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A norming study and library of 203 dance movements

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Abstract. Dance stimuli have been used in experimental studies of (i) how *movement* is processed in the brain; (ii) how *affect* is perceived from bodily movement; and (iii) how dance can be a source of *aesthetic experience*. However, stimulus materials across—and even within—these three domains of research have varied considerably. Thus, integrative conclusions remain elusive. Moreover, concerns have been raised that the movements selected for such stimuli are qualitatively too different from the actual *art form* dance, potentially introducing noise in the data. We propose a library of dance stimuli which responds to the stimuli requirements and design criteria of these three areas of research, while at the same time respecting a dance art–historical perspective, offering greater ecological validity as compared with previous dance stimulus sets. The stimuli are 5–6 s long video clips, selected from genuine ballet performances. Following a number of coding experiments, the resulting stimulus library comprises 203 ballet dance stimuli coded in (i) 25 qualitative and quantitative movement variables; (ii) affective valence and arousal; and (iii) the aesthetic qualities beauty, liking, and interest. An Excel spreadsheet with these data points accompanies this manuscript, and the stimuli can be obtained from the authors upon request.

Keywords: action perception, dance, affect, Laban, movement library

1 Introduction

The past decade has witnessed the flourishing of a cognitive science of *dance*. Dance has been used in experiments to study the neural underpinnings of *movement* perception, *affect* perception, and as a source of *aesthetic experience* (for reviews see Bläsing et al., 2012; Cross & Ticini, 2011). Depending on the specific research domain and aims, however, stimulus materials have varied considerably (Christensen & Calvo-Merino, 2013). This hampers the comparison of results across studies and reaching integrative conclusions. In addition, some reservations have been expressed regarding the *type* of movements used as dance stimuli. Striving for experimental control, researchers have used movements that are qualitatively quite far from the actual art of dance (for a discussion, see Jola, Ehrenberg, & Reynolds, 2011a). Therefore, the aim of the present work is to assemble a set of dance stimuli that is informed by a dance art–historical perspective (Bullot & Reber, 2013), while at the same time being useful to research in cognitive science. We provide a dance movement library of 203 stimuli coded in movement, affective, and aesthetic dimensions of the dance, using common coding procedures within the fields of movement perception, affect perception, and aesthetic appreciation of dance.

1.1 *Movement, affect, and aesthetics*

1.1.1 *Movement.* Cognitive and neurobiological studies of movement representation using dance as an instance of complex motor actions have shown that such movements are processed in a distributed action observation network (AON) (Brown, Martinez, & Parsons, 2006;

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Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005a; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2005b). Moreover, such movement representations are susceptible to functional and structural change due to dance expertise (Bläsing, Tenenbaum, & Schack, 2009; Calvo-Merino et al., 2005a; Cross, Hamilton, & Grafton, 2006; Hänggi, Koeneke, Bezzola, & Jancke, 2010; Jang & Pollick, 2011). Among the studies using dance (movements or photographs), most have used ballet movements. Other popular styles include contemporary (Cross et al., 2006), Indian (Calvo-Merino, Urgesi, Orgs, Aglioti, & Haggard, 2010b), tango (Brown et al., 2006), or capoeira (Calvo-Merino et al., 2005a). Because such experiments often involve neuroimaging, researchers control stimulus characteristics carefully. Stimuli are commonly short video clips of single movements of ~2 s (Jang & Pollick, 2011), ~3 s (Calvo-Merino et al., 2005a), or ~5 s (Cross et al., 2006). Besides this, movement parameters —such as size and extension in space— are controlled for, and in some studies body information is reduced to mere point-light displays (Calvo-Merino, Ehrenberg, Leung, & Haggard, 2010a; Jang & Pollick, 2011). Further control of stimulus characteristics includes removal of colour and sound information, and the blurring of the dancers' faces.

To ensure that stimuli respond to these strict design requirements, they are usually created in collaboration with professional dancers and choreographers who help to select and code the dance movements according to key kinematic properties (Calvo-Merino et al., 2005a; Calvo-Merino, Jola, Glaser, & Haggard, 2008). Gross, Crane, and Fredrickson (2010) took an alternative approach: they filmed actors to create a library of a bodily action (knocking). Stimuli were subsequently coded in shape–effort qualities according to the framework of dance theorist and pedagogue Rudolf Laban (1988). According to this approach, the effort dimensions are *time*, *space*, *weight*, and *flow* of the movement. Time refers to movement speed (fast, hurried vs slow, indulgent), space regards the extension in space (large vs small), weight refers to the accent with which the movement is executed (upwards, ie light, soft vs downwards, ie heavy, hard), and flow regards the execution itself (bound, constrained, tense vs free, open, relaxed). In empirical research, trained professionals code these dimensions along rating scales, allowing a theory-based selection of study-relevant movements.

1.1.2 *Affect.* Regarding people's responses to affective stimuli, a distinction needs to be made between the *perception* of affect (ie *recognizing* affect in a stimulus) and the affective response of the individual (ie the actual *affect* elicited by the stimulus in the participant) (Bastiaansen, Thioux, & Keysers, 2009). While research on the affective responses induced by music has paid attention to both processes, and their interrelation (Brattico, Bogert, & Jacobsen, 2013; Hunter, Schellenberg, & Schimmack, 2010; Juslin & Västfjäll, 2008), studies on affect and *body movement* have generally relied only on *affect perception* tasks. Stimuli have mostly been everyday body movements (Atkinson, Dittrich, Gemmell, & Young, 2004; Atkinson, Vuong, & Smithson, 2012; Castellano, Villalba, & Camurri, 2007; de Gelder, 2009; De Meijer, 1989; Ma, Paterson, & Pollick, 2006; Pollick, Lestou, Ryu, & Cho, 2002; Pollick, Paterson, Bruderlin, & Sanford, 2001; Thoma, Soria Bauser, & Suchan, 2012). However, *dance movements* have also been used to that end, showing that affect can be induced by the abstract movements of a dance (Brownlow, Dixon, Egbert, & Radcliffe, 1997; Camurri, Lagerlof, & Volpe, 2003; Dittrich, Troscianko, Lea, & Morgan, 1996; Hejmadi, Davidson, & Rozin, 2000; Lagerlöf & Djerf, 2002; Montepare, Goldstein, & Clausen, 1987; Pollick et al., 2002). Anger and happiness are perceived from high-frequency movements when the body limbs reach out from the body centre. The movement's accent or stress plays a role in distinguishing them: towards the ceiling = happy versus towards the floor = anger. Importantly, people tend to exhibit higher agreement for arousal than for valence ratings (Stevens, Vincs, & Schubert, 2009a; Stevens et al., 2009b; Vincs, Stevens, & Schubert, 2009).

Ballet is the most common style used in such studies, but contemporary (Camurri et al., 2003; Castellano et al., 2007; Grosbras, Tan, & Pollick, 2012) and Indian dances (Hejmadi et al., 2000) have also been included. Because the affective qualities of a dance can change considerably even within a short time frame, it has been suggested that stimulus length should be well controlled in video stimuli (Christensen & Calvo-Merino, 2013). Stimulus durations in studies using *everyday* movements (knocking, walking, drinking) in affect perception tasks have been of ~2 s (Kret, Pichon, Grèzes, & de Gelder, 2011), ~3 s (Pollick et al., 2002), or ~5 s (Atkinson et al., 2004). In studies where dance movements were used, stimulus length has varied considerably more: between ~4 and 10 s (Hejmadi et al., 2000); ~5 s (Dittrich et al., 1996); ~30 s (Brownlow et al., 1997; Miura et al., 2010), to even ~2 min long (Camurri et al., 2003) or ~ 4 min-long recordings (Grosbras et al., 2012).

As in research on movement processing, facial information is usually removed to minimize facial emotion recognition, and face-related processing in general. Furthermore, dance stimuli are presented without the accompaniment of music or other sounds (ie in silence), the dancers are dressed in neutral clothes (eg black tight-fitting training clothes), and perform the movements in front of a neutral background. Grosbras and colleagues' (2012) study is an exception, in the sense that they used a genuine performance setting with music.

Stimulus validation experiments in this domain include the assessment of kinematic properties of the movements with computerized algorithms measuring—for instance, the quantity of motion (QoM), the body's contraction index (CI, a measure of the degree of contraction and expansion of the body, ranging from 0 to 1), velocity, acceleration, fluidity (measure of the uniformity of motion) (Castellano et al., 2007), and silhouette motion images (a measure of the 'amount of motion' in *N* frames of a video) (Camurri et al., 2003). These parameters can be used as predictors for affect perception (Pollick, Kay, Heim, & Stringer, 2005). Likewise, specific kinematic properties of the dance movements (eg number of kicks, turns, and jumps) are other stimuli selection criteria (usually coded with the help of dance professionals) that can be used with the same objective (Brownlow et al., 1997). Finally, Laban's framework has also been used in the context of affect perception studies (Camurri et al., 2003; De Meijer, 1989). Interestingly, Gross and colleagues (2010) found that the Laban movement dimensions predicted the affective valence, but not the arousal.

1.1.3 *Aesthetics.* The aesthetic experience a spectator derives from an artwork involves both cognitive and affective processes (Chatterjee, 2003, 2011; Leder, Belke, Oeberst, & Augustin, 2004). However, the affective components of the aesthetic experience *of dance* are still poorly understood. Therefore, in the endeavour to explore the affective processes involved in the aesthetic experience of dance, the affective quality of the stimuli is important. So far, research has shown that expansive movements are preferred to stationary ones (Calvo-Merino et al., 2008), that extremely stretched dance positions are preferred to less extreme ones, that audience preferences have changed over the last decades (Daprati, Iosa, & Haggard, 2009), that movements which spectators find particularly difficult to perform are liked more (Cross, Kirsch, Ticini, & Schütz-Bosbach, 2011), and that more familiar moves are liked more than nonfamiliar ones (Orgs, Hagura, & Haggard, 2013). Neuroimaging studies have shown that the aesthetic experience of dance correlates with an increase of activity in occipitotemporal and parietal regions of the AON (Cross et al., 2011), and the extrastriate body area (Calvo-Merino et al., 2010b). Dance styles used within this context include ballet (Calvo-Merino et al., 2008; Cross et al., 2011), Indian (Calvo-Merino et al., 2010b; Jola & Grosbras, 2013; Jola et al., 2013), and contemporary dance (Grosbras et al., 2012; Miura et al., 2010). Stimuli types vary from simple photographs of dance postures (Calvo-Merino et al., 2010b; Daprati et al., 2009; Jola, Clements, & Christensen, 2012a) to fully ecological settings, such as live performances in a theatre or dance studio (Jola & Grosbras, 2013; Jola, Pollick, & Grosbras, 2011b).

However, the most commonly used type of stimuli are video clips of varying durations: ~3 s (Calvo-Merino et al., 2008, 2010a; Cross et al., 2011), ~3 min (Grosbras et al., 2012), ~5 min (Jola, Abedian-Amiri, Kuppuswamy, Pollick, & Grosbras, 2012b), ~6 minutes (Jola et al., 2013), and even 2.5 hours (Jola et al., 2011b). While most studies have chosen to remove information that is not strictly related to the dance movement (no sound, music, colour, blurring the dancers' faces, etc), some studies have explored the aesthetic experience of dance when these aspects of the performance remain unaltered (Grosbras et al., 2012; Jola & Grosbras, 2013; Jola et al., 2011b, 2013).

In this area of research, professional dancers or choreographers are asked to monitor the selection of dance stimuli from a given dance movement repertoire in accordance with specific research questions. In addition, given that large and impressive movements appear to elicit more positive aesthetic experiences, Cross et al. (2011) suggested controlling the motion energy in video stimuli with dance movements. This is done by quantifying the average of moving pixels from one video frame to another, producing a 'motion energy score' for each video (Bobick, 1997). This score can be used to control the potential effects of the confounding variable 'amount of movement' in the different stimuli used in an experiment (Cross et al., 2011).

Table 1 summarizes this review of previous work. It gives an overview of dance stimulus characteristics across the three areas of research outlined here. The heterogeneity in stimulus materials makes it difficult to integrate conclusions, and in some cases potential confounding variables in the stimulus materials may have gone unnoticed. Also, the procedures to create and select the stimuli are laborious, task-specific, and dependent on the availability of experts. Therefore, we here propose a set of extensively coded dance movement stimuli to enable an enhanced control of the intricacies of movement perception, affect perception, and aesthetic appreciation, while still respecting a dance art–historical perspective. In addition to advancing research in each area, this library also opens a path to integrating their respective results.

1.2 *Stimulus coding experiments for the present stimulus library*

Our main aim is to create a stimuli library for empirical research, with dance movements that retain most of their original artistic qualities. Therefore, the selection of the parameters and their coding relied primarily on dance theory. The goal is to go beyond movement parameters (such as QoM, CI, and acceleration), whose link to neural activity or liking ratings is being investigated elsewhere (Calvo-Merino et al., 2008; Cross et al., 2011), to focus on movement dimensions which also have internal validity in dance theory. Accordingly, the present stimuli were selected with the help of dance professionals. First, qualitative measures of quantity, expansiveness, and other movement parameters were coded: large jumps (eg *grand jeté*) versus small jumps (eg *changement*), long travel through space (eg *grand jeté*) versus no travel through space (eg *changement*), etc (quantitative analyses using these measures are possible). Second, movement qualities were coded along the Laban movement dimensions, as suggested in studies on movement and affect perception. Third, stimuli were coded in affective arousal and valence, which are particularly relevant for studies on affect perception and aesthetic appreciation. Finally, stimuli were rated in different aesthetic dimensions.

This norming study has the following objectives, developed in five sections: (i) to create a stimulus library of dance movements motivated by dance theory (section 2); (ii) to code movement and contextual parameters (section 3); (iii) to provide values of affective valence and arousal (section 4); and (iv) to code the movements along three aesthetic dimensions: beauty, liking, and interest (section 5). An Excel spreadsheet with a list of the coding values for each stimulus accompanies this paper (see supplementary material at http://dx.doi.org/10.1068/p7581). Such a scheme will enable researchers to select stimuli according to their specific research questions. The stimuli are available from the authors upon request.

Table 1. Summary of the main findings, stimulus characteristics, and coding experiments used in each of the three areas of research outlined in the introduction that have used specifically *dance movements* as stimuli.

Highlighted findings	Stimulus characteristics	Common norming procedures
Movement		
The AON supports the representation of movements. Expertise enhances activity in the mirror neuron system.	Length: 2–12 s. Dance styles: ballet, contemporary, Indian, tango, capoeira. Other characteristics: mostly video clips, black/white, neutral background, no sound or music, face blurred, point-light displays.	Selection and coding of movement characteristics with the help of dance professionals. Coding in the dimensions of the Laban theory.
Affect		
Affect is perceived from the abstract movements of a dance. High-frequency movements are related to high-arousal emotions. Valence is more difficult to study with dance movements as it depends more on context.	Length: 2 s–4 min. Dance styles: ballet, contemporary, Indian. Other characteristics: mostly video clips, black/white, neutral background, no sound or music, face blurred.	Selection and coding of movement characteristics with the help of dance professionals. Coding in the dimensions of the Laban theory. Assessment with computer software of kinematic properties (QoM, CI, velocity, acceleration, fluidity, SMI).
Aesthetics		
Large, expansive, and impressive movements are liked most, and the aesthetic experience derived from this appreciation is correlated with enhanced neural processing in the AON, EBA.	Length: 3 s–2.5 h. Dance styles: ballet, contemporary, Indian. Other characteristics: mostly video clips, but also photographs and live performances. Usually, black/white, neutral background, no sound or music, face blurred. But also fully ecological stimuli in colour, with music and facial information.	Selection and coding of movement characteristics with the help of dance professionals. Motion energy.

Notes: AON = Action Observation Network, QoM = quantity of motion, CI = contraction index, SMI = silhouette motion image, EBA = extrastriate body area.

2 Stimulus creation

The source materials for the movement library were live ballet[(1)] performance recordings available on DVD. Using such live shows has the advantage of preserving the ecological qualities of the stimuli because they are closer to the actual *art form* of dance (Jola et al., 2011a). Besides this, it allows exploring the possibilities of more ecological stimuli in a controlled laboratory environment (as compared with real live performances which never are exactly the same twice). Furthermore, stimuli were coded in a number of relevant parameters (see section 3) in order to account for the heterogeneity that may be found in the type of movements and contextual variables of the different clips.

[(1)] Please refer to the supplementary material for the rationale behind the choice of ballet.

The stimuli library was created following three steps. First, 248 dance movements lasting 5–6 s were sampled from live dance performances (‘Stimuli selection’: subsection 2.1). Second, the dancers’ faces were blurred, and colour and soundtrack were removed from the clips (‘Video editing’: subsection 2.2). Third, three professional dance teachers rated the stimuli regarding the technical correctness of the movement, the adequacy of the stimulus cut within the rationale of the dance style, and the physical adequacy of the dancer for the dance style (‘Professional technical assessment’: subsection 2.3.). Finally, 203 stimuli remained in the set: those exhibiting highest technical and adequacy ratings.

2.1 *Stimuli selection*

The video clips were selected from 12 DVD recordings (table 2) spanning 5 years (2005–10). This was important because although the choreographies may be a hundred years old, the execution of the movement and the dancers’ bodies change over time (body stretch, height of jumps, athletic execution in general, etc), as do audience preferences (Daprati et al., 2009).

The selection criteria for the stimuli from the raw material were:

- *The ballets.* All dancers were classically trained, from similar schools (Russian, Royal Danish, Royal British, or French ballet techniques), and were world-class performers. The choreographies were all classical or neoclassical and included no contemporary movements. This selection aimed to minimize the effects of different dance styles in the final set.

Table 2. DVD source material.

Ballet	Premiere year, choreographer, country of premiere	Company of the recording	Year and producer of the recording
Bournonville Festival	1844, Auguste Bournonville, DK	Danish Royal Ballet	2008, German television (Arte)
Swan Lake	1895, Marius Petipa and Lev Ivanov, RUS	Mariinsky Theatre	2007, Decca: B000UVLJKO
Swan Lake	1895, Marius Petipa and Lev Ivanov, RUS	Zurich Ballet	2010, Decca: B003CN97YM
Dying Swan	1905, Mikhail Fokine, RUS	Mariinsky Theatre and Kirov Ballet	2006, Bel Air: 7551293
Paquita	1881, Marius Petipa, RUS	Bolshoi Ballet	2008, German television (ZdfDoku)
Romeo and Juliet	1965, Kenneth Macmillan, UK	Royal Ballet, London	2009, Decca: B002E2M5NW
Jewels	1967, Georges Balanchine, USA	Ballet de l’Opéra de Paris	2006, Opus Arte: B000FA577G
Firebird	1910, Mikhail Fokine, FR	Mariinsky Theatre	2008, Bel Air: B0023T9ZR0
Nutcracker	2000, Maurice Béjart, CH	Béjart & Ballet de l’Opéra de Paris	2008, EMI Virgin Classics: B001G5ZO72
Ballet competition, Lausanne	various	various companies	2008, German television (ARD)
Divine Dancers Festival, Prague	various (*Manon*, *Memoire*, *Sleeping Beauty*)	various companies, soloist dancers	2006, Euroarts: B000FVQUMQ
Spartacus	1956, Leonid Yakobson, RUS	Bolshoi Ballet	2006, Decca: B001BWQVVS

Note: DK = Denmark; RUS = Russia; UK = United Kingdom; FR = France; USA = United States of America; CH = Switzerland.

- *Stimulus length*. The length of each clip was set to between 5 and 6 s (24 frames per second). This decision was based on the analysis of previous stimulus materials (see table 1 for reference, and the supplementary material for further details). Also, we intended to make stimulus length suitable for neuroimaging studies on movement processing, *and* for studies targeting the affective responses in observers (see supplementary material for further details). However, we were flexible on the exact number of frames (between 110 and 144) because the ballet syllabus clearly establishes the start and end points of its movements. To respect this art–theoretical requirement of style, we allowed this flexibility in the stimulus length. The final set includes clips between 110 and 144 frames long; minimum = 4 s, 583.34 ms, ie 110 frames; maximum = 6 s, ie 144 frames; mean = 5 s, 41.67 ms, ie 121 frames). Stimuli were cut by one of the authors with ballet experience (JFC), using the software Adobe Premiere Elements v. 7.0.
- *Stimulus selection*. The sampling criteria for the selection of the stimuli were the following. First, only one soloist female dancer should be on view for the length of the stimulus, or there should be the possibility to blur other dancers around; or *if* there were any in the picture, they should be standing still. Stimuli were selected with dancers of only one gender based on two main conclusions from the study by Gross et al.'s (2010) study. They suggested (i) using large numbers of stimuli when testing for emotion induction through abstract body movement, and (ii) enhancing external validity by including a large number of different actors in the clips. There was simply not enough material to fulfil these recommendations with male dancers.

Second, no change in camera perspective was admitted for the duration of the stimulus (Reeves, Lang, Young Kim, & Tatar, 1999). Also, we made sure that no arms or legs were 'outside' the frame for the duration of the clip. This was achieved for all stimuli except for two where the hand of the ballerina is out of the canvas for a couple of frames. The canvas of clips was enlarged or diminished to make the dancers the same height in all clips.

Third, we chose only sequences with between 2 and 5 complete ballet movements and ensured that movements were not cut off before their actual climax according to the corresponding ballet syllabus. It is recommended to respect this because, especially expert participants are sensitive to whether a movement is 'finished off' or not (see section 2.3).

Fourth, only abstract movements were included—no propositional or referential ones. A number of studies have recommended using only abstract movements for affective body movement stimuli because pantomime and culturally recognizable gestures could bias the affective response to such stimuli (Boone & Cunningham, 1998; Camurri et al., 2003; Christensen & Calvo-Merino, 2013; Gross et al., 2010).

Fifth, to avoid selection biases, *all* possible sequences complying with the above criteria and of 5–6 s (110–144 frames) were selected from the recorded material. This left us with 248 clips of ballet movement sequences.

2.2 *Video editing*

Three video editing procedures were carried out to enhance the internal validity of the stimuli, aiming to limit the transmission of affect through channels of emotional expression other than body movement. First, the dancers' faces were blurred with the software Final Cut Express. The aim was to block facial processing, which is related to activity in the 'fusiform face area' (Kanwisher, McDermott, & Chun, 1997). Second, stimuli were transformed into black and white to control for preferences or recognition due to colour processing. Colour aids object recognition and its processing requires distinctive and additional neural pathways as compared with grayscale visual stimuli [superior parietal lobule and precuneus bilaterally, the right hippocampus, and the right fusifom gyrus (V4)]; (Bramao, Faisca, Forkstam, Reis,

& Petersson, 2010). Third, the soundtrack—including the music—was deleted from the clips to avoid auditory affect induction. It may be remarked that there is no such thing as dance without music, though this remains a discussion beyond the scope of this project. Research on music has shown its emotional power (Blood & Zatorre, 2001; Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). Therefore, it should be controlled for when assessing the power of abstract movement to express affect.

2.3 *Professional technical assessment*

We awarded dance theory a central role in the selection of the dance movement sequences for the final library. Only movement sequences complying with the technical requirements of ballet were selected. This selection included three relevant aspects. First, the *technical correctness* of the movement execution. This means that the positioning of the body in space has to be correct (ie are the limbs of the body in the correct positions at the exact points in time? Are the feet, hands, knees, head, etc maneuvered in the technically right way? And, is the performance—apart from being technically correct—also artistic in its expression?).

Second, expert assessment of the *meaningfulness* of the movement within the video clip (ie is the cut of start and endpoints correct and meaningful from the standpoint of the underlying dance theory?). For instance, within the theoretical framework of many formal dance styles, dance movements have a start and an end. Although these starting and end points may not be intuitive to a layperson, they are evident to the expert. Furthermore, there may be particular moments (or positions) within a sequence of movements where an expert would consider it more adequate to cut the sequence than in other. Figure 1 illustrates this point for a ballet movement.

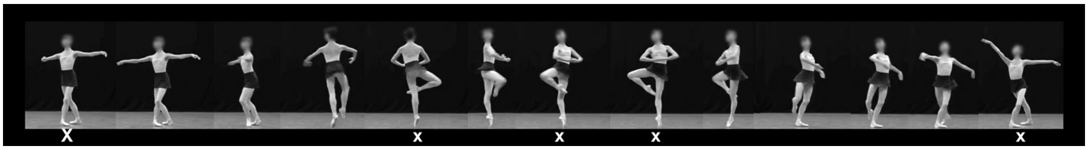

Figure 1. Example of a ballet movement, a '*pirouette passé en dehors*'. It is illustrated as a turn to the right on one leg starting in a crossed position (*4ème croisée pliée*) and finishing in another crossed position (*4ème croisée allongée*). Only the pictures marked below with a cross are canonical positions within the ballet syllabus. Cutting the movement sequence at one of these points would be feasible. But if the movement is cut off before or after such canonical position/moment, that particular sequence is not meaningful to an expert. Thus, in this example, if the movement has to be cut off *before* the actual end of the *pirouette passé en dehors* due to stimulus duration considerations of an experiment, then care should be taken to select one of the canonical movement positions as the last frame of the clip. The positions in the screen shots that do not have a cross are connecting movements (feet or knees turned in, not stretched, 'wrong' alignment of body parts, 'wrong' positioning with relation to space, etc). These 'in-between positions' cannot be avoided, but they should not be the first or last of a stimulus.

Finally, the *physical adequateness* of the dancer in the video clip was also examined. The physical attributes a ballet dancer is required to exhibit—such as curvature of feet, turn out of hips, knee/leg stretch, and so on—is independent from the movement's *technical correctness*. It therefore requires separate expert consideration.

Thus, only dance sequences that make sense technically and that are meaningful from a dance theoretical point of view, and which are executed by high-level dance experts, were selected. To eliminate stimuli that did not fulfil these criteria, dance professionals evaluated each clip.

2.3.1 *Method.* Three professional ballet teachers (age: $M = 43$ years; $SD = 12.13$ years; dance experience: $M = 34.67$ years; $SD = 14.43$ years) rated each of the 248 videos on the following 7-point Likert scales: (i) *technical correctness* of the execution (ie whether the movements were executed correctly respecting the ballet syllabus: 1 = technically incorrect to 7 = technically correct), (ii) *meaningfulness of the stimulus cut* attending to the rationale of the respective ballet movement (ie whether the stimuli were cut respecting start and endpoints of the ballet movements: 1 = bad cut, not meaningful to 7 = good cut, meaningful), and (iii) *physical adequacy* of the individual ballerinas for ballet (ie attention to the length of limbs, neck, curvature of feet, stretch of knees, etc: 1 = physically inadequate to 7 = physically adequate).

The program DirectRT (Empirisoft Corporation) was used to present the stimuli on a 19 inch screen on an Intel® Core™ 2 Duo Sony Vaio Laptop. The clips were played over black background, with a canvas size of 16 × 10 cm, dancers occupying about 8–9 cm on the screen (from feet to head, not counting arm movements). Viewing distance was about 40 cm. The experimental sessions took place in a dimly lit, silent room. Participants received a chocolate gift in return for their participation.

Stimuli were presented twice, once for each of the scales technical correctness and meaningfulness of the stimulus cut in a randomized block design. After these two blocks, one randomly selected stimulus for each dancer was presented (38 different dancers, ie 38 stimuli), and raters indicated their ratings of physical adequacy for each dancer on the 7-point Likert scale. Stimuli presentation was randomized.

2.3.2 *Results.* All clips were rated from moderate to high in all three dimensions: technical correctness of the execution of the movement ($M = 5.43$; $SD = 0.89$), meaningfulness of stimulus cut of the video clip ($M = 5.06$; $SD = 0.82$), and physical adequacy of the ballerina ($M = 6.00$; $SD = 1.00$) (see the supplementary material for interrater reliability statistics).

Given the mean value of physical adequacy ($M = 6$ on the 7-point scale; $SD = 1$; range = 4–7). We considered this sufficient proof that all the dancers were of very high physical quality and their movements could be included in the set. Subsequently, we proceeded to inspect the two remaining scales. The ratings of technical correctness and meaningfulness of the stimulus cut were strongly correlated (rater 1: $r_s = 0.254$, $p < 0.001$; rater 2: $r_s = 0.867$, $p < 0.001$; rater 3: $r_s = 0.550$, $p < 0.001$), which underscores the need of taking meaningfulness into account.

We selected only those stimuli with a minimum average score of 4 and the lowest SD ($\leqslant 2.08$) for meaningfulness of the stimulus cut, and a minimum average score of 4 and the smallest SD ($\leqslant 1$) for technical correctness. This procedure left us with a set of 203 stimuli. Descriptive values for the final set were: technical correctness of the execution of the movement ($M = 5.57$; $SD = 0.87$), meaningfulness of stimulus cut of the video clip ($M = 5.27$; $SD = 0.82$).

2.4 *Summary of the stimulus creation*

These procedures led to the exclusion of 45 clips. The final library includes 203 stimuli. Each clip shows an internationally renowned female ballet dancer—with her face blurred, in black and white, and without music or other sounds—performing a technically sound and meaningful ballet sequence. Fading the clips in and out should be considered to minimize surprise reactions and to soften the problem outlined in figure 1. For two examples of the type of stimuli and for notes regarding further issues related to the experimental design and programming see the supplementary material.

3 Movement coding

Our next step was to have each video clip coded in terms of movement features, following two distinct procedures used in previous studies (consult section 1.1 and table 1 for reference). One coding was *ballet technique based* and the other was *Laban theory based* (shape–effort theory). The aim of these procedures was to provide movement descriptors (ballet technique based) and measures of the quality of the movement (Laban theory based), and to check whether results from previous studies hold for the present stimulus set.

Accordingly, the 203 video clips were first coded by a dance professional (one of the three from section 2) in movement and contextual parameters such as the extension of body limbs in space, pirouettes, and jumps, according to the Russian Ballet syllabus (Vaganova ballet technique—cf Vaganova, 1969) (subsection 3.1). Subsequently, twelve students from the Trinity Laban Conservatoire of Music and Dance, London, coded the stimuli in the four dimensions of the shape–effort theory of Laban (1988): time, space, weight, and flow (subsection 3.2).

3.1 *Coding of movement parameters and contextual variables according to ballet technique*

Twenty-five movement and contextual parameters—6 quantitative and 19 qualitative—were coded for each clip [the six quantitative movement descriptors were later submitted to a principal component analysis (PCA)—see section 3.1.1]. The parameters are listed and described in table 3. See figure 2 for examples of the movements summarized in the table.

The quantitative parameters refer to the number of times a particular movement is executed within a clip. The relevant movement descriptors are: total number of movements in the clip, number of pirouettes, distance travelled in space, number of changes in space, number of times a movement has an accent towards the floor (‘*pliés*’), and number of times a movement has an accent upwards, towards the ceiling (‘*relevés*’). Such a coding scheme provides researchers with information about the frequency and liveliness of the movement in a clip, and can guide the selection of stimuli that are homogeneous with regards to any of the descriptors: clips that contain the same total number of movements, for instance. Likewise, these values can be included in regression models to explain the variance in separately obtained subjective ratings or physiological measurements of individuals’ responses to the clips.

The 19 qualitative variables are grouped into four movement descriptors: presence of specific movements, movement dynamics, contextual variables, and selection variables. Thus, if researchers wish to use clips with no jumps, this is possible choosing only clips coded ‘0’ in this variable. Or, if the aim is to control for the ‘impressiveness’ that a leg kick of 180° may cause in the observer, clips with such movements can be excluded by not including clips coded with a ‘1’ in the variables *développé à la seconde* and *battement devant*. Similarly, if contrast is relevant in a study, it might be desirable to choose only such clips with black background (coded ‘2’) and where the dancer wears a white dress (coded ‘0’), and possibly to exclude clips where there are stage props in the picture (coded ‘1’), etc. Please refer to the Excel spreadsheet for the scores of each of these parameters for each clip. Table 4 provides the number of video clips in each category.

3.1.1 *Dimension reduction with PCA.* The 6 quantitative movement descriptors were submitted to a dimension reduction to explore how this set of movement descriptors relates to previous findings. Very different fields of research have consistently used quantity, path, and manner of movement as features to describe bodily movement (Dahl & Friberg, 2007; De Meijer, 1989; Laban, 1988; Montepare, Koff, Zaitchik, & Albert, 1999; Talmy, 1985, 2000a, 2000b). The first feature regards *the way* in which a movement is executed (eg manner: ‘shape’, ‘form’, ‘strength’). The second describes how the movement *relates to space* (eg path: ‘direction’, ‘force’). The third is about the *pace and frequency* of the movement (eg quantity: ‘tempo’, ‘velocity’, ‘amount’, ‘speed’). To explore whether the present set of stimuli would fall into the same three-component structure, we used the codings of the above quantitative movement descriptors in a PCA.

Table 3. Contextual and movement-relevant parameters used to code the clips. The quantitative movement descriptors were grouped into three components by means of a principal component analysis (see section 3.1).

Variable name	Description	Component
Quantitative variables		
Number of *pirouettes*	Count of how many times the dancer turns around the body axe, be it in pirouettes or other technical movements that imply a turn.	quantity of movement
Total number of movements	Count of the total number of movements. The count includes all individual and repetitions of all movements.	
Travel through space	Distance travelled. According to the type of movement, an estimation was made of the space travelled.	'path' (horizontal plane)
Number changes in space	Count of how many times the dancer changes the direction in space. In ballet the space that surrounds the dancer is divided into 8 equal parts. Each count represents a transition between these.	
Number of *pliés*	Count of number of *pliés*, ie bends of the knee. It is a movement with an accent downwards.	'manner' (vertical plane)
Total accent up	Count of the total number of movements with an accent upwards, such as jumps and *relevés* or *piqués*.	
Presence of specific movements		
Attitude back	These are particularly salient ballet movements that are often used in climax situations of a choreography. Their presence/absence in a clip was coded dichotomously. See figure 1 for a representation of the movements. They were coded so that researchers can choose to include or specifically to exclude clips with such 'climax' movements if they wish. Dependent on the objectives of their study.	
Attitude front		
Arabesque		
Battement devant		
Développé		
Grand jeté		
Back curve		
Développé à la seconde		
Couronne allongée		
Quatrième allongée		
End pose		
Qualitative variables		
Movement dynamics		
Jump	The presence/absence of jumps in the clip was coded as 0 = absence of jump; 1 = presence of small jump(s); 2 = presence of big jumps. 'Small' and 'big' jumps are technically denominated as such in ballet nomenclature. For instance, *grands jetés* and *passé scission* are big jumps, while *assemblés* or *petits jetés* are small ones.	
Angle	The angle of the play leg with respect to the body axe was coded in whether the leg at any point in the sequence was lifted higher than 90° in any direction; 0 = no, 1 = yes.	
Specific angle	The specific angle of the play leg with respect to the body axe was coded in four extensions, attending to the maximum extension present in the clip. 0 = the leg did not leave the vertical axe; 1 = the extension is 90° (see figure 1c); 2 = the extension is 120° or more (up to 180°) (see figures 1e and 1g); 3 = the leg was '*passé/retiré*', meaning a 90° angle but a bent knee (see figure 1h).	
Rotation	The presence of rotations was coded both in how many rotations there were in total (see above, 'number of pirouettes') and in whether or not there was a rotation in the clip at all; 1 = yes, 0 = no.	
Location of arms	The location of the arms was coded attending to whether the dancer lifted their arms over the horizontal axe during the clip; 0 = no, 1 = yes.	
Contextual variables		
Background colour	The background colour was coded into 0 = white; 1 = grey; 2 = black.	
Stage props	The presence of stage props was coded dichotomously: 0 = none, 1 = presence.	
Colour of clothes	The colour of the clothes was coded into 0 = white; 1 = grey; 2 = black.	
Selection variables		
School	The school the ballerina was trained in was coded: 0 = Bournonville (Danish); 1 = French; 2 = Russian; 3 = English.	
Ballet	0 = Bournonville Festival 2010; 1 = *Swan Lake*; 2 = *Paquita*; 3 = *Romeo and Juliet*; 4 = *Jewels*; 5 = *Manon*; 6 = *Memoire*; 7 = *La Belle aux Bois Dormant*; 8 = *Firebird*; 9 = Prix de Lausanne 2008; 10 = *Nutcracker*, by Béjart; 11 = *Swan Lake* act 1; 12 = *Spartacus*; 13 = others.	

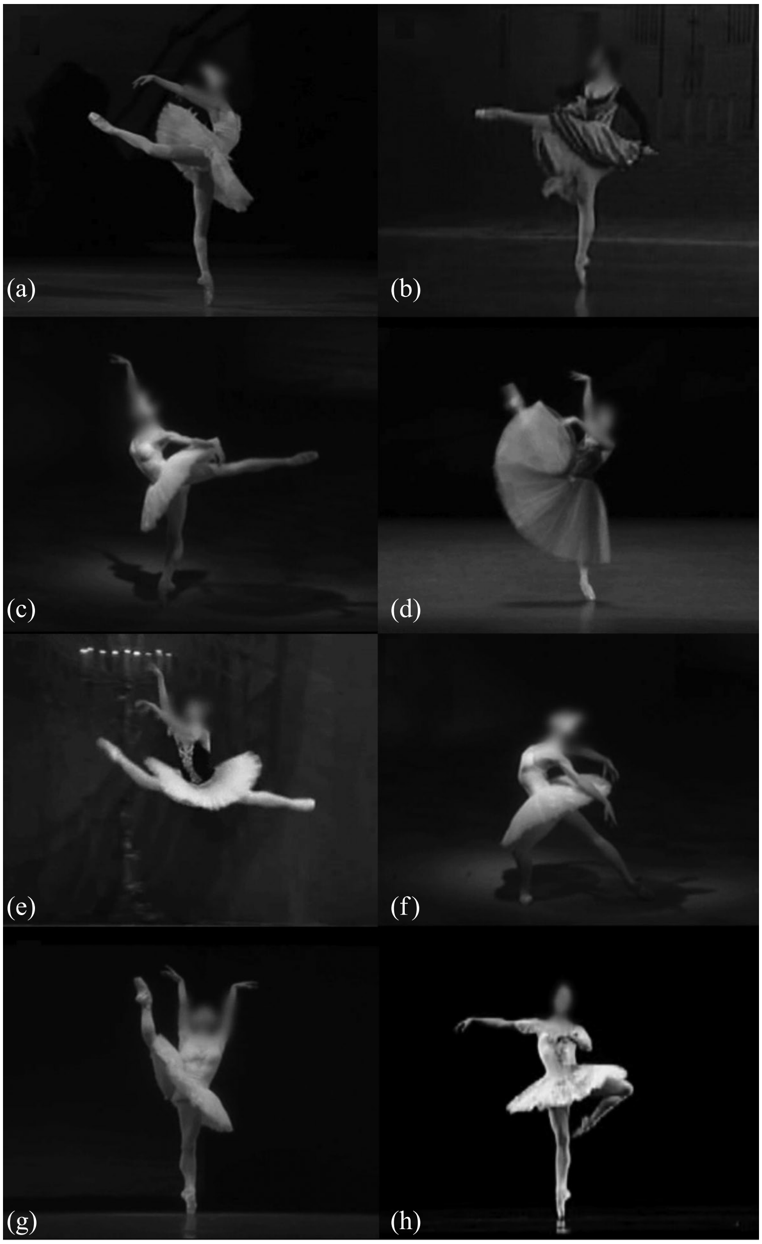

Figure 2. Examples of the video clips and the movements referred to in table 3. (a) *Attitude* back, arms *allongés* (the arms were not rounded, but the elbows almost stretched and the palms of the hands turned outward). (Mariinsky Theatre; Decca 2007: B000UVLJKO). (b) *Attitude* front (Danish Royal Ballet; German television: ARTE 2008). (c) *Arabesque piqué* (Zürich Ballet; Decca 2010: B003CN97YM). (d) *Battement devant* (Ballet de l'Opéra de Paris; Opus Arte 2006: B000FA577). (e) *Grand jeté* (Bolshoi Ballet; German Television: ZdfDoku 2008). (f) Extreme back curve (Zürich Ballet; Decca 2010: B003CN97YM). (g) *À la seconde*, arms *allongés* (Zürich Ballet; Decca 2010: B003CN97YM). (h) *Passé retiré* (Divine Dancers Festival, Prague; Euroarts 2006: B000FVQUMQ). See table 2 for more information about the origin of the movements.

Specifically, to reduce the six *quantitative movement* descriptors, we performed a PCA with orthogonal rotation (varimax). The Kaiser–Meyer–Olkin (KMO) measure verified the sampling adequacy for the analysis (KMO = 0.527), and all KMO values for individual variables were <0.5 [except one (*total number of movements*): KMO = 0.463]. Bartlett's test of sphericity (χ^2_{15} = 132.93, $p < 0.001$) indicated that the correlations between the variables

Table 4. Frequency of video clips in each of the four qualitative movement dimensions.

Variable	Movement	Movement descriptor	Frequency (of 203 stimuli)	%
Specific movements	*attitude* back		38	18.7
	attitude front		11	5.4
	arabesque		62	30.5
	battement devant		22	10.8
	grand jeté		7	3.4
	back curve		59	29.1
	développé à la seconde		29	14.3
	coronne allongée		35	17.2
	quatrième allongée		8	3.9
	end pose		22	10.8
Movement dynamics	jump	no jump	141	69.5
		small jump	42	20.7
		big jump	20	9.9
	angle	under horizontal axe	146	71.9
		over horizontal axe	57	28.1
	specific angle	0°	42	20.7
		90°	78	38.4
		120° or more	57	28.1
		passé retiré	26	12.8
	location of arms	under horizontal axe	104	51.2
		over horizontal axe	99	48.8
	rotation	none	104	51.2
		yes	99	48.8
	number of rotations	no rotation	104	51.2
		1 rotation	39	19.2
		2 rotations	17	8.4
		3 rotations	19	9.4
		4 rotations	12	5.9
		5 rotations	5	2.5
		6 rotations	3	1.5
		7 rotations	2	1.0
		8 rotations	2	1.0
	travel through space	none	22	10.8
		1 m	40	19.7
		more than 1 m, walking	115	56.7
		more than 1 m, jumping	26	12.8
Contextual variables	colour of costume	white	67	33.0
		grey	100	49.3
		black	36	17.7
	stage props	none	115	56.7
		yes	88	43.3
	background colour	grey	76	37.4
		black	127	62.6
Selection variable	school of the ballerina	Danish	16	7.9
		French	52	25.6
		Russian	129	63.5
		British	6	3.0

were sufficiently large to compute a PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Three components had eigenvalues of over Kaiser's criterion of 1 and in combination explained 69.37% of the variance and were retained for the final analysis. Table 5 shows the factor loadings after rotation. Consistent with previous research, the items that cluster on the same components suggest that component 1 represents the *quantity* of movements, component 2 the movement *path*, and component 3 the *manner* of the movement. To make it clearer what each of these descriptors mean in terms of the present type of movements, movement path could be described as movement in the horizontal plane, while movement manner describes movement in the vertical plane. Please refer to the Excel spreadsheet in the supplementary material for the three values for each stimulus.

Table 5. Summary of principal component analysis of the quantitative movement descriptors.

Variable	Rotated factor loadings		
	movement 'quantity'	path (horiz. plane)	manner (vert. plane)
Number of rotations	**0.886**	0.117	0.047
Total number of movements	**0.882**	0.023	–0.089
Travel through space	–0.071	**0.834**	0.025
Number changes in space	0.232	**0.757**	–0.027
Number of *pliés*	0.009	–0.169	**0.779**
Total accent up	–0.048	0.167	**0.761**
Eigenvalue	1.761	1.238	1.164
% of variance	29.347	20.631	19.394

Notes: Factor loadings of over 0.40 appear in bold; horiz. = horizontal; vert. = vertical.

3.2 *Laban movement coding system*

The dance theoretician Laban (1988) developed a system to code and analyze bodily movements and their expressive power (Camurri et al., 2003; Camurri, Volpe, De Poli, & Leman, 2005; see introduction for details). The system is grounded on the notion that any movement is a particular combination of motion parameters and qualities that can be varied structurally. Depending on how they vary, their expressive power also varies. Following the example of Gross and colleagues (2010), the clips were coded following Laban's theory in time, space, weight, and flow. One self-criticism of the study by Gross et al. was that they did not involve Laban theory experts to code their video clips and suggested that some of their less conclusive results might have been due to this fact. To avoid this potential pitfall, the participants for this study were recruited from the Trinity Laban Conservatoire for Music and Dance, London.

3.2.1 *Method*

3.2.1.1 *Participants.* Twelve students (1 male; age: $M = 25.67$ years, SD = 8.70 years; dance experience: $M = 14.75$ years, SD = 6.80 years; Laban movement analysis experience: $M = 1.89$ years, SD = 1.39 years) from the Trinity Laban Conservatoire for Music and Dance, London, rated the dance clips. Participants received a coffee–chocolate gift in return for their participation.

3.2.1.2 *Materials.* The 203 dance clips were presented on a black background by means of the stimulus presentation program DirectRT (Empirisoft Corporation) on a 19 inch screen of a Intel® Core™ 2 Duo Sony Vaio Laptop. Stimulus size was 16 × 10 cm, and dancers' height was about 8–9 cm on the screen (from feet to head, not counting arm movements). Viewing distance was about 40 cm.

3.2.1.3 *Procedure.* To prevent participant fatigue, the 203 stimuli were randomly assigned to four sets, and each participant rated just one of those (rating all stimuli together would have resulted in an experimental session of 4 hours). Fifteen randomly selected video clips were shared among the sets for interrater reliability assessment. Thus, the four sets comprised 62 clips each (47 different and 15 shared).

The experimental sessions took place in the library of the Trinity Laban Conservatoire for Music and Dance, London. The room was dimly lit and silent. Participants first provided written informed consent and demographic information in a questionnaire (gender, age, level of study). After individually completing the computerized task, they also filled in a questionnaire on dance-relevant personal information (years of ballet and general dance experience, and years of Laban movement analysis experience).

Stimuli were presented four times in a fully randomized counterbalanced block design, once for each of the movement dimensions: time, space, weight, and flow. See figure 3 for the four rating scales. The raters indicated their ratings by means of 7-point Likert scales.

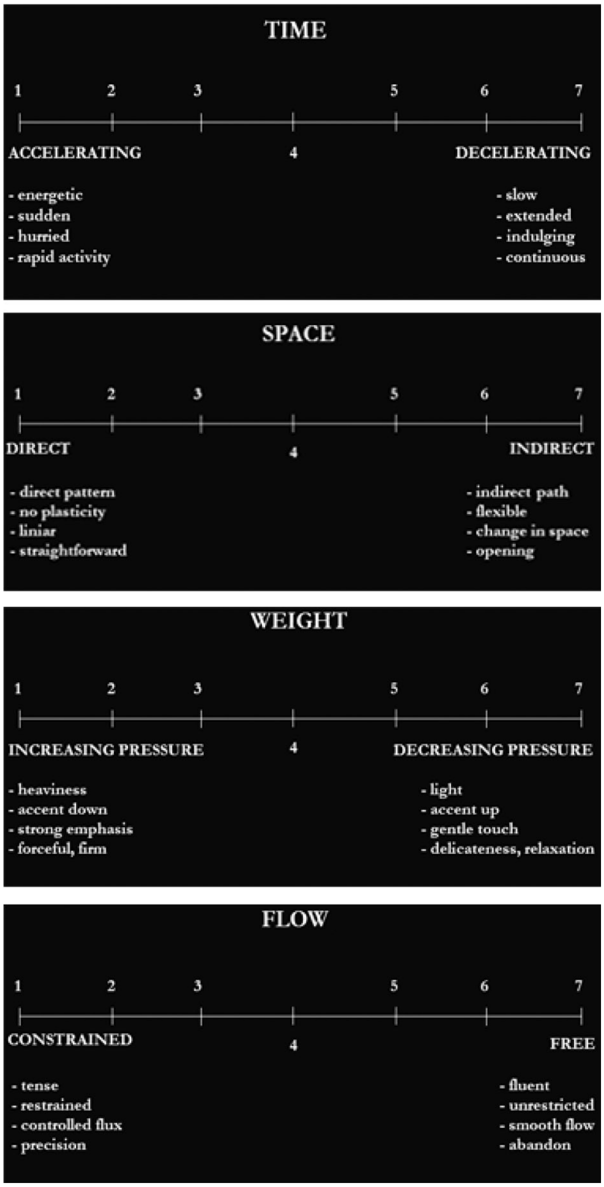

Figure 3. The four rating scales for the Laban dimensions: time, space, flow, and weight.

(*Time*: 1 = accelerating, energetic, sudden, hurried; 7 = decelerating, slow, extended, indulging, continuous. *Space*: 1 = direct pattern, no plasticity, linear, straight forward; 7 = indirect path, flexible, change in space, opening. *Weight*: 1 = increasing pressure, heaviness, accent down, strong emphasis, forceful, firm; 7 = decreasing pressure, light, accent up, gentle touch, delicateness, relaxation. *Flow*: 1 = constrained, tense, restrained, controlled flux, precision; 7 = free, fluent, unrestricted, smooth flow, abandon.) By design, the direction of the scales was designed opposite to how it would be expected. For instance, in the time dimension 'accelerating and energetic' was coded toward 1, while 'more' was usually coded toward higher numbers (ie here: 7). We did this to avoid response tendencies (see the supplementary material for more details on the Laban coding).

3.2.2 *Results*

On average, clips were rated towards the midpoint on all four Laban scales: time ($M = 3.78$, SD = 1.38); space ($M = 3.60$, SD = 1.10); weight ($M = 4.23$, SD = 0.98); and flow ($M = 3.69$, SD = 1.29). Results showed that interrater reliability on the 15 shared videos was moderate with Cronbach's $\alpha = 0.316$ for time, $\alpha = 0.591$ for space, $\alpha = 0.730$ for weight, and $\alpha = 0.530$ for flow.

Time correlated with space ($p > 0.001$; $r = 0.359$) and flow ($p > 0.001$; $r = 0.347$), but not with weight ($p < 0.05$; $r = 0.116$). Space correlated with weight ($p > 0.001$; $r = 0.221$) and flow ($p > 0.001$; $r = 0.469$); and weight correlated with flow ($p > 0.001$; $r = 0.359$).

A PCA was conducted to explore whether the data would confirm the 4-factor structure of the four Laban movement dimensions. The KMO measure verified the sampling adequacy for the analysis (KMO = 0.646), and all KMO values for individual items were >0.5. Bartlett's test of sphericity ($\chi^2_6 = 133.594$, $p < 0.001$) indicated that correlations among items were sufficiently large for PCA. One component had an eigenvalue of over 1, and this was the only component retained. It explained 50.12% of the variance. Table 6 shows the factor loadings of the 'Laban score'.

Table 6. Summary of principal component analysis of the four Laban dimensions grouped into one component.

Variable	Factor loadings: Laban score
Time	**0.834**
Space	**0.733**
Weight	**0.621**
Flow	**0.621**
Eigenvalues	2.005
% of variance	50.123

Note: Factor loadings of over 0.40 appear in bold.

The resulting Laban score component can be regarded as a general feature of movement execution. Thus, a low score in the Laban score component describes a very energetic, direct movement that is forceful and precise in its execution and transmits a sense of tension. High scores designate an indulging, flexible movement that is delicate and smooth, like a gentle touch. As suggested by one referee, this unexpected result of only one extracted factor may be due to the fact that Laban's is a theory of performing dance, rather than a theory of dance perception.

3.3 *Summary of movement coding*

The 203 stimuli were classified with movement descriptors of nineteen ballet-technique-relevant movement properties and coded into another six quantitative movement descriptors which a PCA reduced to three dimensions of movement: movement quantity, path (movement in horizontal plane), and manner (movement in vertical plane). Table 7 shows how these three dimensions relate to previous studies where movement descriptors were grouped into similar categories, as revealed by the PCA of our dataset (Camurri et al., 2003; Castellano et al., 2007; Cross et al., 2011; Dahl & Friberg, 2007; De Meijer, 1989; Laban, 1988; Montepare et al., 1999; Talmy, 1983, 1985, 2000a, 2000b).

The distinction among different movement dimensions outlined so far converges with the results of neuroimaging studies. For instance, the path and the manner of a moving object are processed in distinct neural systems (Wu, Morganti, & Chatterjee, 2008). When participants' attention was directed to the path (where?) of an object, the experience of motion correlated with activity in bilateral inferior and superior parietal lobe (ventral where-pathway in the brain). Conversely, when asked to attend to the manner of the movement (what/how?), enhanced activity was found in bilateral posterolateral inferior/middle temporal regions (dorsal what-pathway). Moreover, vertical motion has been found to engage posterior insula, while horizontal movement was related to an enhanced neural response in hippocampal areas (Indovina et al., 2013). This, altogether, gives support to the differentiation into the different movement dimensions outlined so far.

Table 7. Movement descriptors suggested in previous studies, compared with the present one.

Authors	Theory-based movement descriptors from different studies					
	form	how	strength	direction	tempo	count
Montepare et al. (1999)	form		force	direction	tempo	
De Meijer (1989)	direction		force	directness	velocity	
Dahl and Friberg (2007)	regularity	fluency		direction	speed	amount
Castellano et al. (2007)	CI	fluidity	acceleration		velocity	QoM
Laban (1988)		flow	weight	space	time	
Camurri et al. (2003)					SMI	
Cross et al. (2011)					quantity	
Wu et al. (2008)		manner		path		
Talmy (2000b)		manner		path		
Present study (PCA)		manner (vertical plane)		path (horizontal plane)	movement quantity	

Notes: CI = contraction index of the body, degree of contraction, and expansion of the body); QoM = quantity of detected motion; SMI = silhouette motion images, 'amount of motion'; PCA = principal component analysis.

The four Laban dimensions correlated among each other (except for the weight dimension). By means of a PCA, only one component could be extracted, and not the expected 4, which failed to confirm previous studies. This component, termed 'Laban score ' is thought to indicate how energetic a movement is.

The 25 movement parameters are reported in the Excel spreadsheet, as are the three components extracted by means of the PCA and the Laban score. The mean values of all four Laban dimensions (and SD) are also included.

4 Affective coding

Next, we proceeded to obtain ratings for each clip in terms of elicited affective responses. In the case of dance, research has mostly focused on perceived affect (Pollick et al., 2001). However, research in the field of music has shown that while listeners' ratings of felt and perceived affect are highly correlated, they do differ significantly (Hunter et al., 2010;

Juslin & Västfjäll, 2008; Vieillard et al., 2008). Therefore, extreme care was taken to ensure that participants rated their felt affect and not perceived affect (Bastiaansen et al., 2009). Specifically, we obtained ratings of *valence* and *arousal* following the International Affective Picture System (IAPS) approach (Lang, Bradley, & Cuthbert, 2008), as these two dimensions correspond to different neural and physiological responses (Kreibig, 2010; LeDoux, 2012).

4.1 *Participants*

Eighty-three students (eighteen male) participated in this part of the study (mean age = 21.29 years; SD = 2.56 years). They were all psychology students who had successfully completed the Psychology of Emotion and Motivation course. Thus, they were familiar with the concepts of 'valence' and 'arousal'. As a group, participants had hardly any relevant dance experience, and none had professional ballet experience[(2)] (mean years of dance training = 1.52; SD = 3.02 years, range = 0–19 years; mean years of ballet training = 0.49; SD = 1.98 years, range = 0–16 years), and they showed no extreme enjoyment or aversion towards viewing ballet, as shown by ratings on the 7-point Likert scale (administered in a postexperiment questionnaire: "How much do you enjoy watching ballet?", where 1 was "not at all" and 7 was "a lot") ($M = 4.43$; SD = 1.58).

4.2 *Materials*

The 203 stimuli were randomly assigned to three sets to prevent participant fatigue. Fifteen randomly selected video clips were shared between the sets for interrater reliability assessment. Thus, two of the sets contained 78 clips and one contained 77 clips, of which 15 were shared between the sets. Four additional practice trials were added to each set. These practice clips were the same in all sets. Data from these four clips were not analyzed. The clips were presented randomly in the stimulus presentation program DirectRT (http://www.empirisoft.com) v. 2006.2.0.28. The experiment was set up to run on six PCs (Windows XP SP3 PC Intel Pentium Dual Core), and stimuli were displayed on 19 inch screens.

Stimuli were presented on a black background with a canvas size of 16 × 10 cm and dancers occupying about 8–9 cm of the screen (from feet to head, not counting arm movements). Viewing distance was about 40 cm.

Each stimulus was presented twice in a counterbalanced order, once when rated on valence and once when rated on arousal (ratings were made on two separate 7-point Likert scales). Stimulus presentation was fully randomized.

4.3 *Procedure*

Participants signed up for the experiment in class in exchange for a partial course credit of one of their degree subjects. On the day of the experiment participants gave informed consent, provided personal data (gender, age, and level of study), and were randomly assigned to one of the three sets. Twenty-eight participants rated set A, twenty seven set B, and twenty eight set C. After the experimental session participants provided data regarding (i) their general level of liking of ballet; (ii) years of dance experience; and (iii) of ballet experience.

It was a self-paced task. Participants advanced from screen to screen by pressing the space bar. Each clip was shown twice and before each clip either the word 'arousal' or 'valence' was displayed (random order) to alert participants of the dimension to attend to. After the clip a Likert scale appeared, asking participants to indicate their level of arousal (1 = not arousing at all; 7 = very arousing) or asking them to indicate the valence of their affective state induced by the clip (1 = very negative; 7 = very positive). Ratings were made by means of key press on the number keyboard of the computer.

[(2)] Note: people who dance ballet as a hobby (such as the participant who had 16 years of ballet experience) are not considered professional ballet dancers. To enter into a category of professional (ballet) dancers—as a rough estimation—a person has ideally danced daily since the age of under 10 and is currently dancing *daily* for at least 8 hours (maintenance training, rehearsals, shows, and so on).

The experiment was carried out in a laboratory of the university with six PCs separated in individual booths. The light was turned off during the experimental session. Participants carried out the task in groups of 2–6 people. Each session took approximately one hour. The instructions given to the participants followed the approach proposed in the IAPS procedure (Lang et al., 2008); for more detail on the specific instructions see the supplementary material.

4.4 *Results*

4.4.1 *Descriptive results.* Descriptive statistics showed that the average valence of most clips was neutral ($M = 4.51$; SD = 0.71) and the average arousal was intermediate ($M = 4.00$; SD = 1.06). Table 8 shows the means and SD of the valence and arousal ratings as a function of the movement parameters (see supplementary material for more details about descriptive statistics of the set and about interrater reliability measures). Figure 4 represents the relationship between valence and arousal ratings.

Table 8. Descriptive statistics of the ratings of valence and arousal as a function of a selection of relevant movement parameters (ie size and impressiveness of movements, and the colour of the surroundings, etc) ($N = 203$).

Variable	Levels	*n*	Valence		Arousal	
			mean	SD	mean	SD
Jump	no jump	141	4.339	0.728	3.694	0.982
	small jump	42	4.823	0.532	4.648	0.894
	big jump	20	5.032	0.408	4.797	0.906
Angle	0°	42	4.073	0.880	3.740	1.234
	90°	78	4.613	0.634	4.032	0.938
	>90°	57	4.600	0.880	3.911	1.001
	passé	26	4.523	1.081	4.523	1.081
Location of arms	under axe	26	4.391	0.967	4.467	1.207
	over axe	177	4.531	0.668	3.932	1.022
Background colour	grey	76	4.739	0.616	4.080	0.986
	black	127	4.365	0.986	3.961	1.103
Stage props	none	115	4.348	0.666	3.762	1.055
	yes	88	4.715	0.723	4.311	0.987
Colour of clothes	white	67	4.284	0.694	3.519	1.173
	grey	100	4.648	0.692	4.165	0.921
	black	36	4.53	0.722	4.439	0.876

4.4.2 *Regression model of the movement parameters predicting valence and arousal ratings.* To test whether the prediction about the movement parameters predicting ratings of subjective affect (Castellano et al., 2007; Gross et al., 2010; Ma et al., 2006; Pollick et al., 2001, 2002) was also true for our movement library, we ran a regression model on the data. The predictor variables entered into the model were movement quantity, path (horizontal plane), manner (vertical plane), and the Laban score; the dependent variables were the valence and the arousal ratings, respectively. The variables retained in the regression model after backwards computation for valence and arousal ratings were path (horizontal plane), movement quantity, and Laban score. They explained 31.5% of the variance in the valence ratings, and 35.6% of the variance in the arousal ratings. See table S2 in the supplementary material for the model coefficients.

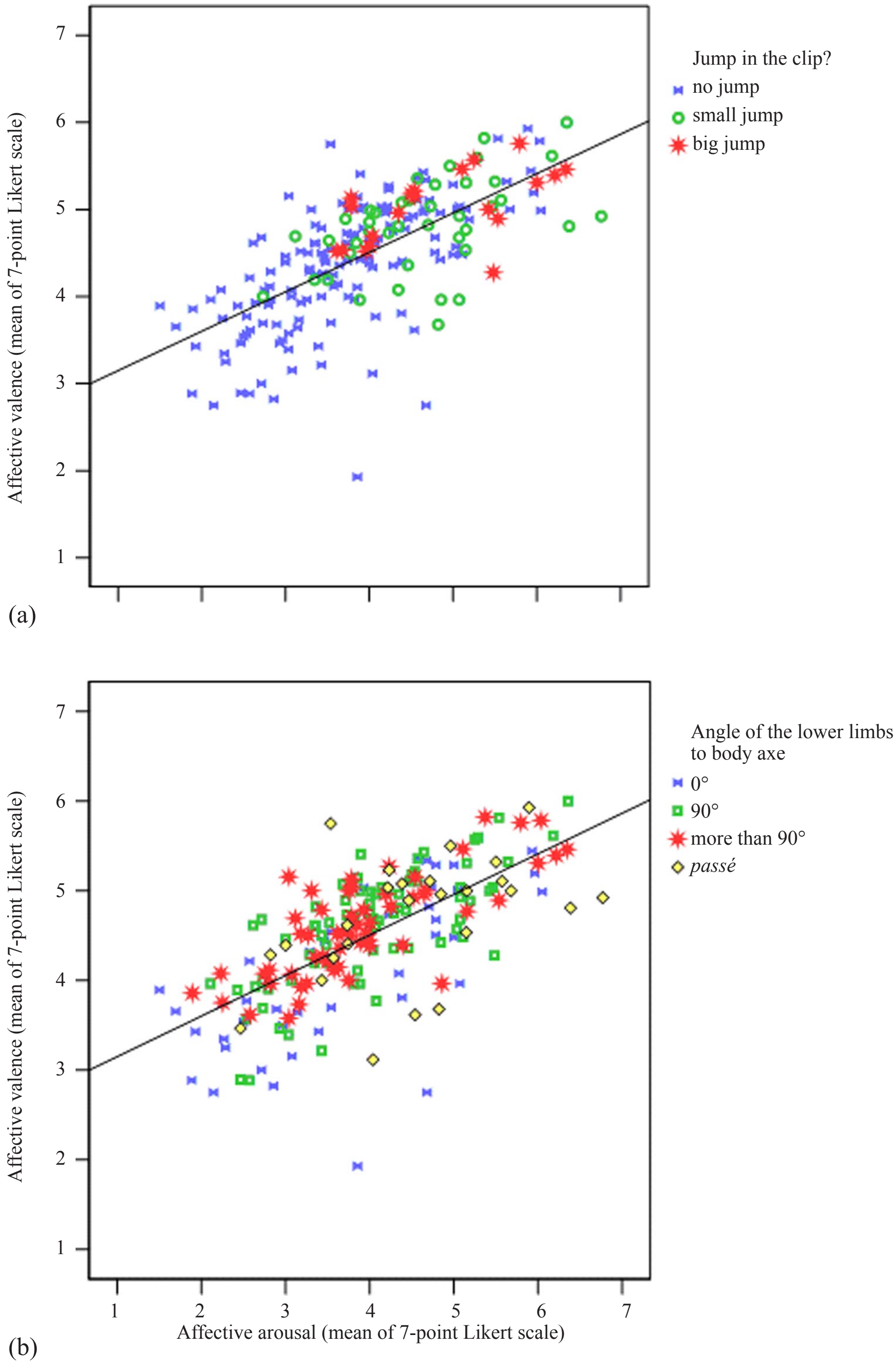

Figure 4. [In colour online, see http://dx.doi.org/10.1068/p7581] The two scatterplots are provided to illustrate the distribution of the arousal and valence ratings as a function of the different movement and contextual characteristics of the stimuli. (a) Jump in the sequence? (this relates to the size and impressiveness of jumps). (b) Angle of the limbs from body axe? (this relates to the size and impressiveness of large stretches of the limbs away from the body centre, eg impressive leg kicks, etc). It can be observed that the different stimuli characteristics are quite homogeneously distributed along the axes of the two rating scales arousal and valence (the supplementary material include four additional scatterplots, figure S2, representing other movement characteristics and how they relate to the arousal and valence ratings).

4.5 *Summary of emotion coding*

Results show that the valence and arousal ratings roughly follow a normal distribution. Most clips are neutral in valence and moderate in arousal. A regression model showed that the best prediction for the affective reactions elicited by these stimuli were the quantitative movement descriptors path (horizontal plane), movement quantity, and the Laban score. This means that the experience of more positive affect and higher arousal were related to movements that were more expansive in space (horizontal path), which contained higher frequency of movements (quantity), and which were more energetic, direct, and forcefully precise in execution (Laban score[(3)]) were related to the experience of more positive affect and higher arousal. This is in line with horizontal movement being more salient to the human perceptual system (Zago & Lacquaniti, 2005). Interestingly, the Laban score obtained for the present movements significantly predicted both arousal and valence ratings, while in the study by Gross and colleagues (2010) the Laban codings predicted only the valence ratings.

The mean valence and arousal ratings for each stimulus are displayed together with their SDs in the Excel spreadsheet (supplementary material). Researchers can, thus, eliminate those clips that have been found to induce negative affect (valence and arousal). This was proven to be important in a study with online psychophysiological measurement of musical experience, conducted in the laboratory of Robert Zatorre: here, data obtained while listening to musical excerpts that were rated as inducers of negative affect were eliminated as part of the data analysis strategy (very negative musical excepts may also induce arousal and thus confound the results). The result was a much cleaner dataset (Salimpoor et al., 2009).

5 Aesthetics coding

Within the field of empirical aesthetics, a number of rating scales are used to assess different aspects of an individual's experience of an artwork. Leder, Augustin, and Belke (2005) proposed five main verbal labels to probe for these differential aspects: preference, liking, beauty, pleasure, and interest. In our norming study we include the aesthetic assessment of three of these aspects which are clearly differentiable (beauty, liking, and interest; see supplementary material for further specification). In the experiment described in this section participants were asked to keep in mind that the stimuli they would be rating were artworks—specifically, dance movements. This aesthetic orientation has been shown to be a crucial component of the process of aesthetic appreciation (Cattaneo et al., 2013; Cupchik et al., 2009; Leder et al., 2005).

5.1 *Participants*

Eighty-five students (twenty-five male) participated in this part of the study ($M = 22.08$ years; SD = 4.67 years), none of which had taken part in any of the above experiments. As a group, participants had hardly any relevant dance or ballet experience (mean years of dance training = 1.68; SD = 3.32 years, range = 0–15 years; mean years of ballet training = 0.51; SD = 2.01 years, range = 0–14 years), and showed no extreme enjoyment or aversion towards viewing ballet, as shown by ratings on the 7-point Likert scale (administered in a postexperiment questionnaire: "How much do you enjoy watching ballet?", where 1 was "not at all" and 7 was "a lot") ($M = 4.34$; SD = 3.32).

5.2 *Materials*

The 203 stimuli were randomly assigned to four sets to prevent participant fatigue. Fifteen randomly selected video clips were shared between the sets for interrater reliability assessment. Each set contained 62 clips, of which 15 were shared across all four sets. Four additional practice trials were added. Data from these four clips were discarded before data analysis. The four practice clips were the same for each set.

(3) Reminder: Laban score is inversely coded; therefore, the value is negative.

The clips were presented as described in section 4 ('Affective coding'). However, in this part participants rated three Likert scales (7-point scales) in three counterbalanced blocks: beauty, liking, and interest. Stimuli presentation was fully randomized within blocks.

5.3 *Procedure*

The same procedure was followed as in section 4. Participants were randomly assigned to one of the four sets. Twenty-one participants rated set A, twenty one set B, twenty one set C, and twenty two set D. It was a self-paced task; participants advanced from one screen to the other by pressing the space bar. In the instructions special care was taken that participants were aware of the distinction between the three types of judgment they would be asked to perform.

The verbal label for the beauty scale was 1 = ugly (Spanish: *feo*) to 7 = beautiful (*bello*), and for the liking scale it was 1 = I don't like at all (Spanish: *no me gusta nada*) to 7 = I like it a lot (Spanish: *me gusta mucho*). For the interest ratings a different answer format was chosen. We anticipated that participants would find it odd to be asked to rate their 'interest ' for a dance movement, especially as they were nonexperts. We see the label 'interest' related to the phenomena of 'wanting' discussed in the field of the cognitive neuroscience of reward as the 'craving' for something that results in a motivation to engage in actions to obtain 'more of it'. To get in this mind-set, participants were instructed to imagine that they had a limited amount of money (eg 10 euro) and that they would be asked to indicate how much they would pay (from 10 cent to 70 cent) to see the clip they just saw once again. In so doing, we assumed that money-spending behaviour is a good indicator of how much a person wants something—that is, how interested he or she is in it. This measure is similar to recently used procedures in the field of neuroaesthetics of music (Salimpoor et al., 2013). During the experiment, pictorial representations of the three Likert scales were displayed on the screen asking the participant to make their judgment, with the corresponding label displayed above. Likert scales for beauty and liking ranged from 1 to 7, while the interest scale went from 10 to 70 (cents). In order to maintain the same format, the latter ratings were later recoded into 1–7 as the other two scales before data analyses. The ratings were made by means of key press on the number keyboard of the computer. Participants carried out the task in groups of 2–6 people. Each session took approximately one hour. After four practice trials, participants had the opportunity to ask further questions if required and the experimenter emphasized that it would be especially important to answer according to the very first thing they would feel and not deliberate over it too long.

5.4 *Results*

5.4.1 *Descriptive results.* Descriptive statistics showed that most of the clips were found moderately beautiful ($M = 4.52$; SE = 0.053) and liked ($M = 4.34$; SE = 0.054), while most clips did not elicit high interest ratings ($M = 3.07$; SE = 0.052) (see the supplementary material for more descriptive information and interrater reliability statistics).

5.4.2 *Results of the aesthetic ratings.* There were strong correlations between all three aesthetics scales: beauty scores correlated with liking ($p < 0.001$; $r = 0.676$), and with interest ($p < 0.001$; $r = 0.727$); and liking scores correlated with interest ($p < 0.001$; $r = 0.568$). A repeated-measures ANOVA with one factor (aesthetic dimension: interest, liking, beauty) was conducted to determine whether there were differences between the ratings made in the three scales. The main effect aesthetic dimension was significant ($F_2 = 630.067$, $p < 0.001$). Follow-up paired samples t-tests showed significant differences between the three scales, beauty ratings were higher ($M = 4.530$, SD = 0.754) than liking ratings ($M = 4.345$; SD = 0.808) ($t_{202} = 4.155$, $p < 0.001$), and than interest ratings ($M = 3.074$; SD = 0.7445) ($t_{202} = 37.519$, $p < 0.001$). Liking ratings were higher than interest ratings ($t_{202} = 25.168$, $p < 0.001$).

5.4.3 *Regression model of the movement parameters predicting the aesthetic codings.* In line with previous studies about particular movement parameters predicting aesthetics ratings (Calvo-Merino et al., 2008; Cross et al., 2011), we ran a regression analysis. The predictor variables entered into the model were path (horizontal plane), manner (vertical plane), movement quantity, and Laban score; the dependent variables were the ratings of beauty, liking, and interest, respectively. The variables retained in the regression model after backwards computation were movement path, movement quantity, and Laban score. They explained only 9.8% of the variance in the beauty ratings, and 10.9% of the variance in the liking ratings. Movement path and movement quantity explained 8.7% of the variance in the interest ratings. See table S3 in the supplementary material for the model coefficients.

5.5 *Summary of aesthetic codings*

Results show that the three aesthetics rating scales roughly followed a normal distribution. There were significant differences among the ratings in the three scales, confirming that also behaviourally these three concepts tap into different aspects of the aesthetic experience (Leder et al., 2005). The regression model showed that the best predictors of beauty and liking ratings were the quantitative movement descriptors movement path (horizontal plane), movement quantity, and the Laban score (though the proportion of variance accounted for by these variables was not high). The dance clips participants found particularly beautiful were those that included many (quantity) expansive horizontal (path) movements which were executed in an indulging, flexible, and gentle fluent way (Laban score[(4)]). Such movements were also liked more. Interest ratings depended crucially on whether the clips included many movements (quantity) that were also expansive horizontally in space (path). Horizontal movements may be particularly salient to the human perceptual system (Zago & Lacquaniti, 2005).

Stimuli can be selected according to the particular dimension of the appreciative process important for a particular study—whether it focuses more on the cognitive or affective components. According to Leder and colleagues (2005), the aesthetic dimension beauty relies more on cognitive process, while liking and interest are more related to the affective value the stimulus has for the individual. We found significant differences between the three scales, with the beauty and liking ratings being the highest. This suggests that ballet movements may be especially suited to elicit this kind of processing. Means and SDs are provided for each stimulus in the three aesthetic rating scales in the Excel spreadsheet (supplementary material).

6 Comparison across experiments

The resulting stimulus set comprises 203 ballet dance stimuli coded in 19 qualitative movement variables (10 specific movements; 6 movement dynamics; and 3 contextual variables). Furthermore, another 4 movement descriptors are included: (i) 3 obtained by PCA from the 6 movement dynamics descriptors which revealed that path (movement in horizontal plane), manner (movement in vertical plane), and quantity of the movements are the basic dimensions of these 6; and (ii) one obtained by PCA on the four movement dimensions of the Laban shape–effort theory. Furthermore, clips were rated in felt affective valence and arousal and in the aesthetic dimensions beauty, liking, and interest. Regression models showed that the movement factors path, movement quantity, and the Laban score were those that best predicted both affective and aesthetics ratings.

As a final perspective over the relationships between the most relevant variables (main and summary variables) coded throughout the here-reported experiments, we provide a correlation matrix (see table 9). Starting from the leftmost column, the table illustrates that the variable manner does not show any correlations or trend effects with the other variables.

[(4)] Reminder: it is inversely coded; here, the value is positive.

Table 9. Correlations resulting from all coding experiments.

	Movement coding				Affective perception		Aesthetic appreciation		
	manner (vert.)	path (horiz.)	quantity	Laban score	valence	arousal	beauty	liking	interest
Movement coding									
manner (vert.)	1	0.000	0.000	–0.014	0.083	0.034	0.060	0.057	0.037
		1.000	1.000	0.839	0.237	0.632	0.397	0.420	0.596
path (horiz.)		1	0.000	0.130	0.136	0.090	**0.173***	**0.205****	0.135
			1.000	*0.064*†	*0.054*†	0.202	**0.014**	**0.003**	*0.054*†
quantity			1	**–0.313****	**0.489****	**0.467****	**0.231****	**0.211****	**0.263****
				0.000	**0.000**	**0.000**	**0.001**	**0.002**	**0.000**
Laban score				1	**–0.362****	**–0.473****	0.066	0.102	**–0.159***
					0.000	**0.000**	0.353	0.148	**0.024**
Affective perception									
valence					1	**0.673****	**0.394****	**0.374****	**0.425****
						0.000	**0.000**	**0.000**	**0.000**
arousal						1	**0.139***	**0.283****	**0.437****
							0.049	**0.000**	**0.000**
Aesthetic appreciation									
beauty							1	**0.680****	**0.727****
								0.000	**0.000**
liking								1	**0.575****
									0.000
interest									1

Notes: * Correlation is significant at the 0.05 level (2-tailed); ** correlation is significant at the 0.01 level (2-tailed) (both given in bold); † correlation with a trend effect (2-tailed) (given in italics); horiz. = horizontal; vert. = vertical.

The variable path shows trend effect correlations with the Laban score and the affective responses: the softer and expansive the movements, the more positive and highly arousing they were perceived to be. More expansiveness in space was correlated with higher ratings in the scales of beauty, liking, and interest. Also, quantity of movement correlated with positive valence and high arousal, and all the aesthetics ratings. Besides this, the negative correlation with the Laban score also confirms that the latter has something to do with how the movement is executed. These data are in agreement with previous research, both with studies where movement parameters were quantified with the help of dance professionals and with studies using computerized movement quantification indices. High scores in such movement parameters correlate with enhanced neural activity in the AON, high subjective arousal, and increased aesthetic experience (Calvo-Merino et al., 2008; Camurri et al., 2003; Castellano et al., 2007; Cross et al., 2011; Ma et al., 2006; Pollick et al., 2001, 2002). Now, a different level of understanding of this correlation is possible given our dance-theory-sensitive way of coding movements.

The Laban score is negatively correlated with valence and arousal. This basically confirms the positive correlations among valence and arousal ratings and the variables movement path and movement quantity, respectively. Regarding the aesthetics dimensions, the Laban score correlates with interestingness. Given that the Laban score represents *how energetic* the movement is, these three data points together seem to suggest that a dance movement's interest depends on its saliency (horizontally expansive movement of high frequency) and, at the same time, on the fluent quality of the movement (Laban score). This result fits with Berlyne's (1974) theory when applied to dance, in that it connects the quality of the movement with arousal and aesthetic value.

Additionally, affective valence and arousal are both correlated with all three *aesthetics* ratings, which is coherent with previous work in the field of empirical aesthetics with paintings. In particular, nonexperts tend to find art that evokes positive and pleasant responses as more likable, more beautiful, and more interesting than art works which induce negative and/or only low arousal states in them (Leder et al., 2004). The latter will commonly be considered unappealing or boring. For views on how to contextualize such results in the empirical aesthetics domain, please refer to the following authors: Berlyne (1974), Chatterjee (2003, 2011), Freedberg and Gallese (2007), Leder et al. (2004), Reber, Schwarz, and Winkielman (2004), and Shimamura (2012).

An Excel spreadsheet with all relevant data points about this movement library accompanies this manuscript (supplementary material), and stimuli can be obtained from the authors upon request. Please do refer to the supplementary material for a discussion of the potential limitations of this stimulus library.

7 Conclusion

We have developed a library of ballet movements for scientific research into diverse aspects of movement processing, ranging from low-level processing of movement patterns to high-level processing of aesthetic quality and experience. Although the stimuli may not be suitable to assess all possible research questions, this library has a number of advantages. First, it has been extensively coded in variables which are relevant to three different areas of research: movement, affect perception, and aesthetic appreciation. Second, the stimuli present a high level of experimental control due to the rigorous selection criteria and removal of conflicting information from other emotion conveying modalities such as the face, colour, music, and other sounds. Third, they offer a rather high level of ecological validity because they were taken from real dance performances and may therefore more easily also be considered 'art' by participants who are experts in the dance domain (Bullot & Reber, 2013; Christensen & Calvo-Merino, 2013). Fourth, the set was selected controlling for selection biases due to personal taste, while also respecting the rationale of the movements.

We conclude that the resulting ballet movement library affords behavioural, psycho-physiological, and neuroscientific studies whose research questions span aspects of motor, affect, and aesthetic perception. The numerous coding parameters provided for each clip allow for both a *theoretically motivated* and for a *movement-based* stimulus selection. This may enhance the level of experimental control in future studies, without sacrificing ecological validity for dance stimulus materials. Therefore, related fields—such as sports sciences, memory, or health psychology—may also find these stimuli useful.

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