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Emotions Move Us: Basic Emotions in Music Influence People's Movement to Music

Birgitta Burger[*1], Suvi Saarikallio[*2], Geoff Luck[*3], Marc R. Thompson[*4], Petri Toiviainen[*5]

[*] *Finnish Centre of Excellence in Interdisciplinary Music Research, Department of Music, University of Jyväskylä, Finland*

{[1]birgitta.burger, [2]suvi.saarikallio, [3]geoff.luck, [4]marc.thompson, [5]petri.toiviainen}@jyu.fi

ABSTRACT

Listening to music makes us to move in various ways. Several factors can affect the characteristics of these movements, including individual factors and musical features. Additionally, music-induced movement may be shaped by the emotional content of the music. Indeed, the reflection and embodiment of musical emotions through movement is a prevalent assumption within the embodied music cognition framework. This study investigates how music-induced, quasi-spontaneous movement is influenced by the emotional content of music. We recorded the movements of 60 participants (without professional dance background) to popular music using an optical motion capture system, and computationally extracted features from the movement data. Additionally, the emotional content (happiness, anger, sadness, and tenderness) of the stimuli was assessed in a perceptual experiment. A subsequent correlational analysis revealed that different movement features and combinations thereof were characteristic of each emotion, suggesting that body movements reflect perceived emotional qualities of music. Happy music was characterized by body rotation and complex movement, whereas angry music was found to be related to non-fluid movement without rotation. Sad music was embodied by simple movements and tender music by fluid movements of low acceleration and a forward bent torso. The results of this study show similarities to movements of professional musicians and dancers, to emotion-specific non-verbal behavior in general, and can be linked to notions of embodied music cognition.

I. INTRODUCTION

Listening to music makes us to move in various ways (Leman, 2007; Leman & Godøy, 2010). Several factors can affect the characteristics of these movements: Individual factors, such as personality and preference, have been found to influence movability to music (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010), as have music-intrinsic features, such as beat strength and pulse clarity (Burger, Thompson, Saarikallio, Luck, & Toiviainen, 2010; Van Dyck et al., 2010). Additionally, music-induced movement may be shaped by the emotional content of the music. Emotions are an essential component of musical expression (e.g., Gabrielsson & Lindström, 2001), which can have a strong influence, for instance, on the listener's mood (e.g., Saarikallio, 2011).

The ability to successfully express and communicate emotional states to observers via body movements was demonstrated as early as 1872, when Darwin assigned certain body movements and postures quite specifically to emotional states. Joyful movements, for example, were described as jumping with an upright torso and head, whereas anger was characterized by trembling and shaking. Sad movements were described as passive, and a downward directed head. More recently, Wallbott (1998) conducted a study with professional actors performing certain emotions and found characteristic movement features for each emotion category; joy and anger were associated with an upright torso, whereas sadness was expressed with a more collapsed body. Anger was the most active emotion, followed by joy and sadness. Dynamics and power were mostly related to anger, less for joy, and even less to sadness. Spatially expansive movements were used to express anger and joy, whereas sad movements covered less space. Employing a different approach, De Meijer (1989), studied actors performing several movement characteristics instead of emotions. These movements differed in terms of general features, such as force, velocity, and spatial orientation. Observers rated fast, active, open, light, and upward directed movements with raised arms and a stretched trunk as being happy, and strong and fast movements with a bowed torso and a high force as being angry. In contrast, slow, light, and downward directed movements with arms close to the body were described as sad.

Emotions are a central element of music, and music-related emotions have been the subject of a large number of studies. According to Krumhansl (2002), people report that their primary motivation for listening to music is its emotional impact. Using different emotion categories and models, such as basic emotions, dimensional models, or domain-specific models, various rating experiments have shown that listeners are able to perceive emotional content in music (Eerola & Vuoskoski, 2011).

Musical emotions are conveyed not only by the music itself, but also through movement. While movements are required, for example, to produce sounds when playing a musical instrument, studies have shown that there are certain additional movements that are not used for the actual sound production, but for conveying emotions and expressivity (e.g., Wanderley, Vines, & Middleton, 2005). Dahl and Friberg (2007) investigated a marimba, a bassoon, and a saxophone player, who performed a piece of music with different emotional intentions. When presented with only visual elements of the performance, observers could detect the happy, angry, and sad performances, but failed to identify the fearful performances. Happy intention was found to be communicated by movement cues such as medium regularity and fluency, high speed, and high amount of movement of the whole body, whereas angry intention was conveyed by medium regularity, low fluency, high speed, and somewhat high amount of movement. Sad intention was expressed by very regular and fluent movement, low in speed and quantity. Burger and Bresin (2010) developed a small robot displaying different emotions based on the movement cues found by Dahl and Friberg (2007) and used, for example, large, fluent, and circular movements to convey happiness, large, irregular and jerky movements for anger, and slow, regular, and reduced movements to convey sadness. In a perceptual experiment, all emotions were successfully recognized by observers.

More direct links between music and emotion-specific movement have been investigated using professional dance, in which movement is the only way to convey expressivity and emotion. Camurri, Lagerlöf, and Volpe (2003) describe a study in which professional dancers performed the same dance with different emotional intentions. Happiness was found to be associated with frequent tempo and tension changes, long stops between changes, and dynamic movement, whereas anger was characterized by short movements, frequent tempo changes, shorter stops between changes, and dynamic and tense movement. Sadness was portrayed by long and smooth movements, few tempo changes, and low tension. Furthermore, Boone and Cunningham (1998) reported results of a dance study in which actors displayed different emotions. They found that happiness was characterized by upward arm movements away from the torso, whereas anger was associated with a great number of directional changes of the torso, as well as tempo changes. Sadness was portrayed with downward gaze, low muscle tension, and a slackened body.

Besides being an important cue in music performance and professional dance, movement also plays a considerable role in every-day music behavior. Keller and Rieger (2009), for example, stated that simply listening to music can induce movement, and in a self-report study conducted by Lesaffre et al. (2008), most participants reported moving when listening to music. In general, people tend to move to music in an organized way, for example by mimicking instrumentalists' gestures or rhythmically synchronizing with the pulse by tapping their foot, nodding their head, or moving their whole body in various manners (Leman & Godøy, 2010). Moreover, Leman (2007) suggests, "Spontaneous movements [to music] may be closely related to predictions of local bursts of energy in the musical audio stream, in particular to the beat and the rhythm patterns". Such utilization of the body is the core concept of embodied cognition, which claims that the body is involved in or even required for cognitive processes (e.g., Lakoff & Johnson, 1980/1999, or Varela, Thompson, & Rosch, 1991). Human cognition is thus highly influenced by the interaction between mind/brain, sensorimotor capabilities, body, and environment. Following this, we can approach music (or musical involvement) by linking our perception of it to our body movement (Leman, 2007). One could postulate that our bodily movements reflect, imitate, help parse, or support the understanding of the content of music, be it musical features, such as beat, rhythm, melody, or tonality, or emotional characteristics. Leman suggests that corporeal articulations could be influenced by three (co-existing) components or concepts: "Synchronization", "Embodied Attuning", and "Empathy", which differ in the degree of musical involvement and the kind of action-perception couplings. "Synchronization" forms the fundamental component, as synchronizing to a beat is easy and spontaneous. The beat serves as the basic musical element from which more complex structures emerge. The second component, "Embodied Attuning", concerns the linkage of body movement to musical features more complex than the basic beat, such as melody, harmony, rhythm, tonality, or timbre. Following this idea, movement could be used to reflect and imitate the musical structure to understand it. Finally, "Empathy" is seen as the component that links music, or rather musical features, with expressivity and emotions; to feel and identify with the music and thus imitate and reflect the affective content of the music by using body movement.

II. AIM

The aim of this study was to investigate influences of emotional content of music on music-induced, quasi-spontaneous movement. We first conducted a motion capture experiment (experiment 1) and computationally extracted various movement characteristics from the data. Additionally, the perceived emotional content (basic emotions) of the music used in the first part was gathered in a rating experiment (experiment 2). Based on the material mentioned above, we predicted that different emotions would be characterized by different combinations of movement features, reflecting emotional qualities of music. Music perceived as happy or angry would result in active and complex movements with an upward-directed torso, with happy music having a greater amount of fluidity than angry music. Music perceived as sad and tender would result in a small amount of movement of low complexity and a forward-directed torso, with a greater amount of fluidity for tender than for sad music.

III. METHOD

The data used in this study were obtained in two consecutive experiments. In experiment 1, music-induced movement data were collected. In experiment 2, the (perceived) emotional content of the stimuli used in experiment 1 was assessed.

A. Experiment 1 – Movement Task

1) Participants. A total of 60 participants took part in experiment 1 (43 females; average age: 24, SD: 3.3). Six participants had received formal music education, and four participants had a formal background in dance tuition. Participants were rewarded with a movie ticket.

2) Stimuli. Participants were presented with 30 randomly ordered musical stimuli representing the following popular music genres: Techno, Pop, Rock, Latin, Funk, and Jazz. All stimuli were 30 seconds long, non-vocal, and in 4/4 time, but differed in their rhythmic complexity, pulse clarity, and tempo.

3) Apparatus. Participants' movements were recorded using an eight-camera optical motion capture system (Qualisys ProReflex) tracking, at a frame rate of 120 Hz, the three-dimensional positions of 28 reflective markers attached to each participant. The locations of the markers are shown in Figure 1a, and can be described as follows (L = left, R = right, F = front, B = back): 1: LF head; 2: RF head; 3: LB head; 4: RB head; 5: L shoulder; 6: R shoulder; 7: sternum; 8: spine (T5); 9: LF hip; 10: RF hip; 11: LB hip; 12: RB hip; 13: L elbow; 14: R elbow; 15: L wrist/radius; 16: L wrist/ulna; 17: R wrist/radius; 18: R wrist/ulna; 19: L middle finger; 20: R middle finger; 21: L knee; 22: R knee; 23: L ankle; 24: R ankle; 25: L heel; 26: R heel; 27: L big toe; 28: R big toe.

4) Procedure. Participants were recorded individually and were asked to move to the stimuli in a way that felt natural. Additionally, they were encouraged to dance if they wanted to, but were requested to remain in the center of the capture space indicated by a 115 x 200 cm carpet.

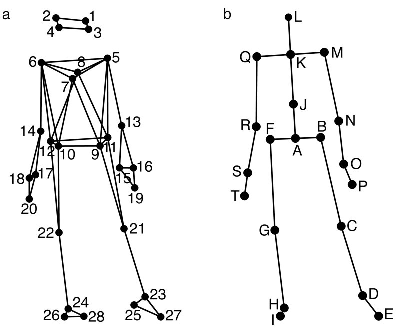

Figure 1. (a) Anterior view of the location of the markers attached to the participants' bodies; (b) Anterior view of the locations of the secondary markers/joints used in the analysis.

5) Movement Feature Extraction. In order to extract various kinematic features, the MATLAB Motion Capture (MoCap) Toolbox (Toiviainen & Burger, 2011) was used to first trim the data to the duration of each stimulus and, following this, to derive a set of 20 secondary markers – subsequently referred to as joints – from the original 28 markers. The locations of these 20 joints are depicted in Figure 1b. The locations of joints C, D, E, G, H, I, M, N, P, Q, R, and T are identical to the locations of one of the original markers, while the locations of the remaining joints were obtained by averaging the locations of two or more markers; joint A: midpoint of the four hip markers; B: midpoint of markers 9 and 11 (left hip); F: midpoint of markers 10 and 12 (right hip); J: midpoint of sternum, spine, and the hip markers (midtorso); K: midpoint of shoulder markers (manubrium), L: midpoint of the four head markers (head); O: midpoint of the two left wrist markers (left wrist); S: mid-point of the two right wrist markers (right wrist). From the three-dimensional joint position data, instantaneous velocity and acceleration were estimated using numerical differentiation based on the Savitzky-Golay smoothing FIR filter (Savitzky & Golay, 1964) with a window length of seven samples and a polynomial order of two. These values were found to provide an optimal combination of precision and smoothness in the time derivatives. Subsequently, the data was transformed into a local coordinate system, in which joint A was located at the origin, and segment BF had zero azimuth. Six movement features were then extracted from these data:

- Posture:
  - Torso Tilt: vertical tilt of the torso (Joints A–K), positive tilt being related to bending forward (see Fig. 2).
- Local Features:
  - Magnitude of Head Acceleration (Joint L).
  - Magnitude of Hand Acceleration (Joints P and T).
- Global Features:
  - Fluidity: overall movement fluidity / smoothness measure based on the ratio of velocity to acceleration. High velocity and low acceleration result in fluid movement, whereas low velocity and high acceleration result in non-fluid movement.
  - Body Rotation: amount of rotation of the body (Joints M and Q) around the vertical axis.

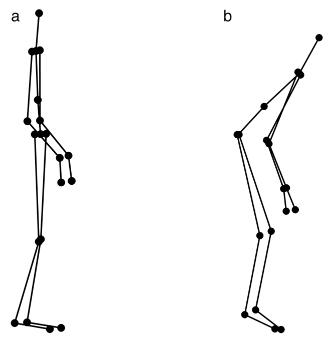

Figure 2. Torso Tilt. (a) Upright body position; (b) Bent forward body position.

- Complexity:
  - Movement Dimensionality: based on Principal Components Analysis (PCA) of the position data (all joints) assuming the degree of movement complexity or dimensionality to be reflected in the number of PCs needed to explain the movement. The cumulative sum of the proportions of variance contained in the first five PCs was taken as the measure of this variable. The mean of this cumulative variance across all data was 85%. When the cumulative sum is low, the underlying movement is complex, as a high number of PCs is needed to explain the movement sufficiently. A high cumulative sum, on the other hand, implies a simpler movement, as it can be sufficiently explained with a low number of PCs. Figure 3 illustrates this feature by displaying projections of the first five Principal Components of high and low dimensional movements.

Subsequently, the instantaneous values of each variable were averaged for each stimulus presentation. This yielded a total of six statistical movement features for each of the 30 stimuli.

B. Experiment 2 – Perceptual Task

1) Participants. Thirty-four Finnish musicology students participated in experiment 2 (17 females; average age: 25.7, SD: 5.9). All participants were familiar with concepts in the research field of music and emotions.

2) Stimuli. The same 30 musical excerpts as in experiment 1 were used. The excerpts started at second 7.5 of the original excerpts and lasted for 15 seconds. This was done to conduct the experiment in a reasonable time, while keeping the original emotional character of the stimuli.

3) Procedure. The participants were randomly divided into two groups that were presented with the stimuli at the same time, but in two different random orders. Each stimulus was presented once, followed by a break of 40 seconds. The participants' task was to rate each stimulus according to its emotional content on four different scales:

- not happy – happy
- not angry – angry
- not sad – sad
- not tender – tender

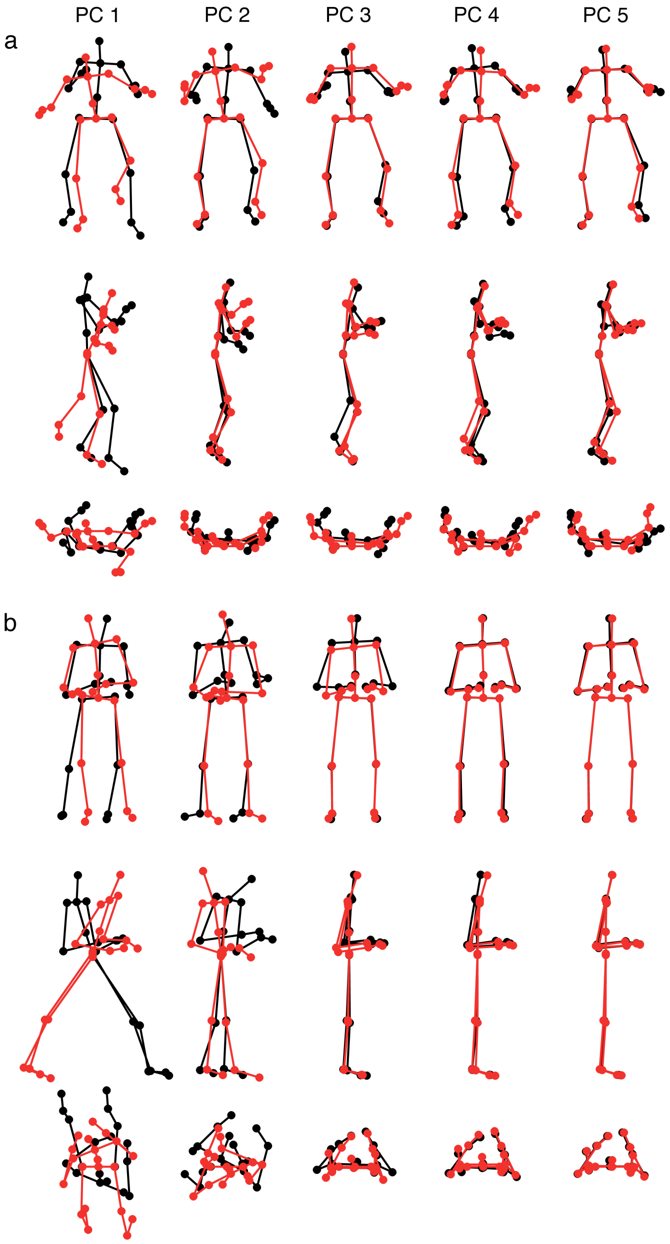

Figure 3. Movement dimensionality illustrated by displaying the projections of the first five Principal Components of high dimensional movement (a) and low dimensional movement (b). The extreme deflections of the projections/dimensions are plotted from the front, from the side, and from the top. (a) High movement dimensionality, as movement is visible in all five PC projections, thus a high number of Principal Components is needed to explain the movement; (b) Low movement dimensionality, as most movement is found in the projection of PC 1 – a low number of PCs can sufficiently explain the movement.

Responses were given on a series of seven-point Likert scales. The participants were explicitly told in the instructions to rate the excerpts according to what they thought the music expressed/conveyed and not what they personally felt when listening to the music.

IV. RESULTS

In order to perform further analysis, we first ensured consistency between participants by calculating Cronbach's alpha values for both the movement features and the ratings of the emotional contents. The values are displayed in Table 1:

Table 1. Cronbach's alpha values for both the movement features (a) and the ratings of the emotional contents (b).

(a)		(b)	
Movement feature	**α**	**Emotion**	**α**
Torso Tilt	.88	Happiness	.85
Head Acceleration	.97	Anger	.94
Hand Acceleration	.96	Sadness	.86
Fluidity	.95	Tenderness	.91
Body Rotation	.84		
Movement Dimensionality	.80		

These values indicate sufficiently high inter-subject consistency for subsequent averaging of movement features and emotion ratings across participants to receive one value per stimulus.

Next, to ensure that the participants could differentiate and reflect the emotions in their rating behavior, we correlated the emotion ratings with each other. The results are shown in Table 2.

Table 2. Results of the correlation of the rating items with each other.

	Happiness	**Anger**	**Sadness**
Anger	-.71		
Sadness	-.83	.36	
Tenderness	.42	-.84	-.02

The high negative correlations between Happiness and Anger, between Happiness and Sadness, and between Tenderness and Anger indicate that participants could clearly distinguish between these emotional characteristics. The weak positive correlations between Happiness and Tenderness and between Anger and Sadness could indicate that participants could less clearly distinguish between these emotions. Sadness and Tenderness ratings resulted in a zero-correlation, suggesting that there is no relation between these two emotions. These results are in line with previous work (Eerola & Vuoskoski, 2011).

Subsequently, each of the four rating items was correlated with the six movement features to investigate relations between the perceived emotions and the music-induced movement features. The results are shown in Table 3. Correlations with significance values less than $p<.01$ are indicated in boldface.

Table 3. Results of the correlation between the movement features and the rating items.

	Happiness	**Anger**	**Sadness**	**Tenderness**
TorsoTilt	-.13	-.32	.39	**.58*** **
HeadAcc	.10	.37	-.30	**-.63*** **
HandAcc	.25	.15	-.40	**-.47** **
Fluidity	-.07	**-.47** **	.39	**.66*** **
RotRange	**.55** **	**-.47** **	-.27	.38
MoveDim	**.54** **	-.42	**-.58*** **	.19

**$p < .01$, ***$p < .001$

As can be seen, the correlations between emotion ratings and movement features suggest different sets of movement features being characteristic for each perceived emotion.

Torso Tilt correlated positively with Tenderness ($r(30)=.58$, $p<.001$). This suggests that the participants were bent forward during tender music.

Both Acceleration features showed high negative correlations with Tenderness (Head Acceleration: $r(30)=-.63$, $p<.001$; Hand Acceleration: $r(30)=-.47$, $p<.01$). Thus, participants tended to use low acceleration of the upper body when the music was considered tender.

Fluidity exhibited a significant negative correlation Anger ($r(30)=-.47$, $p<.01$), and a positive correlation with Tenderness ($r(30)=.66$, $p<.001$), suggesting that participants moved in a fluid way with tender music, but in a more jerky fashion when the music had an angry character.

Body Rotation correlated positively with Happiness ($r(30)=.55$, $p<.01$), and negatively with Anger ($r(30)=-.47$, $p<.01$), suggesting that participants rotated their body to happy music, whereas they performed less body rotation with music that expressed anger.

Movement Dimensionality showed a significant positive correlation with Happiness ($r(30)=.54$, $p<.01$) and a significant negative correlation with Sadness ($r(30)=-.58$, $p<.001$). Thus, participants tended to use high-dimensional movements for happy music, and less complex movements for music that expressed sadness.

V. DISCUSSION

The results of this study suggest that the emotional content of music may influence characteristics of music-induced movement, and determine the quality of such movements in a particular way. Each emotion rating correlated significantly with a different set of movement features that could therefore be assumed to be emotion-specific.

Our analysis revealed Happiness to be positively related to Movement Dimensionality and Body Rotation, suggesting that happy music was embodied by rotation of the body and high-dimensional movements. Movement Dimensionality in this specific form was not part of previous studies, though the feature might be related to features that were used earlier. For example, the descriptions by Camurri et al. (2003) (dynamic movement, changes between low and high tension, and frequent tempo changes with long stops), by Wallbott (1998) (active, dynamic, and spatially expansive movements), or by De Meijer (1989) (fast, active, open, light, upward directed) could result in complex movement. In previous research, movements expressing happiness were found to be related to movements of the hands and arms (e.g., Boone & Cunningham, 1998; de Meijer, 1989). Although, in the present analysis, hand acceleration did not significantly correlate with the happiness ratings, hand and especially arm movements can be expected to increase the dimensionality of movements, as the arms offer the best possibilities to move freely in different directions and independently from other body parts. Moreover, the relationship of Body Rotation and Happiness is supported by Burger and Bresin (2010), whose robot conveyed happiness by performing circular movements.

Anger was found to be negatively correlated with Fluidity and Body Rotation, indicating that participants, when being exposed to music that is considered angry, were moving in an irregular and jagged way while not rotating the body. The co-occurrence of non-fluid movements and anger is well supported by the literature: Dahl and Friberg (2007) mentioned low fluency, Camurri et al. (2003) frequent tempo changes and short movements, Boone and Cunningham (1998) directional and tempo changes, and Darwin (1872) trembling. Jerkiness and non-fluency of movement might explain the negative correlation between Body Rotation and Anger, as smooth rather than jerky movements are associated with rotations of the body.

The result that sad music is reflected in rather simple movements of low dimensionality seems straightforward – sad music might not encourage movement as much as more active music – and is also supported by previous research. For example, Dahl and Friberg (2007) referred to low amount and speed of movement, Camurri et al. (2003) to low tension, few changes, long and smooth movements, and Wallbott (1998) to inactive movements covering little space – all characteristics that indicate low dimensionality.

Tenderness was found to be positively related to Torso Tilt and Fluidity and negatively related to Acceleration of Head and Hands, indicating that tender music was embodied through a forward tilted torso and fluid movements with low acceleration. These movement characteristics would certainly fit to tender music, as tender music might not consist of strong and easily perceivable beats. Additionally, a forward tilted body, opposite to an upright torso showing alertness, could emphasize the relaxed character of tender music.

The results could provide support for Leman's (2007) concept of "Empathy": the participants (unconsciously) identified the underlying emotions in the music and used their body to express and reflect the affective content. However, the emotional content is created and shaped by features of the music, like rhythm, timbre, or tonality – characteristics that could also be linked to the concept of 'Embodied Attuning'. Participants rate the perceived emotional content of music consistently (Eerola & Vuoskoski, 2011), and in order to change the emotional characteristics, musical features are to be changed. Thus, it may be difficult to distinguish between 'Embodied Attuning' and 'Empathy', suggesting that they are overlapping and co-existing. However, since music can express and convey emotional characteristics, we argue that the affective content of music has an unconscious effect on music-induced movement and suggest seeing "Empathy" as an abstraction of "Embodied Attuning".

VI. CONCLUSION

This study offers insights into emotion-specific body-related nonverbal behavior, and indicates that the emotional content of music has an (unconscious) influence on music-induced, quasi-spontaneous movement. Characteristic movements and movement combinations were identified for different emotional characteristics of music: Happy music was characterized by body rotation and complex movement, whereas angry music was found to be related to non-fluid movement without rotation. Sad music was embodied by simple movements and tender music by fluid movements of low acceleration and a forward directed torso. It is thus argued that the body reflects emotional qualities of music, which can be seen as support for the notion of embodied music cognition, especially for the concept of "Empathy". Additionally, the results show similarities to emotion-specific movements of professional musicians and dancers, and to emotion-specific nonverbal behavior in general.

Previous research in the field tended to use professional actors, musicians, or dancers performing certain emotional states, likely to result in exaggerated, artificial, and/or very stereotypic movements. This study, on the other hand, focused on laypersons and investigated how emotional content of music affects movement when participants are not actively and consciously paying attention to the emotional content of the music. As a consequence, the resulting movements might lack stereotypicality and thus be more diverse and difficult to analyze than movements performed by professional dancers. However, we believe that our approach is ecologically more valid than the acted emotion approaches for investigating influences of emotional content of music in everyday behavior.

Future work could include the music to be rated on different emotion scales, such as those emotions used in music-specific models. This might extend the relationships with the movement characteristics and cluster them in a more distinct way. The movement data could additionally be analyzed with different movement features, as obviously our set of features did not capture all possible movement characteristics. For example, features that are related to the shape of arm movements could be a valuable extension. Finally, an emotion recognition experiment could be conducted in which participants are asked to rate the movements presented as point-light videos regarding the emotion conveyed or reflected. This would give insight into the perception of emotions in music-induced, quasi-spontaneous movements.

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