Music and Motion—How Music-Related Ancillary Body Movements Contribute to the Experience of Music

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Expressive performer movements in musical performances represent implied levels of communication and can contain certain characteristics and meanings of embodied human expressivity. This study investigated the contribution of ancillary body movements on the perception of musical performances. Using kinematic displays of four clarinetists, perceptual experiments were conducted in which participants were asked to rate specific music-related dimensions of the performance and the performer. Additionally, motions of particular body parts, such as movements of the arms and torso, as well as motion amplitudes of the whole body were manipulated in the kinematic display. It was found that manipulations of arm and torso movements have fewer effects on the observers' ratings of the musicians than manipulations concerning the movement of the whole body. The results suggest that the multimodal experience of musicians is less dependent on the players' particular body motion behaviors than it is on the players' overall relative motion characteristics.

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Expressive body movements are the focus of a large body of research. In conversations, so called "nonverbal gestures" are thought to form a distinct language that is communicated through body movement (Bull, 2001). In the context of music, classical musical instruments are played through body motions, which can be used to convey important meanings. Generally, two major types of performer movements can be distinguished: one, instrumental actions and two, ancillary or expressive movements (Cadoz & Wanderley, 2000; Wanderley, Vines, Middleton, McKay, & Hatch, 2005). The former are responsible for sound production, while the latter have an intrinsic relationship with the music, representing a link between the music and the expressive intention of the musician (Davidson, 1993). Wanderley (2002) showed that ancillary movements occur frequently in musical performances, even though these movements are not essential for musical performance. Furthermore, these motions varied considerably across performers and remain more consistent within performers. These movements are not randomly performed, but rather are used to communicate a holistic, musical, expressive unit (Wanderley & Vines, 2006).

Many studies have shown that musicians' movements can visually convey structural and expressive information (for an overview see Juslin, 2003; Vines, Krumhansl, Wanderley, & Levitin, 2006) and can also influence musical intelligibility (Thompson, Graham, & Russo, 2005) and perceived tone duration (Schutz & Lipscomb, 2007). Through detailed analysis of music-related performer motions, studies have found that performer motions can contain body sway, arm and/or head movements as well as subtle facial motions, such as eyebrow movements or facial expressions (see Juslin, 2003). In the field of sound synthesis, applied research on creating human-computer interfaces for synthetic music devices developed mapping algorithms of body motions into auditory information (Camurri, Mazzarino, & Volpe, 2004; Wanderley & Battier, 2000).

It has been shown that people can easily discern expressive intention through performer body movements. Wallbott (1998) claimed that underlying emotions are detectable through the recognition of emotionally-associated body movements. In particular, Dahl and Friberg (2007) investigated how certain body parts convey specific emotions. Participants were asked to recognize the emotional intentions of sadness, happiness, fear, and anger in sequences showing a marimba, a saxophone, and a bassoon player. For the first instrument, Dahl and Friberg displayed only certain body parts of

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the player, such as only the head, only the torso, without hands, or in full sequence. They found that the emotional intentions, except for fear, were clearly detectable by the participants. Surprisingly, only small differences in the participants' responses between the viewing conditions of the marimba player were found, indicating that expressive intentions are possibly conveyed by all of the body parts involved in the marimba performance.

Even when displaying simplified body representation through the use of so-called "point-light displays," in which body motions are presented through moving light points fixed to certain parts of the body (see Johansson, 1973), observers still can identify emotions remarkably well, for instance in gait (Montepare, Goldstein, & Clausen, 1987) and knocking movements (Pollick, 2004). Previous studies have shown that in a number of areas in human motion recognition, kinematic displays produce similar results to natural videos (Scully, 1986). In music and dance performances, body motion can be used to discriminate expressive or emotional intentions (Brownlow, Dixon, Egbert, & Radcliffe, 1997; Dittrich, Troscianko, Lea, & Morgan, 1996; Sörgjerd, 2000; Walk & Homan, 1984).

Using the aforementioned technique of point-light displays, Davidson (1993) recorded violin players performing three different levels of musical expressions: deadpan, standard, and exaggerated. In a perceptual experiment in which participants had to recognize these expressive intentions, Davidson found that the three different expressive levels were clearly perceivable from viewing the reduced, point-light representation of the body. In addition, by presenting the participants with only visual or only auditory information, Davidson found that the participants were best able to distinguish the three levels of expressive intentions when no auditory information was provided. Similar results were also found by Vines et al. (2006), although in this case the stimuli consisted of videos of performances. Davidson (1993, 1994) concluded that the body movements of musicians are more revealing indicators of expressive intention than the sound. This shows that visual cues constitute an important channel of information in the perceptual experience of music.

Although peoples' perception of expressive states conveyed through reduced body representations is remarkable, it remains unknown which aspects of the motion kinematics convey expressive information or how movements of specific body parts may influence perception. As has been demonstrated, body motions of musicians can have an influence on music perception. Therefore instrumentalists' movements, especially ancillary movements, are an interesting source for investigating the contribution of different visual aspects of body motions on musical perceptual experiences. This study used clarinetists and, by manipulating certain motion components of the players, examined whether those visual changes of their spatial and kinetic presentation caused corresponding changes in observers' musical judgments. The stimuli used consisted of standard performances of four clarinet players that were presented to participants in the form of kinematic displays.

To measure the observers' experience in the perceptual experiments, participants were asked to rate specific musical dimensions. The study focused on ratings of musical *tension*, *intensity*, *fluency*, and the *professionalism* of the performer. These dimensions combined and covered judgments of the musicians, the performance, and the music itself. It was decided not to ask for emotional ratings—such as those proposed by Russell (1980) to define two-dimensional spaces of pleasure-displeasure (valence) and degree of arousal (activity)–due to the fact that no emotional instruction was given to the players and due to the fact that the study was interested in the correlations of visual cues to the musical judgment in "standard" performances only.

The reasoning for choosing the four musical dimensions of tension, intensity, fluency and professionalism was that, according to Todd (1999) and Clarke (2005), sound evokes certain kinds of motion expectations. As sound in the everyday world is able to specify movement characteristics of its source, it is possible that music can generate a mental representation of fictional motions of a virtual performer (Clarke, 2005). Inappropriate or manipulated visual presentations should therefore create a perceptual conflict in the observer, resulting in modified judgments regarding the music and the performer. Therefore, the professionalism and the fluency of the *performers* should be influenced by changes in body movements. In addition, the tension and the intensity of the perceived *music* should be influenced by unfitting performances that create perceptual conflict in the observer. In order to provide a reference parameter across the visual performer manipulations, the original audio of the performances remained constant in every condition.

Following general description of the recording of the stimuli and the method and design used, we briefly review the major findings of a validation experiment in which the information conveyed by kinematic displays was compared to that conveyed by the original video sequences (Nusseck, Wanderley, & Schoonderwaldt, 2007). In order to establish an objective impression of how the players actually performed and moved, their physical motion behavior was further analyzed by looking at kinematic changes in the displays, which were then correlated with the perceptual results of the experiments. In the following described experiments, the movement behaviors of the players were systematically manipulated: either the motion of certain body parts such as the players' arms or the torso was altered (Experiment 1) or the motion amplitude of the player's whole body was altered (Experiment 2). Findings from these studies can be used to understand the importance of performer movements during music performances and may provide insight into the origin and utility of music-related ancillary movements.

General Method

Recordings

Four clarinet players (3 male, 1 female) were asked to perform an excerpt from the first movement of Brahms' First Clarinet Sonata 1, Op. 120. They played the piece without piano accompaniment and without the use of a metronome, therefore starting directly at the fifth bar. All players stood in front of a music stand and were asked to play in a standard manner (i.e., such as during a concert performance). They were explicitly asked to neither exaggerate nor to include emotional expressions that were not originally intended by the composer. They had to choose the performance style which they thought would best present the piece and reflect their own experience.

During their performances, the players were recorded with a digital video camera (Canon GL2 3CCD MiniDV) and a VICON motion-capture system at the IDMIL, McGill University. Passive markers were attached to specific body parts and joints on each performer, following the marker placement used in the VICON Plug-In Gait model, allowing the system to track their 3-dimensional position over time. The data obtained were used to reconstruct the performances and to create the kinematic displays.

Sound was recorded by a microphone placed in front of the players at a distance of approximately 1.5 meters away from the instrument. The sound level was adjusted to avoid distortion. For the stimulus sequences, the maximum volume of each player was adjusted to one another.

The goal of this study was to investigate the direct influence of music-related ancillary body movements on observers' perceptions regarding the performance and the performer. Clarinetists were chosen because none of their visible body movements – except for small finger movements that are barely visible – are directly related to sound production. Due to the fact that the clarinet is a wind instrument, breathing constitutes an additional action-generating action. This cue was eliminated by using only the first phrase of the piece (bars 5-12, see Figure 1), which is performed without any in-between breathing. The sequences started when the performers had already breathed in and ended before they inhaled again. Although short, this phrase is the most consistent phrase for all players (we describe this in further detail in the section about the musical structure).

Kinematic Displays of Musicians

The players' kinematic displays were created directly from the motion-capture data. The points used in the display figure represent the head, neck, arms (shoulder, elbow, and wrist), hip, and legs (hip, knees, heels, and toes). To obtain a rough outline of a human shape, single points were connected with a line to produce a stick figure of each player (see Figure 2). Such body representation offers two advantages: first, the motions can be analyzed directly by measuring the 3D coordinates of the points and second, it is easy to manipulate and alter the figures by systematically adjusting the coordinates of the data set.

Measuring Musical Expression

Listening to musicians play music generates an intuitive musical impression regarding the performer and the performance. As mentioned above, to measure how observers may have experienced the music and perceived the musicians, the participants were asked to provide aesthetic responses by rating the following four specific music-related dimensions.

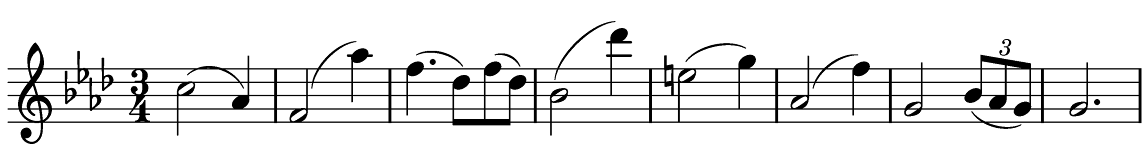

FIGURE 1. Bars 5-12 of Brahms Clarinet Sonata, Op. 120, No. 1

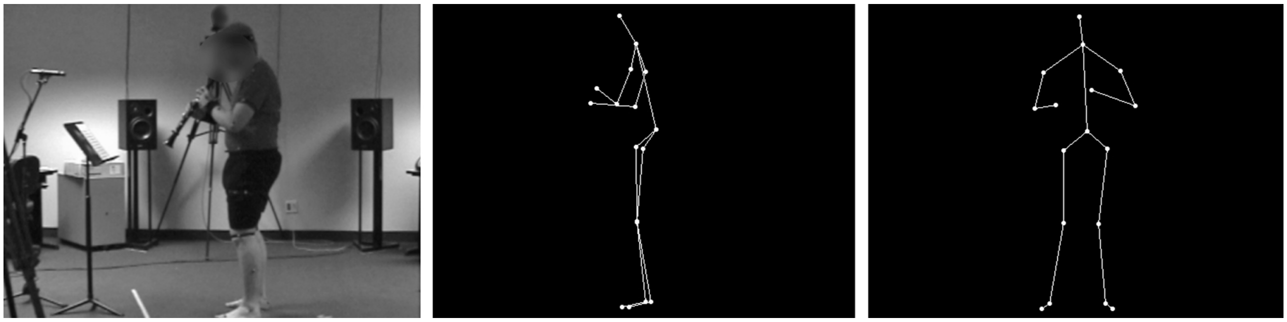

FIGURE 2. Screenshots of one player. (left: video; middle: stick figure, side view; right: stick figure, front view). Note that the performer's face in the video picture is blurred to hide performers' identity, though there was no blurring during stimulus presentation in the experiment. (Source: Nusseck et al., 2007)

TENSION

Musical tension is a complex phenomenon that is difficult to formalize and quantify. Often tension is described as changes of excitement, resolution, fulfillment, and expectations (Farbood, 2006). Krumhansl (1997) found correlations between tension ratings and judgments of emotions in musical pieces. Tension therefore was considered a general expressive dimension. In addition, the experience of tension often is related to different structural features of music, such as pitch range, loudness, dynamics, note density, harmonic relations, and implicit expectations of the musical progress (Krumhansl, 2002; Vines et al., 2006). Therefore, tension generally is considered a global indicator for music perception with a one-dimensional output obtained by summing up the aforementioned multidimensional inputs. Fredrickson (2000) showed that judgments of tension were easily comprehensible for observers and similar for musicians and nonmusicians. Vines et al. (2006) found that different manners of performer movements elicit different tension ratings. Interestingly, they found that if the visual presentation contained high tension, the audiovisual experience of the performance was judged as having higher tension than when presented the audio channel alone. In contrast, if the visual portion was perceived to have low tension, the multimodal judgment was lower in tension. The general dimension of tension therefore depends consistently on the visual display.

In this study, tension was described to the participants as being related to relaxation and stress, as well as to the sincerity and engagement of the performer. High tension refers to a feeling of excitement and involvement, whereas low tension refers to uncertainty and unsteadiness. This study sought to determine, among many other interests, if the experience of musical tension depends on certain patterns of body movements of the performer.

INTENSITY

Intensity relates to the expressiveness of the performance. It is well documented that listeners can perceive intended expressive nuances from musicians' movements. For instance, Davidson (1993, 1994) found that observers could easily tell three expressive intensities apart when performers were asked to play in different expressive manners.

Many studies, however, use the term expressiveness as a nonspecified quality that is simply present or absent from the musical performance (Juslin, 2003). Expressiveness therefore often is confused or combined with emotional expression. In this study, participants were told to rate intensity by focusing on the expressive intensity in the performance. High intensity rankings meant that the player exaggerated the performance in relation to a possible neutral playing of the piece, while lower intensity rankings reflected more inexpressive player performances. Since intensity also often is related to the amount of player body motion (Paterson, Pollick, & Sanford, 2001), intensity judgments should vary when certain body motion characteristics are manipulated.

FLUENCY

For this dimension, participants were asked to rate the smoothness of the performance. Players generally tend to use the smoothness of body motions to control the flow of rhythmic phrases. Furthermore, different fluency levels can be used to communicate different expressivenesses, i.e., a smoother performance often is interpreted with a sad intention whereas jerkiness is associated with anger and fear (Dahl & Friberg, 2004, Sloboda, 2000). The fluency of performances, however, is a function of the type of piece, such as a piece containing parts with staccato or nonrhythmical structures. This study used a musical piece without composition-related breaks or rhythmical interruptions to investigate whether certain manipulations of visual body motions could influence the observer's experience of fluency.

The participants were told that if the player performed with fluid movements over the whole phrase, the performance should be rated with high fluency, while low fluency ratings would be related to a less smooth and somehow uncertain performance. The participants were explicitly asked not to detect breaks or jerkiness, but to rate an overall balance of how fluent the performance was. It was expected that variations in this dimension would be found when the visual motion flow of the players had been manipulated.

PROFESSIONALISM

Chaffin and Logan (2003) showed that during the learning of a new musical piece, musicians' motion behavior moved through stages from basic and ordinary to expressive, with the latter corresponding to a more holistic sense of the musical piece. Wanderley et al. (2005) found that clarinet players tended to decrease their performance movements in active or technically demanding passages in a piece, while easier passages were accompanied by more intensive movements. At times, players appeared to shift the onsets of their movements according to their musical experience, by either slightly anticipating or following the music. This behavior also affects the perception of musical phrasing (Vines et al., 2006).

In this study, participants were asked to rate the musician's skill at playing the instrument. The extremes referred to a player who appeared to be a beginner on the instrument versus a player who appeared to be a professional on the instrument. With this parameter, it was predicted that body motions would provide information regarding the performers' level of skill and, therefore, manipulating body motions would result in a different professionalism rating for the performer.

Design and Apparatus

The perceptual experiments presented in this study were conducted with the Psychophysics Toolbox 3 (Brainard, 1997; Pelli, 1997) on an Apple G4 notebook. Kinematic displays were visually presented on the screen of 560×420 pixel size with 25 fps and the sound of each player was provided through headphones. All sequences were stored as QuickTime movies created with the Make-QT-Toolbox in Matlab.[1]

Participants had to press the space bar to start a video sequence. The movies were presented in randomized order and were presented only once. After the sequence ended, the participants were asked to rate the musical tension, intensity, fluency, and professionalism on a 7-point Likert scale (Likert, 1932). After the ratings were made, the participants were asked to start the next trial by pressing the space bar.

A sequence of practice trials involving a clarinetist who was not part of the main study was presented to each observer to ensure participant understanding of the procedure and the rating scales. They were told to provide their ratings intuitively but with the highest confidence possible. The order of the presented musical dimensions was the same on every trial.

Validation Experiment

Generally, live performances or even video recordings of musicians contain a large amount of contextual and situational information, such as the player's clothes, hairstyle, body shape, or the environmental background. It is difficult then to distinguish what specific information influences the perceiver's judgment regarding the musical performance. As previously mentioned, the use of kinematic displays—where contextual and situational information about the performer and the environment is removed—allows for the recognition of various aspects of movement behavior (see Pollick, 2004). This experiment investigated whether this also is valid for musical movements. This validation experiment was conducted in order to compare participants' judgments of video recordings with that of kinematic displays of the same clarinetist performance (Nusseck et al., 2007).

For this validation experiment, the video recordings obtained during the motion capture sessions were used and two kinematic displays (side view and front view, see Figure 2) were created from the recorded data. Using the above described method and design, participants were asked to provide judgments using the previously mentioned four musical dimensions—tension, intensity, fluency, and professionalism.

The results obtained show that both presentation styles produced similar judgments (see Figure 3), indicating that the absence of high-level information sources did not influence the participants' musical experience. Furthermore, presenting a frontal or a side view of the musician also did not change the aesthetic and musical view of the performance. This result differs from the results obtained on sex classification of point-light walkers, where results are dependent on the chosen viewpoint (Halevina & Troje, 2007) and suggests that both frontal and side motions contain sufficient music and performance related indicators.

To test if the different musical dimensions were judged independently of one another, the cross-correlation of the dimensions (see Nusseck et al., 2007) was analyzed. Overall, the coefficient of determination r^2 was low for all combinations, indicating that the four judged musical dimensions were treated individually and independently

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[1]The kinematic displays used are available at: http://www.music.mcgill.ca/~mwanderley/Nusseck_Wanderley/

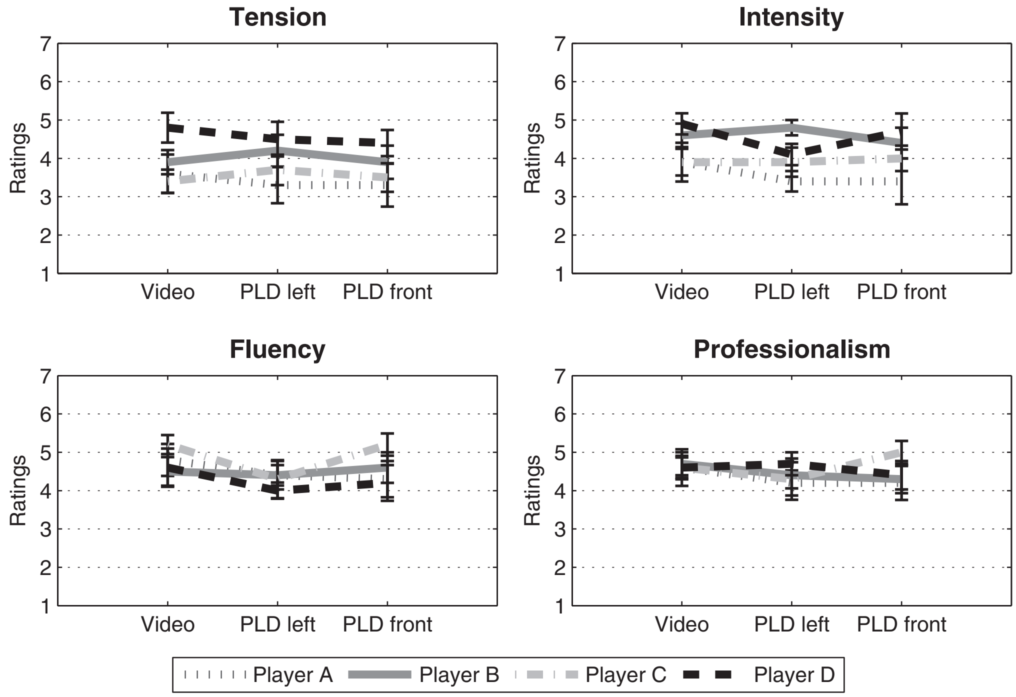

FIGURE 3. Mean ratings of each player for the different presentation styles (PLD: kinematic display). Error bars show the standard error of the mean.

of one another. For fluency and professionalism, however, the coefficient was about .50, $r^2(119) = .49$; $p < .09$, suggesting that fluent and smooth performances were sometimes perceived with a higher level of instrumental expertise.

In addition to the above mentioned results, there were some additional interesting findings worth noting. A detailed look at the individual player ratings (Figure 3) shows that for tension and intensity, Player D received the highest ratings while Player A received the lowest. It seems that the kinematic displays from these two players contained very different characteristics. Since both players showed no significant effect for the presentation style, these differences also were transmitted through the kinematic displays, suggesting that the difference could be located in their distinct body motions. This difference, however, seems to have less effect on fluency and professionalism. Whereas some characteristics of the displays seem to influence the perception of tension and intensity, the impression of the smoothness and the skill of the players was not influenced, neither for the video nor for the kinematic display.

Taking only Players B, C, and D into account, the ratings show a different order of their fluency ranking than their tension and intensity rankings. In fluency, Player D was rated slightly lower than Players C and B. From these results, it seems that a high degree of tension and intensity was accompanied by a lower degree of fluency. Naively speaking, this is quite an obvious finding, since one could expect that a performance where movements present more jerkiness would be rated with higher tension. Nevertheless, this was found in both the video and the kinematic display, indicating that this seems to be due to specific body motion behaviors.

In summary, this experiment confirmed that kinematic and full-video displays convey similar amounts of communicative information for observers. It also verified the chosen methodology of using the four musical dimensions described above for measuring listeners' perception. These findings, however, raised the question of how the players actually moved when they performed. In order to address that question, the body motion behaviors of each individual player were analyzed.

Physical Analysis

Several previous studies have identified correspondences between particular body parts, such as hands and the head, and the recognition of the performers' expressiveness (Dahl & Friberg, 2007; Davidson, 1994; Juslin, 2003). Nevertheless, it remains unclear which body motions directly account for expressive variations in the perception of musical performances (Sloboda, 2000).

Generally, two kinds of sources have to be distinguished: the music itself as an expressive container, and the expressive motions through the human body. For instance, previous studies found that different tempos often were associated with different expressions. Slow pieces often were related to sadness, while fast performances were related to happiness, jealousy, and anger (Juslin, 2003). The association of slow tempo and sadness, however, could have its basis partly in the evocation of slow bodily movements that a sad person would make. Analyzing the motion behavior is therefore an interesting source for detecting expressive intentions.

The following physical analysis provides a general overview of how the players moved while performing. It mainly focuses on motion velocities and patterns, as well as on the tempo of the piece. A more detailed analysis of individual performance behaviors, such as circular movements of the clarinet bell or shifts of performers' center of mass, is beyond the scope of this paper and is treated elsewhere (Bernardin, Wanderley, Bardy, & Stoffregen, 2009; Wanderley, 2002). The parameters that were expected to correlate with the perceptual judgments in the experiments were therefore the main focus.

Movement Analysis

Kinematic displays have the advantage that the analysis of the actual movements of the players can be done by looking at the position changes of the individual display points (markers) at each time frame. For this study, the motions of each performer were analyzed by calculating the 3D displacements between two time frames of every visible data point. The resulting value therefore is related to the velocity of these markers. The higher the value, the larger was the motion of the markers at that time. In this paper we will therefore refer to this value as "motion velocity." It is defined as

$$v_t = \frac{1}{dt}\sqrt{(x_{t+1}-x_t)^2+(y_{t+1}-y_t)^2+(z_{t+1}-z_t)^2} \qquad (1)$$

where x, y, and z are the coordinates of the *nth* position marker at time t. The time increment dt is given by the recording frequency of the motion capture (100 Hz). It is constant for all time sequences and therefore does not influence the calculation.

By drawing these values over time, motion velocity graphs were created, displaying faster and slower motions of selected display points (Figure 4). Additionally, collecting motion values of different individual motion points at each time frame yields overall velocity patterns of more general body areas. For instance, the movements present in the kinematic displays of the clarinet players can be divided into two major regions of body motion: (a) the arms and (b) the torso. In arm movements, motions of the hands, elbows, and shoulders, as well as the movement of the instrument, are included. The movements of the torso describe the whole body displacement, including leg and hip motions, body sway, and trunk rotations. Therefore, these two major regions of body movement were used to analyze the different performance styles in more detail (Figure 4).

In order to analyze the different performances in more detail, the marker coordinates of the stick figures were used. The arm motion was calculated using the marker in the head, the neck, and the three markers on each arm. Unfortunately, arm movements are also influenced by full body movements. In order to eliminate this influence, the neck coordinates were subtracted from all arm positions. This allowed the neck to be fixed to a virtual origin, so that only arm motion remained. This same procedure was used for the head. The torso motion was taken from the neck, the hip, and markers on both legs.

MOTION VELOCITY GRAPHS

The motion velocity graphs in Figure 4 show that the use and the amount of body movements differ a great deal across the four performers. Player A barely moved at all, having only a small amount of motion in the arms and almost no motion in the torso, while Player B performed with more activity in both torso and arms. However, the torso movements of this player were rather constant (around zero) and contained some large motion peaks. Player C performed with slowly varying torso motions yielding a few large peaks, but with pronounced arm movements. In contrast, Player D performed with more active body sway, but less arm motion.

Interestingly, torso motion appears quite individualistic. Arm motions, however, show some similarity across the four players. This has also been shown by Wanderley (2002), where overall movements of clarinet players were found to be specific to individuals, while movements related to breathing, rhythm, and musical structure were similar across players (but with varying amplitudes and frequencies). Furthermore, Varfaille, Quek, and Wanderley (2006) showed that the clarinet bell generally follows a circular motion path, which confirms the similar arm motions.

The four players also show specific consistencies in peak patterns at related time points. The second lowest

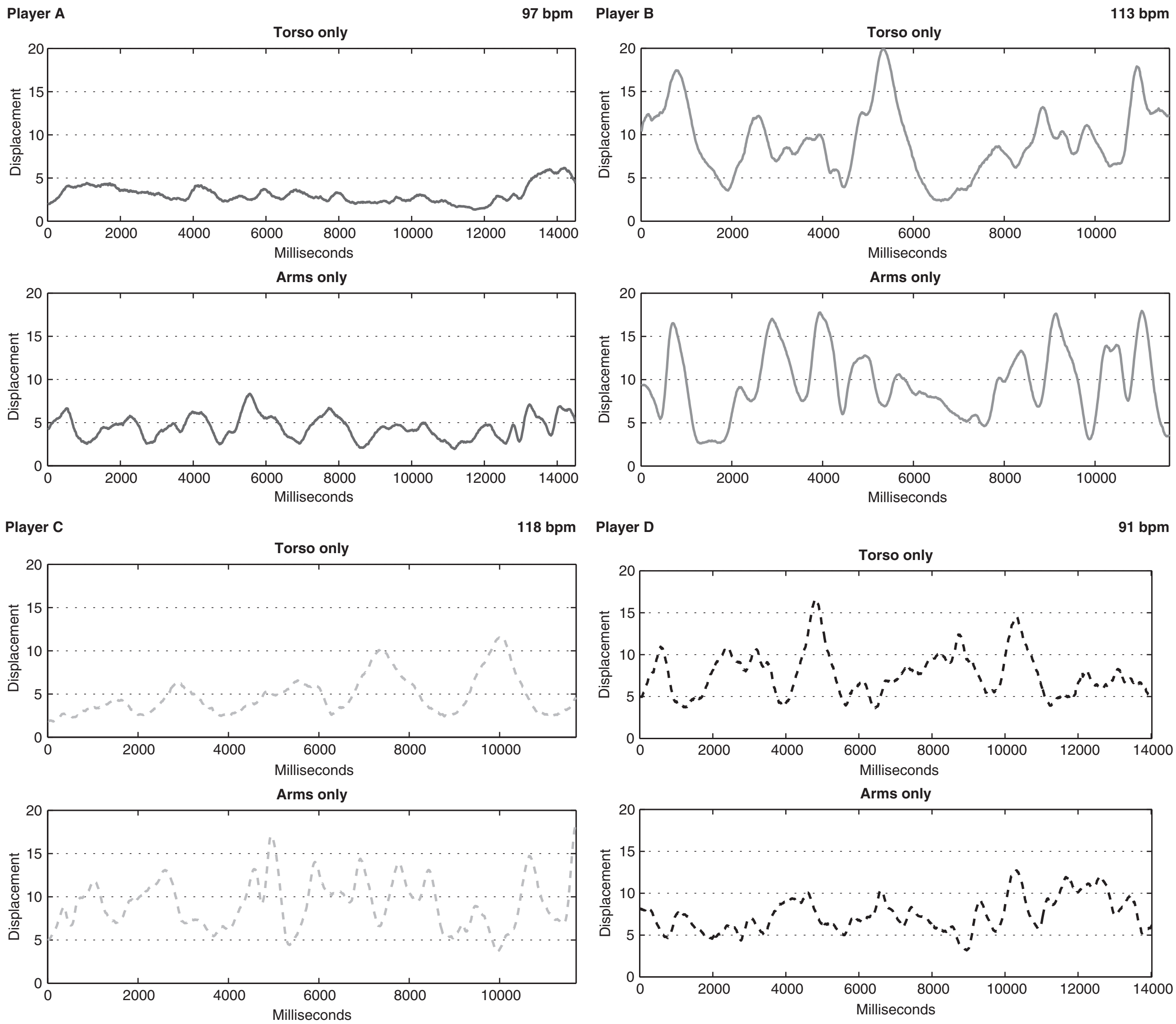

FIGURE 4. Motion velocity graphs for each player of the performed phrase separated for torso and arms only. The y-axis shows the sum of the 3D displacements between two subsequent frames. In the top right corner is the average tempo of the player in beats per minutes (bpm).

peak in the arm motion, for instance, of Player A at about 6000 ms is quite similar to Player B at about 4000 ms, Player C at about 3000 ms, and Player D at about 5000 ms. Note that the different timings result from the different tempos of the performance. Additionally, all players show a rather similar arm motion behavior towards the end of the phrase.

The notation in Figure 1 shows that the phrase performed included some large note jumps and two small regions of more sophisticated tone and rhythm variations, with the first region being the three-eighth pattern (bar 7) and the second region being the triplet at the end of the phrase (bar 11). Both regions appear to correspond with arm motion behaviors of the players at analog times. The motion velocity graphs (Figure 4) show that shortly before the first region, players roughly made a peak motion behavior in the arms, which was then followed by less active movements during the part of musical variation. This is in accordance with findings by Wanderley et al. (2005) that performers reduce motion activity in more technically demanding parts. All players seem to prepare themselves for these musical parts. The triplet at the end, however, seems to be accompanied by phrase ending motion behavior in the arms of all players. These findings indicate that the four performers seemed to use the arms in a roughly similar way to perform the piece. The fact

TABLE 1. Motion Index Averages of All Arm Parts and the Total Index for All Players.

	Head	Shoulder (R)	Shoulder (L)	Elbow (R)	Elbow (L)	Hand (R)	Hand (L)	**Total arms**
Player A	0.43	0.38	0.40	0.75	0.90	0.87	0.73	**4.45**
Player B	0.99	0.57	0.55	1.99	1.75	2.07	1.65	**9.58**
Player C	0.75	0.67	0.65	1.71	1.68	2.07	1.65	**9.19**
Player D	0.59	0.57	0.58	1.44	1.38	1.53	1.37	**7.45**

that players received a nearly equal rating for the professionalism dimension in the validation experiment might be a result of these similar arm motions.

TEMPO

Although the players were asked to play naturally and in a way that was appropriate for the piece, the average tempo of the performances varied considerably (values shown in Figure 4, top right corner). Overall, tempo did not correlate with the amount of torso motion. Player D performed the phrase rather slow but also, as the motion graph shows, with extensive torso movements. In contrast, Player A used a similar tempo but almost lacked torso movements entirely. For the two faster players, Player B performed with more movement of the body, while the fastest player, Player C, showed less active body motion.

Arm motions, however, showed a better correlation with tempo. The slower tempos were performed with a lower total amount of arm motion (Players A and D), whereas the faster tempos were performed with more arm motion (Players B and C). Nevertheless, arm motion patterns with more peaks did not seem to correlate with the tempo—Player D was the slowest performer but had a rather sophisticated arm motion pattern. In summary, the different tempos of the performances were not directly reflected in the motion patterns of the performers.

Furthermore, the perceptual responses to the musical dimensions in the validation experiment also did not correlate with the tempo of the performances. Player D performed with the slowest tempo and had the highest ratings for tension and intensity, whereas Player A performed in a similar tempo and was ranked the lowest.

MOTION INDEX

The velocity graphs (Figure 4) show the detailed motion behavior of the players. To summarize the general tendency of how much the players moved individual body parts, we calculated the mean velocity for each region for the whole sequence. This provided a single value representing the totality of position changes for each player. This value will be referred to as "motion index."

Table 1 presents the motion indices of the points used for the arm motions for all players, and their total motion index, which is the sum of all individual parts. Similarly, Table 2 provides the motion index values for the torso motion and the total indices for each performer.

Table 1 shows that the elbows and the hands are the primary active parts in the arm region. While playing the clarinet, elbows often move up and down, whereas the hands, although tied to the instrument, are responsible for the movements of the clarinet itself. As could be expected, the motion index values of the right hand are always higher than those of the left hand, since the left hand is closest to the clarinet reed. Therefore, for all players, the right hand moved more according to the movement of the whole instrument (note that the left thumb is hooked at the back of the clarinet to support the instrument).

In contrast, the torso motions seem to be more distributed across the trunk and the upper leg region. The neck and the hip region have the largest motion index values. The motion indices for the hips, knees, heels, and toes decrease the lower the body part is, due to the

TABLE 2. Motion Index Averages of All Torso Parts and the Total Index for All Players.

	Neck	Hip	Hipbone (R)	Hipbone (L)	Knee (R)	Knee (L)	Heel (R)	Heel (L)	Toes (R)	Toes (L)	**Total torso**
Player A	0.52	0.38	0.38	0.39	0.48	0.34	0.18	0.18	0.12	0.14	**3.10**
Player B	1.49	1.21	1.22	1.16	1.17	1.11	0.70	0.37	0.56	0.25	**9.23**
Player C	0.85	0.68	0.72	0.71	0.49	0.57	0.21	0.32	0.11	0.13	**4.79**
Player D	1.35	1.03	1.09	1.06	0.91	1.17	0.35	0.42	0.18	0.15	**7.70**

fact that the players were standing generally motionless at their position. Only Player B lifted the heels a little bit and stepped up on the toes for a short while.

Perceptual Correlations

The results of the validation experiments showed that, for tension and intensity, some players were rated significantly different. The question here is whether this difference results from physical motion behaviors. Taking only these two musical dimensions into account, Player D was ranked the highest, followed by Players B and C, and finally by Player A. Where does this order come from?

Maintaining the total motion indices of both arms and torso, Player B performed always with the largest amount of movement, followed by Players C and D in different orders. Player A had the lowest absolute value of all players. These values indicate that the total amount of movement does not seem to be responsible for the order of the players' ratings. Even for the individual body parts, Player D performed mainly with lower motion index than Player B.

As previously shown, the performed tempos of the piece were not found to be in correspondence with the amount of movement. Furthermore, the different tempos also do not correlate with the tension and intensity ranking of the four players. Tension and intensity seem to be unrelated to the total amount of movement and to the tempo.

The analysis showed that the performances of the players were rather individual in the amount of motion but quite consistent in the local behavior of single body motions. Specific findings of the perceptual experiment, however, such as a certain player ranking, are difficult to correlate with the physical parameters. This paper contributes to the understanding of the relationship between music production and observer perception maintaining the above mentioned parameters. The following experiments will provide general perceptual judgments of the musicians, with which the motion values of the players will be correlated.

Experiment 1

The physical analysis of the clarinetists' motions showed that performances were quite similar in arm behavior, but differed with respect to torso movements. How do these body parts interplay to create a perceptual image of the player? Do they have an individual role for the multimodal impression of the musician? In the first perceptual experiment, the contribution of the individual player body motions to the observers' musical experience was investigated through the systematic manipulation of certain motion behaviors of the players.

Studying which areas of the musicians' body convey information about expressive intentions, Davidson (1994) used point-light displays of one pianist and showed participants specific body parts. Davidson found that when the head of the player was present in the visual displays, it was essential for the accurate perception of the intended expressions. Other parts, however, such as elbows or shoulders, did not communicate the different intentions.

In order to investigate the communicative value of motion behaviors, the motions of the four performers were modified. By using the same stick figures as in the validation experiment, the movement of certain display points was "frozen" while the movements of the remaining points were left unmodified. Specifically, two types of display were presented: the first display, which consisted of arm movements only (the torso movements were frozen) and the second, which consisted solely of torso movements (the arm movements were frozen). The full players' shape was visible throughout the entire sequence. By using this freezing technique, the communicative necessity of different body motions for the perception of musical performances could be investigated.

By preventing certain body parts from moving, the existing movement ratios between individual limbs were changed, resulting in the creation of new performances. In order to keep these ratios intact while manipulating performer movements, a third type of display was created in which the visual information was played backwards while the sound remained unchanged. This condition manipulated the temporal stimulus configurations while keeping the amount of motion and specific motion patterns, but without synchronization to the original sound. This permitted the investigation of whether performed motion patterns have to be in correspondence with the audio. Verfaillie (2000) showed that observers of human gait motions could easily detect when the movement was played in reverse order. In fact, complex movement patterns are somehow sensitive to temporal order. Observers who saw a biological movement sequence in scrambled temporal order did not perceive the biological aspect. Some natural actions exist only in one temporal order and become meaningless when played in reverse, such as an explosion or breaking a glass. By playing the performer movements in reverse order, we also could investigate whether perception of complex musical gestures also was sensitive to order presentation.

We expected to find response differences of the observers mostly regarding performer fluency and professionalism when body movements were manipulated and frozen. Observer judgments regarding tension, intensity, and professionalism were expected to be affected when the visual motions were presented backwards. The role that different arm and torso behaviors of the musicians play in perception, when alternating the motion of different body parts, also was another investigative interest.

Method

The experimental task, design, and equipment were the same as described in the general method section.

STIMULI

Four conditions were created with the front-view kinematic displays of the four players: (a) original motion, (b) motion only in the arms and in the head, (c) only the torso moving, and (d) visual presentation played backwards. The audio was kept unchanged across all four conditions.

To delete the torso motion of the kinematic display, we took a neutral body position of the player[2] and used their neck, hip, and leg points as body reference points. On top of that, we added arm and head points from the original performance. The coordinates of the arms were calculated as vectors according to the original neck coordinates and were set respectively onto the frozen neck of the neutral body. Since the head is fixed to the instrument in a clarinet performance, the original head motion also was calculated onto the frozen neck.

For the frozen arms condition, a neutral arm position was used and was set onto the original body information. The angles of the arms were then recalculated and connected to the neck. Due to the fact that the body and neck often move together, the arms no longer carried any intrinsic motions, but were moved due to the rigid body motion.

In the backward condition, the normal visual channel was played in reverse, while the audio channel remained unmodified. This condition produced a stimulus with reverse visual temporal order but with the same total movement energy as the normal visual condition.

QUESTIONNAIRE

At the end of the experiment, a questionnaire was given to the participants requesting information about their gender, age, musical background, and the confidence of their ratings. The question regarding musical background was split into two parts: which instrument they played and how many years of training they had. Furthermore, they were asked if they were amateur musicians, music students, or professional musicians. If they were music students, they also were asked in which academic year they were. For the confidence rating, a five-point scale was given with “1” for low confidence and “5” for high confidence. A field to fill in general comments also was provided.

PARTICIPANTS

Seventeen undergraduate students (nine female) from the McGill University Schulich School of Music participated in the experiment. Their mean age was 22.6 years old and their average experience with playing an instrument was 11.7 years. Five of the participants played the clarinet as a primary or secondary instrument. The confidence rating showed a mean of 3.7, indicating that the participants were rather sure of their responses.

Results and Discussion

A two-way analysis of variance (ANOVA) was run for each musical dimension for the within-participant factors Presentation (original, arms only, torso only, and backwards conditions) and Player. Figure 5 shows the mean ratings split into the different presentations for each player. Overall, except regarding the dimension of intensity, there was no significant effect for presentation, $F\,(3, 48) < 2.00$, $p > .10$; please note that where there are multiple cases of two or more F ratios and associated p values, the F ratios and p values are summarized by a single expression representing the boundary value of the cases. Intensity, however, showed a marginally significant effect of presentation, $F(3, 48) = 2.39$, $p < .08$. A significant effect of player was found for every musical dimension, $F(3, 48) > 5.01$, $p < .01$, with the exception of tension, $F(3, 48) = 1.21$, $p > .11$. Furthermore, only for intensity was there a significant interaction between presentation and player, $F(9, 144) = 2.49$, $p < .01$. Interestingly, there were no differences between the ratings of the participants who were clarinet players as compared to the non-clarinetist participants.

Using individual ANOVAs for each player separately for the factor Presentation, Player A and Player C showed no significant effects on any musical dimension, $F(3, 48) < 1.79$, $p > .15$. These two players were rated rather constantly across the different visual manipulations. Since Player A performed the piece with less movements, it is not surprising that manipulations in arm and

[2]The player stood in an upright position in front of the camera with the legs symmetric to each other and the torso built a vertical middle line of the stick figure. The arms were in a neutral position in relation to the instrument.

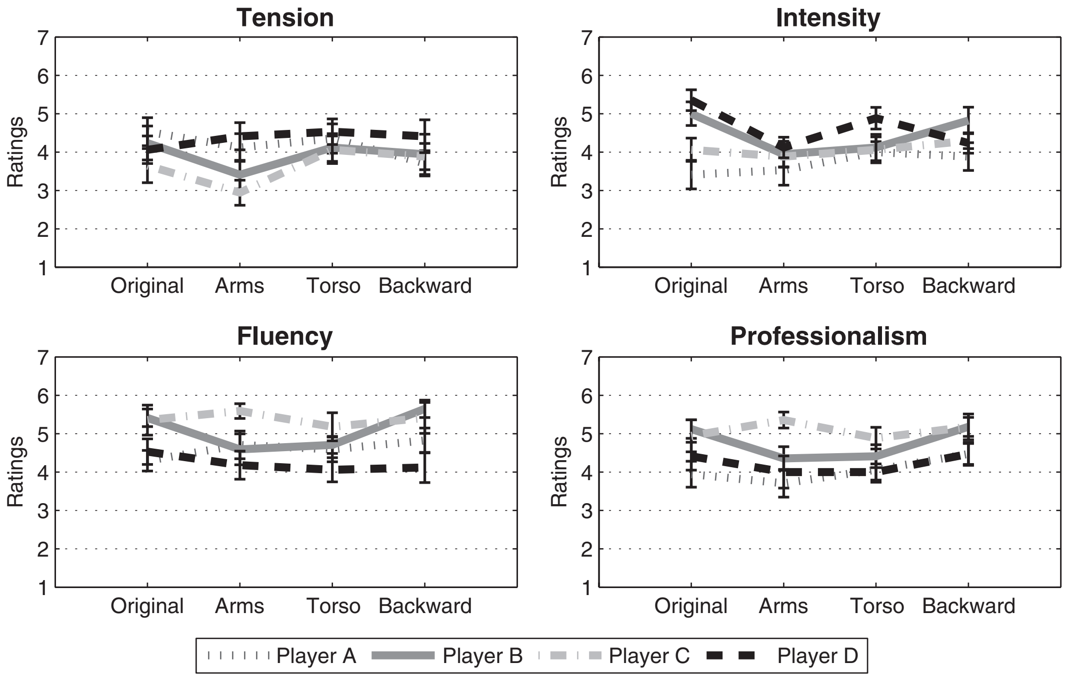

FIGURE 5. Mean ratings of each player for the original motions, arms only, torso only, and the visual backwards condition. Error bars show the standard error of the mean.

torso movements seem to have little or no influence on perception of the musician's performance.

Freezing the arm movements of Player C showed no significant difference on the participants' judgments, even though this player had a focus on arm motions. Despite this lack of significance, this player was rated slightly lower for the arms only condition for tension, whereas in fluency and professionalism this condition seemed to have a slight tendency to be rated higher. For these two parameters, in the arms only condition, this player, Player C, was ranked the highest. This confirms the findings of the validation experiment where lower tension was associated with higher fluency.

Player D also was rated similarly across the presentations, except regarding intensity. For this player, the larger motion index was in the torso (see Table 2). Only for intensity, however, there was a decrease of participants' judgments if the torso was frozen. This missing motion seems to have an effect on the perception of the players' intensity, and appears to have no significant effect on the other three musical dimensions

In contrast, Player B showed significant effects of presentation for all dimensions, $F(3, 48) > 4.40$, $p < .05$, except for tension. This player performed with the largest total motion index of all players in both arms and torso (see Tables 1 and 2). Freezing one motion source resulted in lower ratings for intensity, fluency, and professionalism. This differs from the other players, for which freezing body movements did not affect the observers' judgments. Surprisingly, the freezing conditions obtained very similar ratings across the musical dimensions. It seems that erasing motions in either the arms or the torso affected the musical experience in a global way. Furthermore, the ratings of this player did not show the specific judgment pattern between the dimensions: a lower judgment of tension and intensity was followed by a lower rating for fluency and professionalism. Since this player presented movements distributed across both body regions, it seems that in contrast to the other players, the manipulated visual stimuli were too implausible and Player B received lower judgments in all musical dimensions.

Except for Player D for intensity, there were no significant differences between the original sequence and the backward presentation, $F(3, 48) < 1.41$, $p > .20$. By questioning the participants after the experiment, they reported that they even did not notice that the visual stimulus was played backwards. It seems that the temporal order of the presentation is of no relevance to musical experience, at least for the short clips used here. In this context, the reversed presentation appears to provide sufficient expressive information to produce similar experiences to the normal condition.

It should be noted that the ranking order of the different players in this experiment with reduced movement is very similar to the rankings in the validation experiment: Player D again was rated as the highest in tension and intensity and lowest in fluency, whereas Player C obtained the opposite order: being lowest in tension and intensity, and highest in fluency. Surprisingly, the freezing conditions for both players followed this pattern, as did the backwards presentation. In contrast to the validation experiment, in this experiment there was a player effect for professionalism showing a similar player ranking to that for fluency. This suggests that the impression of musical experience is more related to higher fluency than to tension or intensity.

Conclusions

The objective of this experiment was to investigate whether movements of certain body parts contribute to the perceiver's musical experience of a performance. To do this, either arm or torso motions were frozen in the visual representation of the players. Furthermore, a condition was added where the visual portion of the sequence was played backwards to provide a stimulus with the same total amount of motion energy, but in reversed temporal order. The results showed that the players were rated consistently across the different manipulations. While Player A and Player C showed no influence of the different presentations at all, ratings for Player B changed drastically (except regarding tension). The different presentations of Player D only affected the judgment of intensity.

Overall, it is a quite surprising finding that the drastic manipulation consisting of canceling large body motions resulted in nearly no effects on the experience of the performance, despite the fact that the physical analysis showed that each player focused their performance on a different body part. Freezing these prominent parts and allowing only the other body part to move yielded no difference in the musical percept. As mentioned above, only Player B's ratings were significantly influenced by these manipulations. It seems that by distributing musical ancillary motions across both major body parts—the arms and the torso—the perceptual experience of this player receives the highest ratings when both are moving.

Finally, reversing the visual motions without any correspondence to the original musical motions yielded similar perceptual effects as the original sequence. Ancillary movements of clarinetists, which are driven by musical performance intentions that are determined by the piece being played, seem to be directionally independent body motions. Since the backward motions conveyed motion characteristics that are similar to the real motions, it is possible that a global attribute or a holistic view of the performance is more important than its perfect synchrony with the acoustic signal. This is particularly interesting for the ratings of professionalism, and seems to indicate that for the impression of the musical skill of a clarinetist playing this short phrase, the proper motion behavior of the body is not necessary but the global characteristic of these movements may be.

Experiment 2

Some studies suggest that the perceived expressivity in a musical performance is related to the amplitude and velocity of body movements (see Sloboda, 2000). For example, Paterson et al. (2001) found that, by observing wrist movements that occur during knocking on a wall or lifting an object, higher wrist velocity resulted in higher ratings of expressiveness and was associated with anger, excitement, happiness, and strength. Similar results also were found regarding biological motion, especially regarding the motion of walking (Wallbott, 1998). Davidson (1994) also found that movement quantity had a key role in recognizing expressive intentions. These findings indicate that there is a tendency to experience different perceptual impressions due to larger (or smaller) movements in the performance manner.

While the previous experiment focused on the contribution of certain body parts and found that the overall characteristic of the body motion does play a certain role in experiencing the music, this experiment investigated whether manipulations of the total kinematics of the performers' movements affect the musical percept. Therefore, the general motion indices of the players were increased and reduced by manipulating the movement amplitudes of the kinematic displays. It was expected that these manipulations would cause drastic variation in the observers' judgments of tension and intensity. The possible effects of such manipulations to perceived professionalism were also an investigative interest.

Method

The experimental task, design, and equipment were the same as described in the general method section. After this experiment, participants were asked to fill out the same questionnaire as in Experiment 1.

STIMULI

To alter the full body motions, a "neutral" position of each player was chosen as a baseline reference. The distance between all points of the original motions to their reference point of the neutral figure was calculated. A new figure was then created from these distances taking into account a factor of motion amplitude, i.e., the factor of 1.0 would directly copy the original motions onto the reference figure so that it acted like the original figure, whereas 0.0 would display only the static reference figure. Here, four different factors were used, yielding four different presentations for each player: 150%, 100%, 50%, and 20% of the original movements.

PARTICIPANTS

Fourteen undergraduate students (7 female) from the McGill University Schulich School of Music participated in the experiment. They did not participate in the previous experiments. Their mean age was 21.4 years old and their average experience with playing an instrument was 11.0 years. None of the participants played the clarinet. The confidence rating showed a mean of 3.6, indicating that they were also quite sure of their responses.

Results and Discussion

The results were subjected to a two-way ANOVA with the within-participant factors Presentation (150%, original, 50%, and 20% conditions) and Player. Figure 6 shows the mean ratings of each player for the different musical dimensions. Overall, there was a significant effect of presentation on every dimension, $F(3, 39) > 5.40$, $p < .01$. There was also a significant effect of player, $F(3, 39) > 5.31$, $p < .01$, except regarding tension, $F(3, 39) = 1.59$, *n.s.* For all dimensions, the player-manipulation interaction was not significant ($F(9,117) < 1.12$, *n.s.*, showing that the pattern of ratings were rather similar across all players.

Interestingly, a simple effect analysis of the conditions (*t*-test, two-tailed) individually on each musical dimension showed no effect between the 150% and the original presentation, $t(55) < 0.60$, *n.s.*, except marginally for intensity, $t(55) = 1.89$, $p < .06$, and no effects between the 50% and the 20% presentation, $t(55) < 1.70$, *n.s.*, except for tension, $t(55) = 2.41$, $p < .02$. For all dimensions there was a significant effect between the original and the 50% presentation, $t(55) > 2.19$, $p < .03$.

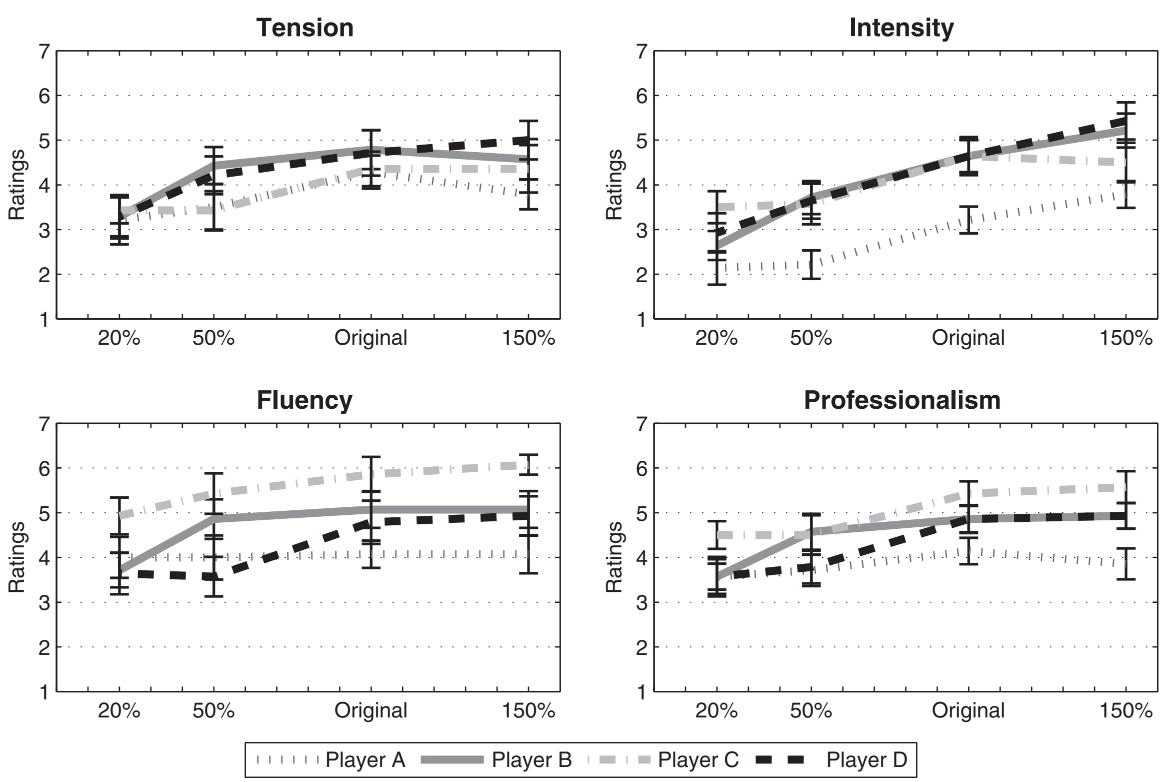

FIGURE 6. Mean ratings of each player for the different motion energy levels in percent to the original motion. Error bars show the standard error of the mean.

Analyzing the individual players with an individual ANOVA for the presentations, Players B and D showed significant effects of presentation on all musical dimensions, $F(3, 39) > 3.70$, $p < .04$. For Player A, the only significant effect was for intensity, $F(3, 39) = 5.58$, $p < .01$. Player C shows significant effects for intensity and professionalism, $F(3, 39) > 3.79$, $p < .04$, and a marginally significant effect for tension and fluency, $F(3, 39) > 3.11$, $p < .08$).

All players showed significant results for intensity, which could be due to changes in the amount of visible movement flow of the points. It also is possible that the participants correlated a higher perceived velocity of the moving points with a higher intensity. Even then, since intensity is loosely related to expressivity, this supports the findings of Paterson et al. (2001) and Davidson (1994).

For the other musical dimensions, increasing the movements did not affect the experience, while reductions down to 20% shifted the ratings for most of the players to a significantly lower value. The expression of tension also appears to be related to the amount of motion. Reducing the motion amplitudes down to 20% of the original movements diminished the rating values drastically. It seems that a certain amount of motion is needed to perceive a performance as tense, and very small movements seem to carry low perceptual tension. Nevertheless, there is no difference between the original and the exaggerated presentation, indicating that larger motions do not cause perceptually higher tension.

Fluency and professionalism showed a similar rating pattern as that for tension. Interestingly, since lowering the motion energy does not take away the smoothness of the motion behavior but just the amplitudes of the movements, the ratings show that this reduction correlates with a perceptual loss of fluency. Larger movements therefore appear to carry more information about the fluency of performances than smaller movements. The skill of the player also appears to somehow be related to the amount of motion with which the player performed. Less performer movement produced a lower rating.

The fluency and professionalism ratings of Players B and D showed an interesting pattern. Between the original sequence and the presentation with 20% of motion energy, for both players the rating value decreased nearly by the same amount, indicating that they seemed to have lost a similar degree of appearance. However, both players received different ratings for the 50% presentation. Whereas at 50% B was rated rather similar to the original sequence, at 50% Player D's ratings reached the rating level of the 20% presentation. The latter pattern also can be found in the ratings for Player C, but only for professionalism. It seems that for both musical dimensions, the original experience can be kept up to a certain threshold while underneath this threshold the judgments lose value. Since the motion energy values do not confirm this threshold, it seems that this pattern is very much individual to each performer.

TABLE 3. Coefficients of Determination (r2) Between the Motion Indices According to the Manipulated Motion Amplitudes and the Perceptual Ratings.

	Tension	Intensity	Fluency	Professionalism
Arm motion	.61**	.79**	**.50****	**.69****
Torso motion	.71**	.79**	.21	.42*
Whole body	**.76****	**.83****	.36*	.58**

*$p < .05$; $< p < .01$

Finally, the order in which the players were rated is similar to those in the previous experiments. Where Players B and D received higher ratings for tension and intensity than Player C, they were rated lower for fluency and professionalism. The changes in the motion amplitudes did not influence this ranking order, indicating that the ratings were given to the players in a similar way independent of the motion variation. Furthermore, the rating patterns of Players B and D indicate that fluency and professionalism seem to interact with each other so that a lower fluency is accompanied by a lower impression of musical experience.

As the transformation of the total motion energy shifted the motion values of each player, the ratings started to overlap at certain points, i.e., the rating value of Player A for the original movements was the same as for Player D with a 50% reduction. To analyze how the changes of amount of motion influenced the ratings we correlated the total motion indices of each player with their rating values. Table 3 contains the coefficients of determination (r^2) for each dimension. Herewith, we calculated the correlations between the motion index of the arms, torso, and the total of both with all perceptual values of the ratings.

Table 3 shows that intensity ratings have the highest correlation with the motion changes. Increases in motion amplitudes were associated with direct increases in perceiving intensity. This correlation is highest for whole body values, but also can be seen in the individual body parts.

Tension also was highly correlation with modifications of body motion. Larger body movements seem to transmit the experience of having more tension. This, however, seems to be mostly maintained by the torso, suggesting that the perception of tension may be more influenced by body posture than by arm movements.

The judgment of the players' skill shows a reduced correlation with body motions, whereas the arm motion alone has quite a high correspondence. This confirms that the arm movements are a good indicator of level of professionalism. As Experiment 1 showed, when examining players' scores, the determinant factor for the perception of professionalism seemed to be the arm's overall motion, not individual motion patterns. Here, the correlation indicates that the amount of motion energy in the arms also influences the professionalism judgments.

The perception of fluency does not seem to be greatly influenced by body motion changes at all. The arm motion values, however, show a rather good fit with the ratings. It seems that larger movements in the arms support the experience of a more fluent and consistent performance.

Conclusion

This experiment investigated the influence of changes in the motion amplitude of the whole body on participant ratings of tension, intensity, fluency, and professionalism. The visual motion of all players was altered to 150%, 50%, and 20% of their original movements. Overall, the results showed that these manipulations influenced the participants' judgments of the performances. The manipulations affected the ratings in a rather similar way across performers, and individual ratings showed similar ranking patterns between players to those obtained in the previous experiments.

For intensity, all players' ratings were significantly influenced by changes in motion amplitude. There was a straightforward correlation between musical intensity and amount of motion. However, it has yet to be proven whether this was due to higher movement velocity or to larger body movement amplitudes. Manipulating the velocity only could elucidate the factors involved in this correspondence in more detail.

A smaller correlation was found regarding tension. Except for Player A, players' ratings showed significant losses between the original and 20% motion energy for tension and professionalism. For fluency, only the ratings for Players B and D were significantly influenced by changes in motion amplitude.

All musical dimensions showed considerable effects by the reduction of motion energy: lower motion amplitudes generally were accompanied by lower ratings of the four dimensions. In fluency and professionalism, some players received individual rating patterns, indicating that this drop in the judgments had an individual aspect, but the overall pattern was approximately equal across all performers.

Overall, the whole motion characteristics of the players seemed to have a larger influence on judgments of musical dimensions than did motion characteristics of individual body parts. Nevertheless, some body motions correlated more with some musical dimensions. The arm motion values, for instance, correlated best for the judgment of the performances' fluency and for the musical skill of the player. The values of torso motion correlated with the expression of tension and intensity more so than the arm values did, whereas for these dimensions the whole body provided the highest correlation.

General Conclusions

The goal of this study was to investigate the effects of clarinetists' body movements on observers' perception of musical performances. In perceptual experiments, participants were asked to watch short sequences of the musicians and to rate them on four musical dimensions of tension, intensity, fluency, and the player's professionalism. These dimensions were not explicitly addressed by the players, i.e., the players were asked to perform in a natural way. For the experiments, we manipulated their visual appearance to see how this affected the ratings of the performances.

We used kinematic displays as stimulus sources, which first were shown to provide sufficient information for the musical judgments in a similar way as in the original video sequences (Validation Experiment). By "freezing" either the motion of the arms or the motion of the torso, we found that overall both manipulations had only small effect on the participants' judgments (Experiment 1). In the same experiment, showing the visual information in reversed order had no influence on the ratings compared to the original version. In contrast, increasing and decreasing the motion amplitudes of all points in the kinematic displays yielded large effects on all musical dimensions (Experiment 2). In general, the main tendency was that lower motion amplitude resulted in lower perceptual ratings.

The physical analysis of the players' motions showed that each player performed the piece with idiosyncratic movement velocities. Their individual body motions appeared to have some consistencies, whereas the total amount of movement differed for the individual body parts, i.e., where one player focused on larger arm motions, another player performed with more body sway. Overall, freezing the movements of these particularly emphasized body parts did not influence the observers' musical perception of the performances. Compared to the original sequence, extra motion did not seem to contain more information for any of the four musical dimensions chosen in this study. In contrast, the ratings of one player were drastically influenced by the manipulations, where freezing a body part resulted in a large decrease in ratings. This player, however, performed large movements in all body parts, where it seemed that the interaction of all motions was the most informative source for this performer and was thus destroyed by motion freezing. Generally, these results led to the assumption that the global movement characteristics of a player communicate musical attitudes more efficiently and this can be transmitted through any part of the body. In principle, blocking the motions of body parts did not affect this result (see also Dahl & Friberg, 2007).

The second experiment showed that motion energy turned out to be well correlated with judgment ratings, with smaller motions yielding lower ratings for all musical dimensions. The correlation between motion index due to the motion changes and the perceptual ratings was highest for the intensity dimension. Surprisingly, freezing certain body parts in Experiment 1 (which also decreased the total amount of motion) did not influence the musical perception.

The order of the players' rankings was similar on nearly all dimensions and across all experiments. The players with high values for tension and intensity were mostly rated with lower fluency and lower professionalism, while the players with relatively lower tension and intensity received higher values for fluency. Playing with high intensity and with resolute musical tension seems to result in a lack of smoothness, creating an impression of reduced musical skill.

Interestingly, one player showed a stable perceptual rating pattern across all experiments. This player performed with very few body motions in the original display, and the ratings on all musical dimensions were rather unaffected by any manipulation (except for intensity, in Experiment 2). In contrast to the player with large body motions mentioned above, this performance indicates that manipulations have to be observable to the audience to generate confusion and variations in the musical judgments. Detailed analyses of how these two players differ and what the manipulations changed compared to the original performance shall be considered for further investigations.

In summary, perceived performance intentionality can be aesthetically influenced through changes in the visual presentation of the player. Specific musical attitudes can be sufficiently communicated through body motion, and they seem to be located in the overall, holistic motion patterns of the player rather than in particular individual body behaviors. We showed that certain body movements are not directly correlated to the musical dimensions used here. It seems to be more the *how* instead of the *amount* of motion that triggers the impression. Additionally, neither freezing body parts nor reversing the visual presentation had an influence on the musical ratings. Therefore, the *how* seems to be an individual player characteristic and was not related to specific, easily definable body movements. This holistic characteristic, however, can be changed by altering the overall amount of body motion, which was found in Experiment 2.

Since this study used only a short excerpt of one musical piece played by one instrument, this work needs to be transferred into different musical styles and instruments. More musicians should be recorded to provide better insights into the analyses of motion and performance differences. Nevertheless, performers, educators and students can take these findings into account to enhance their performing, teaching, and learning, especially when dealing with body movements. Generally, performers base their own actions on self-perceptual experiences and acquire skill through previous performances and perceptions (Rodger, Issartel, & O'Modhrain, 2007). For a person who is learning to play an instrument, it is important to know how body movements influence the performance in both production and perception. Reducing unnecessary movements and learning to focus on specific expression-related body motions is an essential part of the learning process.

Finally, another considerable source of expressive information is the musical structure of the piece. Musical expressiveness also is driven by the music itself (see Todd, 1999) and further experiments may examine how musical features such as key, time, instrument, etc., may influence body movements of the performer. Clearly, this study has shown that body motion is a source of information for communicating musical impressions.

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[3]http://www.enactivnetwork.org

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