Perception, 2013, volume 42, pages 642 – 657

doi:10.1068/p7364

Perceived gesture dynamics in nonverbal expression of emotion

Nele Dael[1] §, Martijn Goudbeek[2], K R Scherer[1]
[1] Swiss Centre for Affective Sciences, University of Geneva, 7 rue des Battoirs, 1205 Geneva, Switzerland; [2] Department of Communication and Information Sciences, Tilburg School of Humanities, Tilburg University, PO Box 90153, 5000 LE Tilburg, The Netherlands
Received 3 September 2012, in revised form 9 June 2013

Abstract. Recent judgment studies have shown that people are able to fairly correctly attribute emotional states to others' bodily expressions. It is, however, not clear which movement qualities are salient, and how this applies to emotional gesture during speech-based interaction. In this study we investigated how the expression of emotions that vary on three major emotion dimensions—that is, arousal, valence, and potency—affects the perception of dynamic arm gestures. Ten professional actors enacted 12 emotions in a scenario-based social interaction setting. Participants ($N = 43$) rated all emotional expressions with muted sound and blurred faces on six spatiotemporal characteristics of gestural arm movement that were found to be related to emotion in previous research (amount of movement, movement speed, force, fluency, size, and height/vertical position). Arousal and potency were found to be strong determinants of the perception of gestural dynamics, whereas the differences between positive or negative emotions were less pronounced. These results confirm the importance of arm movement in communicating major emotion dimensions and show that gesture forms an integrated part of multimodal nonverbal emotion communication.

Keywords: gesture, dynamics, emotion dimensions, emotion expression, movement perception

1 Introduction

Judgment studies have repeatedly shown that people can fairly accurately decode emotionally relevant cues from others' nonverbal expressions and that they use them to make inferences about the emotional states of others. While research in nonverbal emotion communication is well developed in the domains of facial expression (for reviews see Ekman 1992; Keltner et al 2003; Russell et al 2003) and vocal expression (for reviews see Juslin and Laukka 2003; Juslin and Scherer 2005; Scherer et al 2003), a thorough understanding of the role of body movement, posture and especially gesture in emotion communication is still lacking (but see de Gelder 2006; Schindler et al 2008).

Previous studies have shown that static properties of postures enable emotion perception (Coulson 2004; Tracy and Robins 2004). Recently, the dynamic qualities of body movement have gained increasing research attention as carriers of emotionally relevant information (Atkinson et al 2004; Dittrich et al 1996; Glowinski et al 2011; Wallbott 1998). The current study is situated in this growing research area and investigates the effect of expressed emotion on the perception of gesture dynamics.

1.1 *Gesture as a system used in nonverbal emotion communication*

Gesture forms a specific group of body actions; they are performed mostly by the hands, arms, and sometimes the head (such as nodding in agreement). They usually but not exclusively occur during speech interaction. Usually, a distinction is made between gestures and other types of hand, arm, and other body movements based on the defining feature that gestures are

§ Nele Dael is now at the Institute of Psychology, University of Lausanne. Correspondence concerning this paper should be addressed to Nele Dael, Institute of Psychology, University of Lausanne, Bâtiment Anthropol – Quartier Dorigny, CH-1015 Lausanne, Switzerland; e-mail: Nele.Dael@unil.ch

voluntary actions that arise from the deliberative attempt to convey semantic and pragmatic information, and are recognized as such by the viewer (Kendon 2004). However, in the study of body movement gesture is rarely treated as an autonomous expressive system, but is usually included in a broad range of communicative and regulatory body actions with varying degrees of communicative intention and connection to the verbal utterance (Harrigan 2005).

Currently, gesture studies focus on the cognitive–linguistic functions served by gesture (Kita et al 2007; McNeill 2005), largely ignoring the role of gesture in emotion communication. This is surprising since the importance of body movement in emotion expression and perception has been emphasized in neighbouring fields such as dance (Dittrich et al 1996; Sawada et al 2003) or psychiatry (for diagnosing affective disorders, see Hall et al 1995; Wallbott 1985). Recent brain imaging studies have shown that body-selective areas in the brain (extrastriate body area and fusiform body area) are more strongly activated when viewing emotional compared with neutral body expressions. This network of brain activation, possibly modulated by concurrent amygdala activation, could serve to facilitate detection of emotionally salient body stimuli (Peelen et al 2007). But what makes body stimuli 'emotionally salient'? In the next subsection a review of the literature on the kinesics of emotion suggests a number of critical features responsible for emotion perception.

1.2 *Gesture dynamics as candidates for expressed and perceived emotion*

The expressive value of gesture for emotion can be examined via both categorical and dynamic approaches. In a categorical approach, one investigates the types of gestures that are used to convey emotion, based on a functional description [such as self-manipulators and illustrators: see, for example, Dael et al (2012); Ekman and Friesen (1972); Wallbott (1998)] or an anatomical-form description such as certain arm configurations and movement directions (see eg Dael et al 2012; Tracy and Robins 2004; Wallbott 1998). In a dynamic approach one focuses on the dynamic qualities of gestural movements—that is, the way in which gestures are performed with respect to time and space (eg Pollick et al 2001; Wallbott 1985). For example, investigations of point-light displays of full-body emotional expressions [including arm gestures: Atkinson et al (2004, 2007)] have shown that both form and kinematic aspects contribute to accurate emotion recognition.

These studies, however, do not report exactly which movement qualities are responsible for these effects. Only a few other studies have specifically investigated distinct qualities. For example, in a study on emotion perception from arm action, Pollick and colleagues (2001) found that perceived emotional activation (arousal) is positively related to temporal parameters (such as velocity, acceleration, jerk), whereas the correlates of valence were less clearly related to unspecified spatial properties. Other similar studies have corroborated the role of spatiotemporal movement qualities in expressing or perceiving emotion (eg Gross et al 2010; Montepare et al 1999; Sawada et al 2003).

In one of few studies of conversational hand movement quality Wallbott (1985) compared objective parameters (distal cues) and their perceptual representations (proximal cues) of hand movement quality of psychiatric patients with affective disorders during admission and discharge interviews. The results indicated that both distal and proximal cues that are related to hastiness, intensity, fluency, and spatial expansiveness were reliably but incorrectly used in the evaluation of a patient's improvement during the course of therapy. This study illustrates that movement judgments that are related to perceptual attributions of states do not guarantee validity as indicators of the actual, expressed states. So far, emotion perception research has focused on the relationship between movement cues and attributed emotion, without addressing the link to expressed emotion. The question is what dynamic characteristics of speech-accompanying arm movement are indicative of the internal state of the expresser, driving the impression formation process leading to emotion recognition in the perceiver.

In a later study on normal emotion expression Wallbott (1998) reported that judgments of whole-body movement activity, expansiveness (spatial extension), and movement energy significantly differentiated expressed emotions. Values were highest for active emotions such as elated joy, hot anger, and terror, and lowest for sadness, boredom, and contempt. Others reported similar differential effects of (expressed or perceived) emotion on movement quality based on distal or on proximal descriptors (de Meijer 1989; Gross et al 2010; Montepare et al 1999; Sawada et al 2003; Wallbott and Scherer 1986). In addition to these characteristics, the vertical direction of arm movement or the spatial location of the arms is found to differentiate positive from negative emotions in whole-body dance expression (de Meijer 1989) and in sign language (Reilly et al 1992). Arms raised upward have been particularly associated to joy (Coulson 2004; Wallbott 1998) and pride (Tracy and Robins 2004).

1.3 *Emotion dimensions*

It has long been assumed that, in contrast to facial muscle configurations, body movements or postures are not reliable indicators of specific emotions but provide only information of gross affect state (such as liking) or emotion intensity (original studies by Ekman 1965; Ekman and Friesen 1967; see Harrigan 2005). This view is no longer supported by the recent studies mentioned above. However, much of the cited work in this area has been atheoretical, searching to empirically determine which changes in movement quality are associated with specific emotions. Stimulus sets often comprise a limited number of basic emotions, so it is not evident what mechanism underlies the expression and perception process.

Studies that included a large pool of emotions have repeatedly found that differences between emotions could be meaningfully explained by dimensions of intraindividual and interindividual states including arousal, valence, potency, attention orientation, and approach-avoidance action tendencies (Dael et al 2012; de Meijer 1989; Pollick et al 2001; Wallbott 1998). However, evidence is strongest and most replicated for the arousal dimension and less clear-cut for other dimensions. The powerful effect of arousal is also documented in studies of vocal emotion expression (Banse and Scherer 1996; Goudbeek and Scherer 2010).

Nevertheless, emotion research provides evidence for at least three major dimensions underlying emotion experience and expression: arousal, valence, and potency (Osgood 1966; Osgood et al 1975; Smith and Ellsworth 1985). Arousal represents the degree of physiological excitation of the sympathetic nervous system (Frijda 1986; Wundt 1897). Valence refers to the intrinsic pleasantness or goal conduciveness of the emotion-eliciting object or event (Scherer 2001, 2009; Smith and Ellsworth 1985; see also Wundt 1897). Potency refers to the individual's sense of power or control over the emotion-eliciting event (Osgood 1966; Scherer 2001, 2009; Smith and Ellsworth 1985). In a large cross-cultural survey study Fontaine and colleagues (2007) emphasized the importance of these dimensions in explaining the variance in the meaning of emotion words on scales representing 144 features referring to six major components of emotion including bodily or gestural expressions and action tendencies derived from appraisal theory (Frijda et al 1989; Scherer 2001).

1.4 *Research questions*

In this study we investigate how emotion expressed through body movement affects movement perception. We want to focus in particular on gestural arm movement, given that this is one of the most frequently used, but also one of the most understudied means of communication in affective science. By studying its perception, we aim to get a better understanding of the spatiotemporal characteristics of gesture that are indicative of expressed emotion and that can be perceived by lay observers, making them valid and available cues to infer emotion.

On the basis of a componential view on emotion and in accordance with previous literature, we hypothesize that emotional arousal, valence, and potency will be associated with specific spatiotemporal characteristics perceived in gestural arm movement. The predictions

Table 1. Predictions of and support for perceived gesture dynamics associated with expressed emotion dimensions.

Expressed emotion dimension	Perceived gestural arm movement	Support from this study
High (low) potency	forceful (weak)	ME, IE × arousal
	expansive (contracted)	ME, IE × arousal
Positive (negative) valence	fluent (abrupt)	ME, no IE × arousal
	higher (lower) in space	No ME, IE × arousal, IE × arousal × potency
High (low) arousal	abundant (few) movement	ME
	Fast (slow)	ME

Notes: We expect that the effects of potency and valence will be larger for high arousal emotions; ME = main effect; IE = interaction effect.

are summarized in table 1. From our expectation that the overall amount of movement is a function of emotional arousal, we predict that the effects of valence and potency will be more pronounced (and identifiable) for high-arousal emotions.

2 Method

2.1 *Participants*

Forty-three undergraduate students (ten males, thirty-three females), drawn from the subject pool of Tilburg University, participated in this study (age $M = 22.6$ years, SD = 5.2 years) in exchange for course credit.

2.2 *Material*

The Geneva Multimodal Emotion Portrayals (GEMEP) corpus was developed at the University of Geneva (Bänziger and Scherer 2010) and can be used for unimodal and multimodal perception and production research (see Bänziger et al 2012). In this corpus ten professional actors (five females) enacted eighteen emotions in a scenario-based emotional interaction setting. The selection of emotions is based on the literature in emotion psychology and includes some less studied but common emotions in order to increase variability and thus representativeness to everyday situations. The systematic and standardized sampling approach has several benefits, but the use of actors also implies a number of drawbacks, such as possibly stereotypical expressions (see Scherer and Bänziger 2010).

For this study we used a standard selection of GEMEP portrayals based on previous rating studies ensuring high believability and recognizability of the enacted emotion (Bänziger and Scherer 2010; Bänziger et al 2012). In this subset ($N = 120$) each actor expressed twelve emotions (table 2) while producing standardized nonlinguistic sentences during interaction ("ne kali bam soud molen" or "koun se mina loud belam"). For the current study we used video recordings of the frontal view of the body from the knees upwards. The actors did not receive any instructions regarding bodily expression apart from the restriction not to move away from camera view. A complete description of the GEMEP material, recording, and validation procedure can be found in Bänziger and Scherer (2010) and in Bänziger et al (2012).

The selected emotions are characterized by different levels of arousal (activation), valence (pleasantness), and potency (power/control) according to present-day conceptualizations of emotion [such as their positions on a two-or-three-factor model: Russell and Mehrabian (1977), Russell and Barrett (1999); or their associated appraisal outcomes according to the component process model: see table 5.4 in Scherer (2001, 2009)] as well as previous empirical findings (eg Fontaine et al 2007; in Scherer 2005, figure 1). Table 2 lists the theoretical assumptions concerning the position of the selected emotions on the three dimensions. The emotional

Table 2. Selection of emotional states and their theoretical positions on the arousal, valence, and potency dimension.

Arousal	Valence	
	positive	negative
High	**elated joy**	**hot anger (rage)**
	amusement	panic fear
	pride	despair
Low	**pleasure**	**cold anger (irritation)**
	relief	anxiety (worry)
	interest	sadness (depression)

Note: Emotions with high potency are shown in bold.

portrayals are not equally distributed over each of the eight level combinations (2 × 2 × 2) because positive emotions are mostly characterized by high potency and negative emotions by low potency. This is illustrated in the study of Fontaine and colleagues (2007), where almost all positive emotion terms were located on the upper half of the potency dimension. To complement the a priori theoretical arguments for the arousal, valence, and potency values of these emotions, we explicitly asked our participants to judge these emotion dimensions. While not the topic of the current study, these judgments will be briefly presented to argue for each emotion's positioning on the arousal, valence, and potency dimensions.

2.3 *Procedure*

Participants viewed and rated all 120 emotional portrayals. The sound was switched off, and the faces were blurred from the videos to exclude facial and vocal information. The face-blurring procedure was performed in Adobe Premiere Pro, where a Gaussian blurring filter[(1)] was applied to the manually selected face area, which was adjusted for head movement at the frame level.

The presentation order of the portrayals was randomized across participants. Participants rated each portrayal on a total of eleven continuous scales represented by a slider on the screen, which was by default anchored at the midpoint. Participants rated six characteristics of arm movement (amount of movement, speed, force, fluency, size, and height/vertical position). Verbal labels appeared at both ends of each scale. Table 3 presents the verbal descriptions and labels of each arm movement rating scale. When the participants did not perceive any arm movement, they were instructed to put the cursor at the zero point of the

Table 3. Labels and descriptions of the six arm movement rating scales.

Movement scale	Verbal description and labels at opposite ends of the scale
Amount	amount of arm movement: active / passive
Speed	speed by which the arms are moving: slow / fast
Force	physical effort put in the arm movement: strong / weak
Size	spatial extent or span of arm movement: compact / expansive
Fluency	smoothness of speed changes: abrupt / fluent
Height	vertical location of the arms compared to the person's body: low (close to the ground)/high (stretched up in the air)

[(1)] An optimal blurring effect—that is, removing any visible facial expression—was obtained by adopting a Gaussian blurring filter with factor 50 on the blurriness scale from 0 to 100 on the horizontal and vertical dimension of the selected face area.

scale (extreme left). We then assessed the believability of the expression in the framework of using acted expressions for virtual animation, and defined it as the capacity of the actor to produce a believable and convincing bodily expression of emotion, ranging from very low to very high. Following their judgment of believability, participants were instructed to rate an additional four emotion dimensions (valence, potency, arousal, and intensity).

2.4 *Rater reliability and data selection*

Data selection was based on three levels of analysis. First, average interrater correlations based on all eleven scales were above 0.20, so none of the participants was removed based on this criterion [see the online appendix (http://dx.doi.org/10.1068/p7364) for the interrater correlations for the six movement scales, and see Dael et al (submitted) for the interrater correlations for the other scales]. Second, we performed standard outlier analysis (Tukey 1977) on the average scores per participant on each of the eleven scales. Two participants were identified as outliers on at least one scale and were thus removed from the dataset.[(2)] We further identified and excluded two participants who rated at least ten of the eleven scales with values in the range of the five highest or five lowest ratings. Third, assessment of the intrarater variations revealed one participant with an average standard deviation of more than two standard deviations below the average standard deviation across participants ($M = 0.26$, SD = 0.04). The rating pattern of this participant suggested that he or she did not take the task seriously. In total, five participants were removed from the dataset (new $N = 38$).

On this corrected dataset[(3)] we calculated the average interrater correlation and effective reliability per scale [using the Spearman–Brown coefficient (see Rosenthal 2005)]. As can be seen in table 4, the judgment of movement fluency showed the least amount of agreement ($r = 0.28$), but nevertheless all scales were very reliable (overall $R_{SB} = 0.97$).

Table 4. Average interrater correlation and effective reliability per scale.

Movement scale	r	R_{SB}	Movement scale	r	R_{SB}
Amount	0.68	0.99	Size	0.62	0.98
Speed	0.66	0.99	Fluency	0.28	0.94
Force	0.62	0.98	Height	0.42	0.96

Mean: $r = 0.54$, $R_{SB} = 0.97$.

3 Results

3.1 *Believability of the portrayals*

We asked participants to rate the believability of the portrayals as a validation check. The average perceived believability is somewhat lower than the perceived believability reported on the original GEMEP material from which we derived our dataset [$M = 0.51$ versus $M = 0.67$ in Bänziger and Scherer (2010)]. This drop is most likely due to the fact that the faces of the actors were blurred, eliminating an important set of cues in believability assessment.

3.2 *Perceptual validation of emotions on the arousal, valence, and potency dimensions*

In the current study we are interested in how emotion expressed in the body affects movement perception. Before we assess the effects of expressed arousal, valence, and potency on movement perception, we validate a priori defined positions of the twelve emotions on these dimensions.

(2) One outlier participant showed extremely low ratings for the believability scale and three of the four emotion dimension scales. A second outlier participant showed extremely high ratings for the believability scale, which could be due to social desirability.

(3) We report missing data for one portrayal (the portrayal of sadness enacted by actor 10 was not rated). In addition, six data points are missing due to experimental error.

In an exploratory principal components analysis on the ratings of valence, arousal, and potency (reported in Dael et al, submitted), the relative positions of ten of the twelve emotions on the three components representing valence, arousal, and potency confirm the proposed classification of the emotions on the same three dimensions (table 2). Our face-blurred expressions did not allow the raters to accurately detect relief as a positive emotion and pleasure as a high-potency emotion, possibly because of inaccurate judgment strategies such as the overgeneralization of certain cues such as movement speed or force.

We further verified whether the emotion dimension ratings support this theoretical classification in three ANOVAs (one for each rated dimension) with expressed emotion (12) as a within-subjects variable. There was a significant effect of the expressed emotion on emotion dimension rating (for arousal: $F_{6.40, 236.81} = 179.50$, $p < 0.001$, $\eta^2 = 0.83$; for valence: $F_{2.23, 82.42} = 16.41$, $p < 0.001$, $\eta^2 = 0.31$; for potency: $F_{2.87, 106.30} = 26.56$, $p < 0.001$, $\eta^2 = 0.42$; all values are Greenhouse–Geisser corrected for violations of sphericity ($\chi^2_{11} = 5.6, p < 0.001$)]. Crucially, we used planned contrasts to assess whether emotions with opposite positions on the three dimensions significantly differ in the rating of the dimensions. The critical contrasts for the classification matching the rated dimension (eg expressed arousal–rated arousal) were all significant and stronger than constrasts for nonmatching classifications (eg expressed potency–rated arousal). Emotions classified as high in arousal were rated as more arousing than emotions classified as low in arousal ($F_{1,37} = 550.45$, $p < 0.001$, $\eta^2 = 0.94$). Emotions classified as positive were rated as more positive that emotions classified as negative ($F_{1,37} = 50.83$, $p < 0.001$, $\eta^2 = 0.58$). Emotions classified as high in potency were rated as more potent that emotions classified as low in potency ($F_{1,37} = 91.42$, $p < 0.001$, $\eta^2 = 0.71$). These results, complemented by the principal components analysis, show that the rating pattern follows the proposed classification of emotions along the three dimensions. In all, these findings provide empirical support for the theoretical classification of the twelve emotions on the dimensions of valence, arousal, and potency.

3.3 *Effects of expressed emotion on movement perception*

To test whether emotion had a significant effect on perceived movement, we performed a within-subjects MANOVA with emotion (12 levels) and perceived movement characteristic (6 levels: amount of movement, speed, force, fluency, size, and height/vertical position) as two within-subject factors. The general model showed a significant main effect of emotion ($F_{11,27} = 63.10$, $p < 0.001$). The spatiotemporal characteristics of gestural arm movement are thus rated differently for different emotions, as illustrated in figure 1. We continued to analyze the effects of emotional valence, arousal, and potency in one ANOVA per movement characteristic with arousal, valence, and potency as three within-subjects factors with two levels each. To do so, we averaged the ratings for emotions within each level of potency (high, low), valence (positive, negative), and arousal (high, low).

Tables 5 and 6 show a detailed overview of all main and interaction effects.[(4)] The size and number of significant effects show that emotional arm movement strongly influences movement perception. To examine the relative importance of the different emotion dimensions, we compared the effect sizes. The results showed that arousal and potency have significant and large effects on all perceived movement characteristics, whereas the effects of valence were less pronounced (table 5). All main effects are moderated by a number of interactions between all three emotion dimensions (table 6).

A closer look at the effects per movement characteristic reveals a number of patterns that support our hypotheses. Evidently, the perceptual judgment of the amount of movement was higher for the high-arousal emotions ($F_{1,37} = 743.90$, $p < 0.001$, $\eta^2 = 0.95$), but also for high

[(4)] A posteriori pairwise comparisons replicated this pattern of results (Bonferroni-corrected for the number of comparisons, $p = 0.0083$).

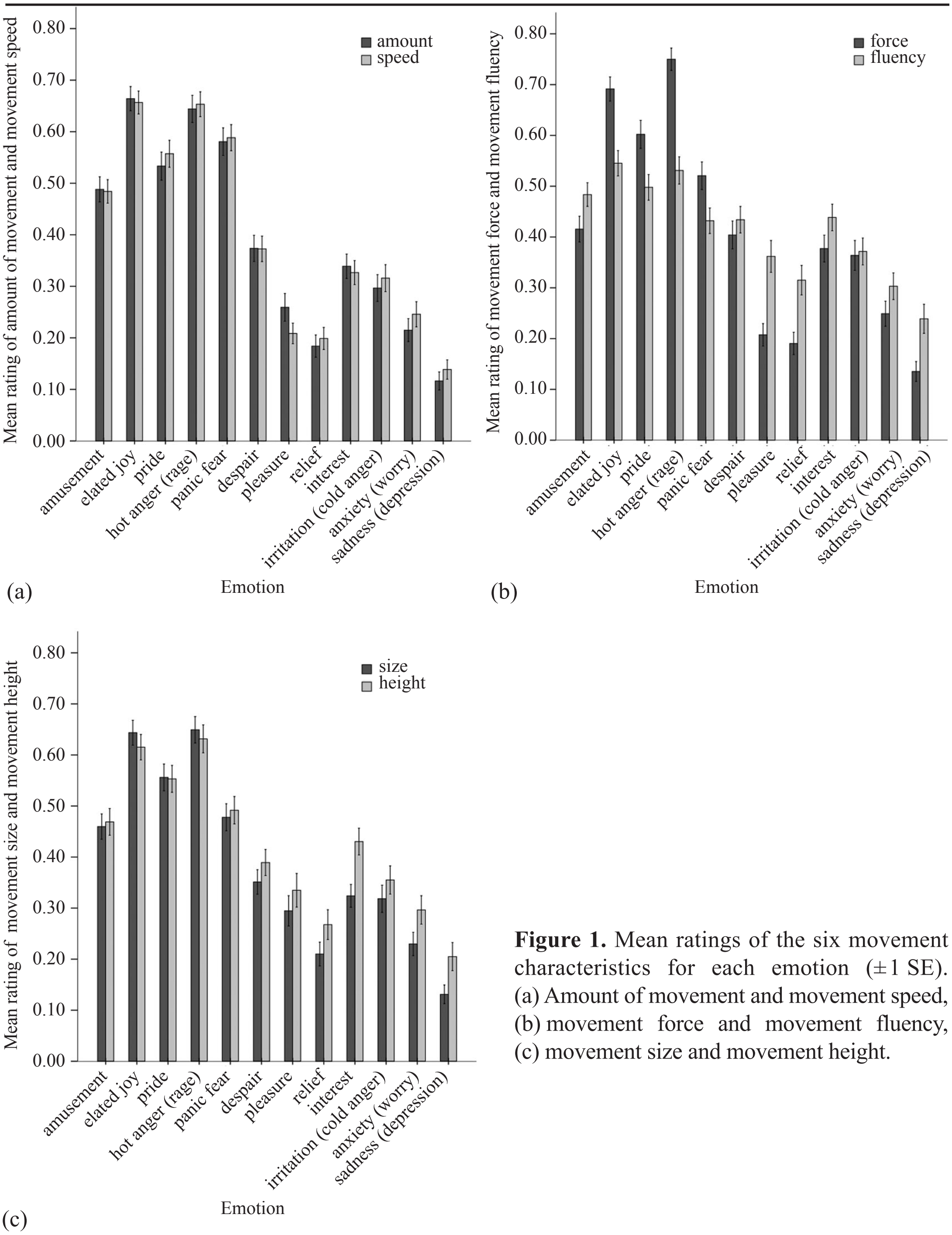

Figure 1. Mean ratings of the six movement characteristics for each emotion (±1 SE). (a) Amount of movement and movement speed, (b) movement force and movement fluency, (c) movement size and movement height.

potency emotions ($F_{1,37} = 429.37$, $p < 0.001$, $\eta^2 = 0.92$), with the main effects being additive (no significant interaction; see also figure 2). Also, as predicted, arousal has a main effect on perceived movement speed ($F_{1,37} = 558.34$, $p < 0.001$, $\eta^2 = 0.94$). Figure 3 shows that high-arousal and high-potency emotions, in particular, are characterized by faster perceived movement than low-arousal and low-potency emotions, while the effect of valence was very small.

We expected that high potency would be positively related to force and size, and that this effect would depend on the level of arousal. This is exactly what we found. The effect of potency on perceived movement force ($F_{1,37} = 469.82$, $p < 0.001$, $\eta^2 = 0.93$) was especially pronounced in the high-arousal group (interaction effect: $F_{1,37} = 46.67$, $p < 0.001$, $\eta^2 = 0.56$) (see figure 4).

Table 5. ANOVA statistics for the main effects of arousal, valence, and potency.

Movement scale	Arousal			Valence			Potency		
	F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
Amount	743.39	***	0.95	0.72	0.40	0.20	429.37	***	0.92
Speed	558.43	***	0.94	15.99	***	0.30	342.23	***	0.90
Force	712.77	***	0.95	60.83	***	0.62	469.82	***	0.93
Size	531.46	***	0.94	0.49	0.49	0.01	450.23	***	0.92
Fluency	40.32	***	0.52	18.69	***	0.34	40.36	***	0.50
Height	80.46	***	0.69	0.99	0.33	0.03	80.03	***	0.68

***$p < 0.001$.
Note: All dfs are 1, 37.

Table 6. ANOVA statistics for the interaction effects of arousal, valence, and potency.

Movement scale	Arousal × valence			Arousal × potency			Valence × potency			Valence × potency × arousal		
	F	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2	*F*	*p*	η^2
Amount	7.41	*	0.17	0.92	0.34	0.02	9.68	**	0.21	4.07	0.05	0.10
Speed	0	0.98	0	8.75	**	0.19	32.23	***	0.47	0.13	0.72	0
Force	8.77	**	0.19	46.67	***	0.56	27.40	***	0.43	0.30	0.59	0.01
Size	1.51	0.23	0.04	24.56	***	0.40	30.75	***	0.45	10.34	**	0.22
Fluency	2.20	0.15	0.06	1.77	0.19	0.05	8.19	**	0.18	3.18	0.08	0.08
Height	6.75	*	0.15	7.25	*	0.16	4.90	*	0.12	13.90	**	0.27

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
Note: All dfs are 1, 37.

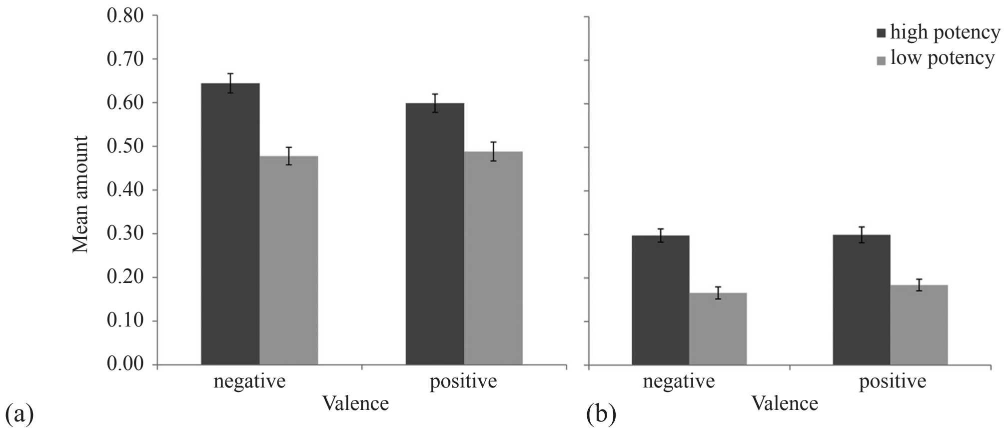

Figure 2. Effects of valence, potency, and arousal on the rating of amount of movement (±1 SE). (a) High arousal, (b) low arousal.

Also, the effect of potency on perceived movement size ($F_{1,37} = 450.23$, $p < 0.001$, $\eta^2 = 0.92$) was larger in the high-arousal group (interaction effect: $F_{1,37} = 24.56$, $p < 0.001$, $\eta^2 = 0.40$) (see figure 5).

We hypothesized that portrayals of positive emotions would be perceived as more fluent and higher in space than negative emotions. We further expected that the level of arousal moderates this effect of valence. The results partially support these hypotheses. Although valence has the

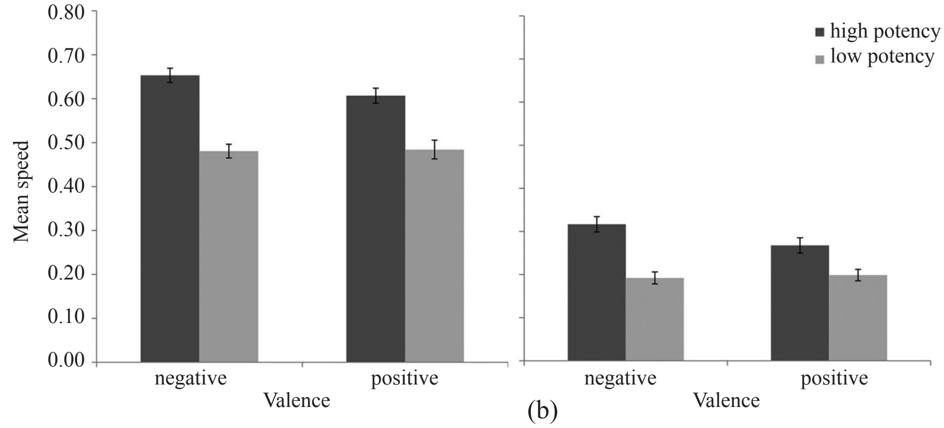

Figure 3. Effects of valence, potency, and arousal on the rating of amount of movement speed (±1 SE). (a) High arousal, (b) low arousal.

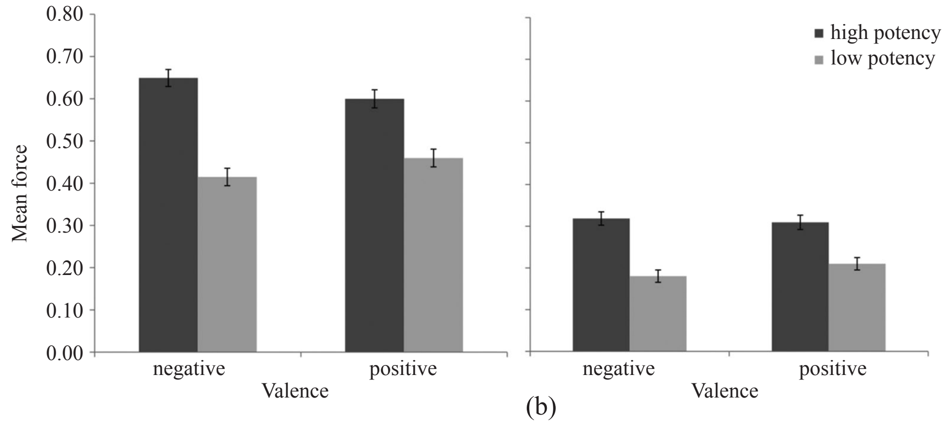

Figure 4. Effects of valence, potency, and arousal on the rating of amount of movement force (±1 SE). (a) High arousal, (b) low arousal.

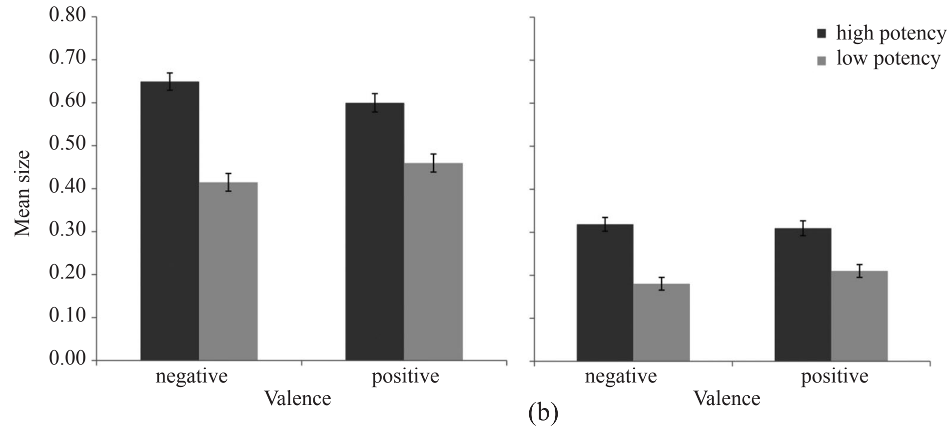

Figure 5. Effects of valence, potency, and arousal on the rating of amount of movement size (±1 SE). (a) High arousal, (b) low arousal.

predicted main effect on perceived movement fluency ($F_{1,37} = 18.69$, $p < 0.001$, $\eta^2 = 0.34$), the effects of arousal and potency were stronger (both $\eta^2 = 0.52$). Moreover, we did not find an interaction between arousal and valence ($F_{1,37} = 2.20$, ns). As can be seen in figure 6, the gesturing in negative, low-potency emotions is perceived as least fluent. We did not find

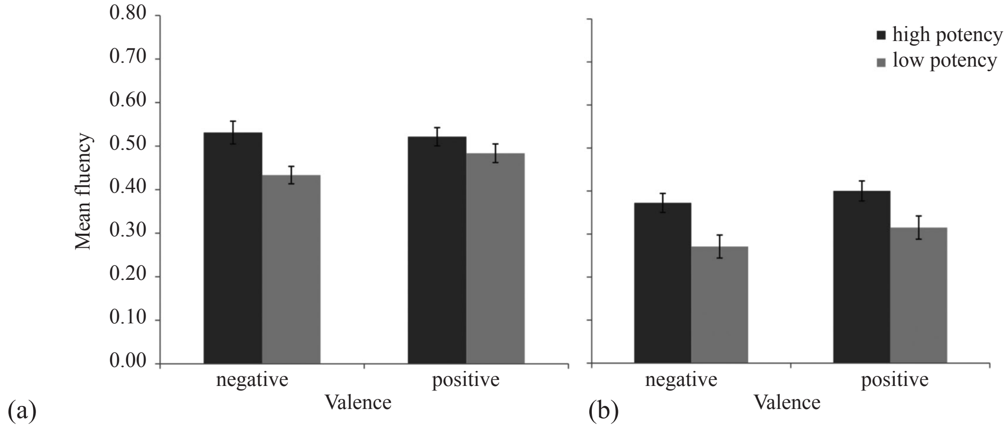

Figure 6. Effects of valence, potency, and arousal on the rating of amount of movement fluency (±1 SE). (a) High arousal, (b) low arousal.

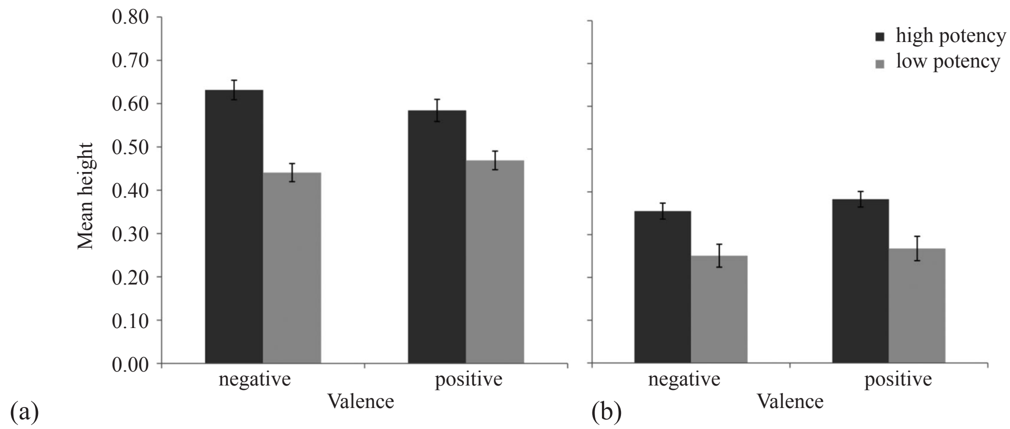

Figure 7. Effects of valence, potency, and arousal on the rating of amount of movement height (±1 SE). (a) High arousal, (b) low arousal.

the predicted main effect of valence on the perception of movement height ($F_{1,37} = 0.99$, ns); however, the two-way and three-way interactions of valence with arousal and with potency were significant (table 6). The effect of valence appears to differ for different levels of potency and arousal: for high-potency and high-arousal emotions the movement is judged as higher in space for negative emotions than for positive emotions, whereas positive emotions seem to be judged as slightly higher in space in high-potency but low-arousal emotions. Despite these small effects for valence, figure 7 shows that mainly arousal and potency drive the perception of movement height.

4 Discussion

In this study we focused on the role of expressed emotion on the perception of gestural arm movements. In particular, we investigated the effects of three major emotion dimensions—potency, arousal, and valence—on six spatiotemporal movement characteristics as perceived by lay judges. Interrater agreement measures showed that the movement rating scales were reliably used.

4.1 *Summary of the results*

The general and most important finding of this study is that potency and arousal strongly affect all investigated perceived movement characteristics (see table 1 for a summary of predictions and their support from this study). Their effects are very similar (slightly stronger for arousal); and strong interactions emerge for perceived movement force and size, the two characteristics that were expected to be related to potency. We found no or only weak interactions between these two dimensions for the characteristics that were expected to be related to arousal—that is, amount of movement and movement speed. This means that the effects of arousal are independent of potency but that the effects of potency are dependent on the level of arousal. These results suggest that arousal as a general response dimension boosts the effect of potency and possibly valence.

4.2 *Limitations*

Two methodological issues are relevant for the interpretation of our results and on which different positions are taken in the literature. The first is the suitability of acted emotional expressions for emotion research, and the second is the stimulus degradation: face blurring and the muting of the audio signal.

Acted expressions are widely used in emotion research because of the many benefits compared with induced or field-recorded expression (cost-efficient, controlled, systematic, possibility to study a variety of social and private emotions with sufficient intensity). However, the actor portrayal approach has also met with some criticism. One of major limitations of this approach is that the results may be affected by the use of stereotypes (Scherer and Bänziger 2010). Thus, the results from this study might not generalize to spontaneous, real-life emotional expression. It should be noted, however, that this issue was taken into account in the GEMEP corpus in terms of both emotion elicitation and validation. In contrast to many other stimulus sets where the expressions are posed based on movement instructions, the professional GEMEP actors used method-acting techniques to produce felt experiences of the target emotions, rendering authentic expressions (Scherer and Bänziger 2010). Also, the GEMEP material used in this study has been extensively validated in terms of recognizability and believability of the expressions (see Bänziger and Scherer 2010). On the basis of these considerations, we believe that the data resulting from this study provide valid information on emotion expression patterns and allow comparison across other studies reported in the literature.

All expressions in our study were face blurred and muted to control the influence of facial and vocal expression on the perception of bodily expression (Aviezer et al 2008; Van den Stock et al 2007). This stimulus manipulation obviously lowers ecological validity and may well have affected the rating of believability, which was lower than for the original GEMEP material.

These two methodological decisions were guided by our perspective to balance internal and external (ecological) validity, taking an intermediate position between a rigid experimental approach [such as the use of point-light displays in Atkinson et al (2004); or the use of avatars in, for example, Coulson (2004); Kleinsmith and Bianchi-Berthouze (2007); Roether et al (2009)] and a naturalistic approach [such as field recordings from public media (Douglas-Cowie et al 2007) or clinician–patient interviews (see Hall et al 1995)].

4.3 *Perceived gesture dynamics of expressed emotion dimensions*

The large amount of significant effects strongly suggests that expressed emotion has a powerful effect on the perception of gestural arm movement. This extends similar effects found on the dynamics of instrumental arm movement (Gross et al 2010; Pollick et al 2001), stylized arm movement (Sawada et al 2003), and whole-body movement (Atkinson et al 2004, 2007; de Meijer 1989; Wallbott 1998) to the context of gestures occurring during speech-based social interaction.

On a physical, lower level the effect of emotional arousal on physical effort mobilization is translated in muscle activity, resulting in more abundant movement. On a more cognitive level arousal is assumed to be related to appraised urgency (Scherer 2001) and the readiness or urge to act upon the environment (Frijda 1986, pages 90–91). This is reflected in an increase of arm gestures, suggesting that the communicative system of gesture is an integral part of this response. In line with previous research, active emotions are expressed and perceived with higher gestural movement activity, speed, force, and size or expansiveness (de Meijer 1989; Wallbott 1998; Wallbott and Scherer 1986). However, contrary to what is reported in Pollick and colleagues (2001) and Montepare and colleagues (1999), arousal was positively related to the perception of movement fluency in this study. This result is most likely due to the difficulty in judging fluency in expressions with little or no movement. Participants were instructed to move the cursor to the end of the scale (extreme left) when they did not observe the movement characteristic in question. This result is a direct consequence of our effort to use nonposed stimuli and maintain a representative sample of emotions, therefore including portrayals where no movement occurred. Moreover, if one were to exclude portrayals where no movement occurred, it would not be obvious how to define the cut-off value of how much movement needs to be perceived in order to be able to judge fluency or even other movement characteristics. This is a topic of research that should definitely be pursued in order to investigate movement perception of unconstrained expressions such as those of the GEMEP corpus.

Regarding the effects of potency, emotions characterized by high power or control—such as hot anger (rage), elated joy, pride, but also cold anger (irritation), interest, and pleasure—were, as predicted, perceived to have larger (more expansive) and more forceful gesturing, especially for high-arousal emotions. The potency dimension is related to coping potential and includes evaluations of adjustment to and control and power over the consequences of the emotion-eliciting event—for example, to remove goal obstruction or stimulate goal attainment (Scherer 2001, 2009; Smith and Ellsworth 1985). Exaggerated gesturing during affective states marked by the individual's sense of power or control emphasizes the message, increasing the communicative impact and influence on the interlocutor. On a social, interpersonal level potency is furthermore related to feelings of dominance and submissiveness towards others (Osgood et al 1975; Russell and Mehrabian 1977). Previous research indicates that postural expansion is related to success experiences (Riskind 1984; Stepper and Strack 1993) and feelings of pride (Tracy and Robins 2004, 2007). Tracy and Robins have argued from an evolutionary perspective that increasing body size has served to signal dominance and attract attention to the individual's achievement or status. On the basis of the current study we similarly argue that gestural space also serves the function of signaling power or dominance.

Even though we did find that positive emotions were perceived as having more fluent gesturing, this effect is very small compared with the effects of arousal and potency. Also, for gesturing height the effect of valence is not pronounced and depends on the levels of both arousal and potency. Differential effects of arousal and potency on the expression of emotional valence have been reported for the material used in this corpus for the vocal domain (Goudbeek and Scherer 2010). The results also quantify earlier studies where a positive association is found between positive emotion and upward movement or height of gesturing (de Meijer 1989; Reilly et al 1992). One explanation for the lack of clear replication is that the measurement may need further refinement in dissociating movement location (high–low) and movement direction (upward–downward). Human perception of emotional valence may rely more on direction than on location (de Meijer 1989). Another explanation is that the studied emotions in these previous studies were not controlled for the level of potency, so the effects ascribed to valence could be due in part to an effect of potency. This study confirms that high-potency emotions have higher perceived gesturing. Hence, as suggested by research on the vocal concomitants of emotion (Banse and Scherer 1996; Goudbeek and Scherer 2010), research on bodily emotion communication should attempt to experimentally or statistically control for the level of arousal and potency when investigating other possible sources of variance.

5 General conclusion

The data reported above clearly confirmed our hypotheses for arousal and potency. In contrast, our hypotheses for valence received only modest empirical support. This study clearly indicates that emotional arousal and potency are important response determinants underlying the perception of spatiotemporal characteristics of gestural arm movement. This research contributes to the field in three important ways. First, we have shown that gesture as a communicative system plays an important role in nonverbal emotion communication, highlighting the multifunctional nature of gesture in serving both cognitive–linguistic and affective–expressive purposes. Second, we aimed to go beyond categorical emotion differentiation and investigated functional dimensions as response determinants, of which the explanatory range goes beyond the often-studied basic emotions. The fact that emotion dimensions have meaningful relationships with gestural arm movement does not preclude the existence of emotion-specific functions, but simply provides an additional and promising approach in the uncharted field of gestural emotion communication. Third, we have identified a number of perceptual cues of gestural expression that are indicative of expressed emotion dimensions. Given that emotion encoding and decoding is an inherently multimodal phenomenon, comparing the relative contribution of different cues in different modalities—be it gestural, postural, facial, or vocal—is an important goal for future research [but see Scherer and Ellgring (2007) for a first attempt to investigate multimodal patterns]. The results presented here show the necessity of and provide a basis for including gesture in multimodal analyses of the emotion communication process.

Acknowledgments. This research is part of the dissertation project of the first author and was supported by the Swiss National Science Foundation (FNRS 51A240-104897), by the National Center of Competence in Research (NCCR) Affective Sciences (51NF40-104897), and by the Faculty of Psychology and Educational Sciences, University of Geneva. Martijn Goudbeek was partly funded by the VICI grant "Bridging the gap between psycholinguistics and computational linguistics: the case of referring expressions", awarded by the Netherlands Organization for Scientific Research (NWO grant 277-70-007). We would like to thank Gerard Verhoek for assistance in data collection. This study was carried out in accordance with APA ethical standards and with the World Medical Association Helsinki Declaration.

References

Atkinson A P, Dittrich W H, Gemmell A J, Young A W, 2004 "Emotion perception from dynamic and static body expressions in point-light and full-light displays" *Perception* **33** 717–746

Atkinson A P, Tunstall M L, Dittrich, W H, 2007 "Evidence for distinct contributions of form and motion information to the recognition of emotions from body gestures" *Cognition* **104** 59–72

Aviezer H, Hassin R R, Ryan J, Grady C, Susskind J, Anderson A, Moscovitch M, Bentin S, 2008 "Angry, disgusted, or afraid? Studies on the malleability of emotion perception" *Psychological Science* **19** 724–732

Banse R, Scherer K R, 1996 "Acoustic profiles in vocal emotion expression" *Journal of Personality and Social Psychology* **70** 614–636

Bänziger T, Mortillaro M, Scherer K R, 2012 "Introducing the Geneva Multimodal Expression Corpus for experimental research on emotion perception" *Emotion* **12** 1161–1179

Bänziger T, Scherer K R, 2010 "Introducing the Geneva multimodal emotion portrayal (GEMEP) corpus", in *Blueprint for Affective Computing: A Sourcebook* Eds K R Scherer, T Bänziger, E B Roesch (Oxford: Oxford University Press) pp 271–294

Coulson M, 2004 "Attributing emotion to static body postures: Recognition accuracy, confusions, and viewpoint dependence" *Journal of Nonverbal Behavior* **28** 117–139

Dael N, Goudbeek M, Scherer K R, submitted "Attributing emotion dimensions to expressive body movement"

Dael N, Mortillaro M, Scherer K R, 2012 "Emotion expression in body action and posture" *Emotion* **12** 1085–1101

de Gelder B, 2006 "Towards the neurobiology of emotional body language" *Nature Reviews Neuroscience* **7** 242–249

de Meijer M, 1989 "The contribution of general features of body movement to the attribution of emotions" *Journal of Nonverbal Behavior* **13** 247–268
Dittrich W H, Troscianko T, Lea S E G, Morgan D, 1996 "Perception of emotion from dynamic point-light displays represented in dance" *Perception* **25** 727–738
Douglas-Cowie E, Cowie R, Sneddon I, Cox C, Lowry O, McRorie M, Martin J-C, Devillers L, Abrilian S, Batliner A, Amir N, Karpouzis K, 2007 "The HUMAINE database: Addressing the collection and annotation of naturalistic and induced emotional data", Second International Conference on Affective Computing and Intelligent Interaction (ACII 2007) *Lecture Notes in Computer Science. Volume 4738* Eds A Paiva, R Prada, R W Picard (Heidelberg: Springer-Verlag) pp 488–500
Ekman P, 1965 "Differential communication of affect by head and body cues" *Journal of Personality and Social Psychology* **2** 726–735
Ekman P, 1992 "Facial expressions of emotion: New findings, new questions" *Psychological Science* **3** 34–38
Ekman P, Friesen W V, 1967 "Head and body cues in the judgment of emotion: A reformulation" *Perceptual & Motor Skills* **24** 711–724
Ekman P, Friesen W V, 1972 "Hand movements" *Journal of Communication* **22** 353–374
Fontaine J R J, Scherer K R, Roesch E B, Ellsworth P C, 2007 "The world of emotions is not two-dimensional" *Psychological Science* **18** 1050–1057
Frijda N H, 1986 *The Emotions* (Cambridge: Cambridge University Press)
Frijda N H, Kuipers P, ter Schure E, 1989 "Relations among emotion, appraisal, and emotional action readiness" *Journal of Personality and Social Psychology* **57** 212–228
Glowinski D, Dael N, Camurri A, Volpe G, Mortillaro M, Scherer K R, 2011 "Towards a minimal representation of human nonverbal affective behavior" *IEEE Transactions on Affective Computing* **2** 106–118
Goudbeek M, Scherer K R, 2010 "Beyond arousal: Valence and potency/control in the vocal expression of emotion" *Journal of the Acoustical Society of America* **128** 1322–1336
Gross M M, Crane E A, Fredrickson B L, 2010 "Methodology for assessing bodily expression of emotion" *Journal of Nonverbal Behavior* **34** 223–248
Hall J A, Harrigan J A, Rosenthal R, 1995 "Nonverbal behavior in clinician–patient interaction" *Applied and Preventive Psychology* **4** 21–37
Harrigan J A, 2005 "Proxemics, kinesics, and gaze", in *The New Handbook of Methods in Nonverbal Behavior Research* Eds J A Harrigan, R Rosenthal, K R Scherer (New York: Oxford University Press) pp 137–198
Juslin P N, Laukka P, 2003 "Communication of emotions in vocal expression and music performance: Different channels, same code?" *Psychological Bulletin* **129** 770–814
Juslin P N, Scherer K R, 2005 "Vocal expression of affect", in *The New Handbook of Methods in Nonverbal Behavior Research* Eds J A Harrigan, R Rosenthal, K R Scherer (New York: Oxford University Press) pp 65–135
Keltner D, Ekman P, Gonzaga G C, Beer J, 2003 "Facial expression of emotion", in *Handbook of Affective Sciences* Eds R J Davidson, K R Scherer, H H Goldsmith (New York: Oxford University Press) pp 415–432
Kendon A, 2004 *Gesture: Visible Action as Utterance* (Cambridge: Cambridge University Press)
Kita S, Özyürek A, Allen S, Brown A, Furman R, Ishizuka T, 2007 "Relations between syntactic encoding and co-speech gestures: Implications for a model of speech and gesture production" *Language and Cognitive Processes* **22** 1212–1236
Kleinsmith A, Bianchi-Berthouze N, 2007 "Recognizing affective dimensions from body posture", Second International Conference on Affective Computing and Intelligent Interaction (ACII 2007) *Lecture Notes in Computer Science. Volume 4738* Eds A Paiva, R Prada, R W Picard (Heidelberg: Springer-Verlag) pp 48–58
McNeill D, 2005 *Gesture and Thought* (Chicago, IL: University of Chicago Press)
Montepare J, Koff E, Zaitchik D, Albert M, 1999 "The use of body movements and gestures as cues to emotions in younger and older adults" *Journal of Nonverbal Behavior* **23** 133–152
Osgood C E, 1966 "Dimensionality of the semantic space for communication via facial expressions" *Scandinavian Journal of Psychology* **7** 1–30
Osgood C E, May W H, Miron M S, 1975 *Cross-cultural Universals of Affective Meaning* (Urbana, IL: University of Illinois Press)
Peelen M V, Atkinson A P, Andersson F, Vuilleumier P, 2007 "Emotional modulation of body-selective visual areas" *Social Cognitive and Affective Neuroscience* **2** 274–283

Pollick F E, Paterson H M, Bruderlin A, Sanford A J, 2001 "Perceiving affect from arm movement" *Cognition* **82** B51–B61
Reilly J S, McIntire M L, Seago H, 1992 "Affective prosody in American Sign Language" *Sign Language Studies* **75** 113–128
Riskind J H, 1984 "They stoop to conquer: Guiding and self-regulatory functions of physical posture after success and failure" *Journal of Personality and Social Psychology* **47** 479–493
Roether C L, Omlor L, Christensen A, Giese M A, 2009 "Critical features for the perception of emotion from gait" *Journal of Vision* **9**(6):15, 1–32
Rosenthal R, 2005 "Conducting judgment studies: Some methodological issues", in *The New Handbook of Methods in Nonverbal Behavior Research* Eds J A Harrigan, R Rosenthal, K R Scherer (New York: Oxford University Press) pp 199–234
Russell J A, Bachorowski J A, Fernández-Dols J, 2003 "Facial and vocal expressions of emotion" *Annual Review of Psychology* **54** 329–349
Russell J A, Barrett L F, 1999 "Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant" *Journal of Personality and Social Psychology* **76** 805–819
Russell J A, Mehrabian A, 1977 "Evidence for a three-factor theory of emotions" *Journal of Research in Personality* **11** 273–294
Sawada M, Suda K, Ishii M, 2003 "Expression of emotions in dance: Relation between arm movement characteristics and emotion" *Perceptual & Motor Skills* **97** 697–708
Scherer K R, 2001 "Appraisal considered as a process of multilevel sequential checking", in *Appraisal Processes in Emotion: Theory, Methods, Research* Series in Affective Science, Eds K R Scherer, A Schorr, T Johnstone (New York: Oxford University Press) pp 92–120
Scherer K R, 2005 "What are emotions? And how can they be measured?" *Social Science Information* **44** 695–729
Scherer K R, 2009 "The dynamic architecture of emotion: Evidence for the component process model" *Cognition and Emotion* **23** 1307–1351
Scherer K R, Bänziger T, 2010 "On the use of actor portrayals in research on emotional expression", in *Blueprint for Affective Computing: A Sourcebook* Eds K R Scherer, T Bänziger, E B Roesch (Oxford: Oxford University Press) pp 166–176
Scherer K R, Ellgring H, 2007 "Multimodal expression of emotion: Affect programs or componential appraisal patterns?" *Emotion* **7** 158–171
Scherer K R, Johnstone T, Klasmeyer G, 2003 "Vocal expression of emotion", in *Handbook of Affective Sciences* Eds R J Davidson, K R Scherer, H H Goldsmith (New York: Oxford University Press) pp 433–456
Schindler K, Van Gool L, de Gelder B, 2008 "Recognizing emotions expressed by body pose: A biologically inspired neural model" *Neural Networks* **21** 1238–1246
Smith C A, Ellsworth P C, 1985 "Patterns of cognitive appraisal in emotion" *Journal of Personality and Social Psychology* **48** 813–838
Stepper S, Strack F, 1993 "Proprioceptive determinants of emotional and non emotional feelings" *Journal of Personality and Social Psychology* **64** 211–220
Tracy J L, Robins R W, 2004 "Show your pride: Evidence for a discrete emotion expression" *Psychological Science* **15** 194–197
Tracy J L, Robins R W, 2007 "The prototypical pride expression: Development of a nonverbal behavior coding system" *Emotion* **7** 789–801
Tukey J W, 1977 *Exploratory Data Analysis* (Reading, MA: Addison-Wesley)
Van den Stock J, Righart R, de Gelder B, 2007 "Body expressions influence recognition of emotions in the face and voice" *Emotion* **7** 487–494
Wallbott H G, 1985 "Hand movement quality: A neglected aspect of nonverbal behavior in clinical judgment and person perception" *Journal of Clinical Psychology* **41** 345–359
Wallbott H G, 1998 "Bodily expression of emotion" *European Journal of Social Psychology* **28** 879–896
Wallbott H G, Scherer K R, 1986 "Cues and channels of emotion recognition" *Journal of Personality and Social Psychology* **51** 690–699
Wundt W, 1897 *Outlines of Psychology* translated by C H Judd (Leipzig: Wilhelm Englemann)