Bigand, 2000; Snyder & Krumhansl, 2001; Toiviainen et al., 2010). Consequently, earlier research has tended to overlook the social aspect of entrainment, or joint action, despite the fact that motor entrainment usually takes place in social contexts (Kirschner & Tomasello, 2010; Repp & Keller, 2008). Therefore, in the study on tempo entrainment, discussed in Chapter 2, the experiments involved groups of participants. Crucially, in this way, the experimental setting resembled the situation of an actual dance club more closely. In addition, experimental sessions generally took place in the evening, as this is the time of day people commonly tend to visit dance clubs. In the study reported in Chapter 3, however, the participants performed the experiments in solo conditions. We took the decision to disregard social context to prevent participants from mimicking each others' movements, in order to capture detailed information about their specific personal movement characteristics. In this particular case, the time of day was of secondary importance: the study concerned specific styles of classical rather than contemporary dance music (which is usually danced to in the evening in clubs). In addition, for the studies reported in Chapters 4 and 5, participants were invited in the morning in order to control for shifts in emotional state over the course of the day, and because people are believed to be more sensitive to emotion induction in the early morning than later in the day (Hill & Hill, 1991; Thayer, Newman, & McClain, 1994). In these two studies, the participants also danced alone, since the presence of others might have affected their emotional state.

Moreover, the music used was as alike as possible to contemporary dance music used in actual dance clubs (with the exception of the experiment discussed in Chapter 3, where the use of classical music was necessitated by the topic under study), such that participants could dance intuitively. These original compositions had a fixed tempo of around 120-128 BPM, which represents the most common tempo in contemporary dance music (Moelants, 2008).

6.2.2. Limitations

Inevitably, this research has limitations. The first concerns the measurement tools used to capture dance movement. Participants wore a hip bag containing a wireless Nintendo Wii Remote Controller, a motion capture hat, jacket, or even a complete suit, and so it could be argued that this obstructed their dance movements. Some levels of freedom were indeed impossible to obtain, as this was not a real-life setting, but an experimental one in which accurate kinematic data needed to be obtained. To counteract this as far as possible, we ensured that the measurement tools were non-intrusive to the participants' mobility.

Another concern has to do with the idea of free dance movement. Since participants were explicitly asked to move to the music (rather than deciding to do so on their own accord), the question could arise whether participants were truly able to move intuitively, authentically, and freely. However, the participants were instructed to move in whatever way they wanted, and the openness of this instruction lead to a wide variety of individual interpretations: some participants moved very actively whereas others made hardly any movements at all. Therefore, in our research, free movement should be understood as unprepared, unchoreographed movement with as few restrictions as possible, within the predetermined, inescapable limits of the motion capture mechanism.

A factor that was not considered in this study was that of personality, despite the belief that it can influence dance movement (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010), affect emotion expression (Mergl et al., 2006) and perception (Vuoskoski & Eerola, 2011), and play a role in the preference for loud bass sounds in music (McCown et al., 1997). The data collected in this research did not allow any detailed investigation of the potential effects of personality. In addition, paired tests were executed in the statistical analyses, in order to control for possible effects of personality, which might have influenced the results we obtained.

Finally, some issues only concern the two empirical studies on emotion and movement (see Chapt. 4 and 5). A first limitation of those studies is that they are reliant on the discrete emotions model. As this model has a higher degree of resolution and differentiation than the dimensional model, and because it enables better comparison of data from different studies than the eclectic approach (Scherer, 2004), we preferred this particular model of emotions for our research. A second limitation deals with the absence of a neutral control condition. Yet, since participants reported overall happy emotional states before any emotion induction took place, to have incorporated a neutral emotional state would perhaps have been to create too artificial a situation without any ecological parallel. Besides, Jallais and Gilet (2010) stated that induced emotions are supposed to be equivalent to naturally occurring emotions. A final issue concerns the fact that measures other than self-reports could have been applied in assessing the participants' emotional state. For example, physiological signals, such as pulse rate and blood oxygenation, have been found to be reliable in differentiating between emotions (Jaimovich, Coghlan, & Knapp, 2012). For our physically rather demanding experiments, such measures would probably have proved unreliable as participants were dancing just prior to the emotion induction assessment; increases in heart rate speed, skin conductance, and so on, might have been a result of the physical exertion involved in the experiment, and only to a much lesser extent due to the emotion induction procedure.

6.2.3. Future work

Research has a tendency to raise a wealth of new questions while answering some initial ones, and this doctoral thesis has laid the foundations for possible future research on music-induced dance movement. First, prospective empirical studies could try to deal with the limitations of this research: they could incorporate measurement tools that facilitate even more levels of freedom with regard to body movement; they could consider the personality of the participants; they could regard emotion models besides the discrete emotions model; they might include a neutral control condition; or they could make an effort to assess participants' emotional state by means of physiological measurements.

Another strategy might be to start from the results of our research. When surveying empirical literature on the influence of music on dance, future researchers could take our results one step further by incorporating new musical stimuli, looking at movement within larger groups of dancers, carrying out experiments in actual dance venues rather than laboratory settings, and so on. Future studies on emotions and movement might also apply similar strategies. In addition, future research could examine other emotional states besides happiness and sadness, study the behavior of other types of participants such as children, older participants, or participants with completely different backgrounds (most of the participants in our studies had a musical and/or dance background), or investigate the effect of dance movement on emotion regulation. However, these ideas are only a handful of suggestions for future studies. We hope that both the strengths and limitations of our research has stirred the inspiration of some and will result in novel studies on music, dance, and emotions.

6.3. Conclusion

The research discussed in this doctoral dissertation contributes to a more profound comprehension of music-induced dance movement. In the course of this research, the influence of emotions and musical features on dance was examined. Based on the theory of embodied music cognition and on the understanding of action-perception coupling, several empirical studies were presented. Evidence that music perception incorporates tight linkages with other systems, such as the motor and emotion system was unveiled. Therefore, in this dissertation, music perception is considered as multimodal, involving auditory, motor, as well as emotional processes. Our research has succeeded in clarifying several issues concerning music-induced movement, and concurrently, it laid down a basis for future research on music-induced dance movement.

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