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Methodology for Assessing Bodily Expression of Emotion

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Abstract The purpose of this study was to develop methods for assessing bodily expression and to provide a preliminary description of movement characteristics associated with positive and negative emotions during a single movement task—knocking. We used an autobiographical memories paradigm for elicitation, observer rating of emotion intensities for recognition, and Effort-Shape and kinematic analyses for movement description. Actors felt the target emotions in nearly all the trials but observers recognized them in relatively few movement trials, especially for the positive emotions. Differences in movement characteristics were identified for the target emotions with both the qualitative and quantitative movement analyses.

Keywords Bodily expression · Emotion recognition · Kinematics · Laban · Effort-Shape

Introduction

Emotions are multi-component response systems initiated by changes in current circumstances appraised as significant to an organism's well-being and expressed through multiple channels, including body movements. Previous studies have begun to describe the types of movements that are generated with emotion, and how movements are altered by emotion (Brownlow et al. 1997; de Meijer 1989; Dittrich et al. 1996; Montepare et al. 1999; Pollick et al. 2001; Walk and Homan 1984; Wallbott 1998). Despite years of work, however, we still do not know how body movements are changed quantitatively when an individual experiences an emotion. If we know the relationship between experiencing an

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emotion and characteristic changes in body movements, it will help us to understand the neuromotor mechanisms involved in emotional expression.

There are several methodological issues that have impeded the study of bodily expression of emotion, primarily related to how emotionally expressive body movements are generated and quantified. To establish the relationship between body movements and emotional experience, it is important that the expressed emotions are felt, are recognized in the body movements, and are expressed during the same movement task so that any emotion effects are not confounded by the characteristics of the movement task itself. It is important to use qualitative and quantitative assessment methods that capture the characteristics of dynamic, expressive movements. Although powerful biomechanical methods exist to describe the complex, three-dimensional characteristics of body movement, biomechanical methods have not been employed routinely in the study of bodily expression. These methodological concerns must be addressed to further advance our understanding of the physical manifestation of emotion in body movement.

Emotion Elicitation

Most previous studies of bodily expression of emotion have used actors to portray the effects of emotion on body movements (Atkinson et al. 2004; Boone and Cunningham 1998; de Meijer 1989; Montepare et al. 1999; Wallbott 1998). The very reasonable assumption underlying this experimental choice is that actors are experts in displaying emotion in the body, as well as the face and voice, and their body movements may amplify and/or distil the particular characteristics of a bodily emotional signal. Certainly, actors base their emotion characterizations on behavior they have observed in themselves and others, and many would agree that a talented actor is quite capable of producing accurate bodily expressions of emotion. While it is likely that actors actually feel the emotions that they portray, this assumption has not been tested explicitly in studies of bodily expression.

Implicit in the study of bodily expression in individuals experiencing an emotion is the assumption that there is a neurobiological basis for emotion to affect body movements in some characteristic way. Recent fMRI studies have shown that brain regions associated with both emotion processing and motor responses are both activated when subjects view images of emotional body postures (de Gelder 2006; Grèzes, Pichon and de Gelder 2007). By quantifying the aspects of motor performance that are affected by an emotion, insight can be gained into the putative coordinative structures associated with a particular emotion. To accomplish this goal, however, it is critical that the observed motor behaviors are captured while the neurobiological processes are active, that is, while an emotion is being experienced.

In this study, we elicited emotions in actors and then observed their body movements. Because we were primarily concerned with how actors felt while moving, we used an autobiographical memories paradigm for emotion elicitation to encourage the actors to feel the target emotions. This approach took advantage of the actors' skill in expressing feelings, and coupled it with an assessment of their emotional experience while moving. Our methodology identified the movement trials in which the target emotions were felt and not just portrayed by actors.

Movement Task

Although bodily expression can occur when specific emotional movements are elicited (i.e., an emblematic gesture such as shaking a fist), it can also occur when performance of a non-emblematic movement is modified so that a feeling is expressed (e.g., stomping out of a room). Body posture, types of body movement, and movement qualities have been associated with specific, different emotions. For example, hot anger has been characterized by a head-up posture, arms stretched out in front of the body, and high movement dynamics (Wallbott 1998). Anger, fear, happiness, sadness and surprise have been associated with specific body postures (Coulson 2004). Trunk movements have been used to discriminate between positive and negative emotions, with stretching movements predicting joy, sympathy, surprise, and interest, and bowing predicting fear, grief, shame, and anger (de Meijer 1989). The emotional intents of dancers' and musicians' movements during expressive performances have been successfully decoded (Boone and Cunningham 1998; Dahl and Friberg 2007; Dittrich et al. 1996). Thus, bodily expression of a particular emotion can be studied by documenting the set of movement behaviors associated with expression of an emotion or by defining the characteristic modifications that make any movement produced with the emotion recognizable. In this way, bodily expression is like vocal expression, where an emotion can be expressed by uttering a specific word (e.g., a curse word) or by changing the vocal characteristics with which an emotionally neutral sentence is spoken (Banse and Scherer 1996; Scherer and Ellgring 2007).

Traditionally, emotions have been assumed to be coordinative structures associated with a tendency to act (Frijda 1986). For certain negative emotions, the actions associated with strong feelings are clear, e.g., the tendency to flee when frightened. For positive emotions, however, it is not clear which bodily actions should be associated with an emotion. For example, joyful actions have been described as promoting free activation (Frijda 1986), a "do anything" motor program which is rather non-specific (Fredrickson and Levenson 1998). Because the positive emotions may not be as closely associated with specific actions (Fredrickson 1998), it is particularly important to study the effect of emotion on performance of non-emblematic movements to understand bodily expression across the range of emotions.

In this study, we assessed bodily expression of emotions in individuals performing a single movement task (knocking). Knocking provided a constrained motor task within which we explored the bodily expressions of anger, anxiety, sadness, pride, contentment, and joy, six emotions that have been identified and studied by a range of emotion theorists (e.g., Fredrickson and Branigan 2005; Izard 1977; Lazarus 1991; Panksepp 1998; Scherer and Ellgring 2007; Tracy and Robins 2007). Because these six emotions range in valence (joy, pride, and contentment vs. anger, anxiety, and sadness), activation level (anger, anxiety, joy, and pride vs. sadness and contentment) and approach-withdraw tendencies (anger, joy, and pride vs. anxiety, sadness, with contentment arguably reflecting neither approach nor avoidance) they allow us to discover how positive and negative emotions might alter bodily movements by decoupling valence from other key dimensions of emotion experience.

Emotion Recognition

To date, most studies investigating the recognition of emotions in body movements have used forced-choice paradigms limited to the target emotions themselves. If the number of choices is too limited, however, movement trials selected as expressing the target emotion may be only marginally related to the target emotion. If the goal of the study is to identify movement trials for subsequent analysis of emotion-related movement characteristics, it is important to use a recognition paradigm that selects only those trials that are particularly expressive of the target emotion.

In this study, we developed and assessed a method to identify movement trials that were predominantly and strongly related to the target emotions. We used a modified forced choice paradigm that asked observers to rate the intensity of a range of feelings that they perceived in the body movements. We then applied criteria to select those trials that were most related to the target emotions. We also assessed emotion communication by examining the relationships between the emotion intensities reported by the actors and perceived by the observers for each of the target emotions.

Qualitative Analysis

Previous studies of bodily expression have used a variety of qualitative methods to describe the effects of emotion on body movements. Wallbott (1998) used a coding system that described body posture, the types of movements performed, and the overall movement qualities. Montepare et al. (1999) used six fundamental characteristics of movement that captured the dimensions of form, tempo, force, and direction. De Meijer (1989) used seven dimensions to characterize general movements, including trunk and arm movement, vertical and sagittal direction, force, velocity, and directness. Dahl and Friberg (2007) used amount, speed, fluency, and regularity cues to assess emotional intent in the body movements of musicians. Although these studies were able to discriminate among emotions based on qualitative movement characteristics, they used different coding schemes, making it virtually impossible to build a comprehensive description of the effects of emotion on body movements.

An alternative method that offers the advantage of systematic qualitative description of body configuration and movement quality is Effort-Shape analysis (Dell 1977). Effort-Shape is derived from the movement analysis system originally created by Rudolf Laban to describe the body motions of individuals engaged in a variety of tasks, including factory workers and dancers (Laban 1988). Effort-Shape analysis is based on the assumption that an individual's inner attitudes (conscious or unconscious) towards effort are present in every movement and can be observed. The effort factors describe how exertion is concentrated during movement in four ways: (1) flow (bound or free), (2) weight/energy (forceful or light), (3) time (sustained or quick), and (4) space (indirect or direct). Shape factors describe how movement changes form in three ways: (1) the form of the body itself (towards or away from the body center), (2) the directional path in space (spoke or arc-like), and (3) how the body shapes itself with respect to the environment (gathering or scattering). An Effort-Shape approach has been used to generate naturalistic synthetic gestures in character animations (Chi et al. 2000) and to describe the movement characteristics of individuals with varying anxiety and depression scores and different personality types (Levy and Duke 2003). De Meijer (1989) incorporated some Laban movement qualities into his assessment of the relationship between general movement features and emotion attributions. An Effort-Shape approach has not yet been applied to body movements associated with a range of emotions during a single movement task.

In this study, we used an Effort-Shape analysis to systematically relate the qualitative aspects of body movements to both positive and negative emotions during a movement task (knocking). We included the four Laban effort factors (flow, weight/energy, time, and space), but only one aspect of shape. Because knocking takes place in a standing position near a vertical surface, the two shape factors that account for the directional path of the body in space and the shape of the body with respect to the environment were less meaningful. Therefore, only the shape factor that describes the form of the body itself was included, with respect to the knocking arm and the torso. Because we were interested in the broad application of a systematic qualitative analysis to studies of bodily expression, our Effort-Shape analyses were carried out by nonexpert observers.

Kinematic Analysis

Ultimately, qualitative methods for describing emotion-related movement characteristics are not sufficient for building quantitative neuromotor models of emotionally expressive movement behavior. Instead, kinematic methods are needed that describe body position and how it changes over time. Kinematic analysis requires 3-dimensional coordinate data generated with a motion capture system; such systems have not been readily available for study of bodily expression until relatively recently.

A few studies have used kinematic methods to describe emotion-related movement characteristics (Pollick et al. 2001; Sawada et al. 2003). Each of these studies reported the kinematics of single joints or segments but they did not provide any information on postural variables or on coordination of multiple body segments. Since it is has been observed that emotion affects body posture as well as limb movement, it is important for studies to describe the effects of emotion on whole-body kinematics. Recently, a library of motion capture data generated by a large number of individuals performing common movements with different emotional intents has been published, but kinematic analyses of the movements are not yet available (Ma et al. 2006). In this study, we used a kinematic analysis to quantitatively assess the effects of both positive and negative emotions on whole body movements during a single movement task.

Purpose of the Study

The purpose of this study was to develop and assess methodologies for studying bodily expression of emotion. The four experiments separately addressed methods for (1) emotion elicitation, (2) emotion perception and recognition, (3) qualitative movement description, and (4) quantitative movement description. We integrated the results of the four experiments to provide a preliminary description of the movement characteristics associated with expression of positive and negative emotions in actors during knocking.

Experiment 1

The purpose of this experiment was to implement and evaluate a method for eliciting specific emotions during a movement task. Elicitation was evaluated by assessing whether or not actors felt the target emotions during movement, and if the target emotions were felt with more intensity than other emotions. Our methodology tested whether the target emotions were actually felt and or were just portrayed by the actors during the movement trials.

Method

Six female university drama students (21.0 ± 2.5 years) with university and community acting experience participated after giving informed consent. The actors wore close-fitting exercise clothes, and 35 lightweight, spherical markers were taped over anatomical landmarks prior to collection of motion data.

The actors were asked to move while experiencing six target emotions (angry, anxious, sad, proud, content, and joyful), and neutral. Knocking was selected as the movement task because it is relatively simple biomechanically and it can be performed expressively (Pollick et al. 2001). The actors stood in one place and knocked against a vertical plexiglass surface while experiencing each of the target emotions and neutral. Five high-speed video cameras were placed around the actor to collect motion data. Another video camera was placed to the side of the actor to record video clips of the knocking movements.

An autobiographical memories paradigm was used to elicit emotions in the actors (Labouvie-Vief et al. 2003; Levenson et al. 1991). Each actor was asked to write down events from her own life in which she felt each of the six target emotions and no emotion at all (neutral). Prior to each movement trial, the actor was asked to recall one of these memories. The actor performed three trials with each emotion in a block. After each block, the actor was asked to recall her best trial and to fill out a questionnaire in which she rated the intensity that she felt 20 feelings (6 target and 14 non-target emotions) while she was knocking during that trial (Table 1). A 5-item Likert scale (1 = *not at all*; 2 = *a little bit*; 3 = *moderately*; 4 = *a great deal*; 5 = *extremely*) was used to score intensity. Trials with an actor-reported intensity $\geq$ 3 for the target emotion were considered *felt*. Since there was not a "neutral" item on the questionnaire, neutral trials were considered felt if the intensity scores for all of the target and non-target emotions were either 1 or 2. In 14% of the trials (6 of 42), the movement data for the best trial were not complete so the next best trial was substituted.

Table 1 Questionnaire items about feelings during knocking

Item	Target emotion	"…how you felt while you were knocking"
1		I felt amused, fun-loving, silly
2	Angry	I felt angry, irritated, annoyed
3	Anxious	I felt anxious, apprehensive, tense
4		I felt ashamed, humiliated, disgraced
5		I felt contemptuous, scornful, disdainful
6	Content	I felt content, serene, peaceful
7		I felt embarrassed, self-conscious, blushing
8	Joyful	I felt glad, happy, joyful
9		I felt grateful, appreciative, thankful
10		I felt hopeful, optimistic, encouraged
11		I felt interested, alert, curious
12		I felt love, closeness, trust
13	Proud	I felt proud, confident, self-assured.
14		I felt repentant, guilty, blameworthy
15	Sad	I felt sad, downhearted, unhappy
16		I felt scared, fearful, afraid
17		I felt sexual, desiring, flirtatious
18		I felt surprised, amazed, astonished
19		I felt sympathy, concern, compassion
20		I felt awe, wonder, amazement

Results

In 33 (92%) of the 36 target emotion trials, actors felt the target emotions. The median intensity score for each of the target emotions across actors was 4.0 (i.e., "a great deal") or higher. In the three trials that were not felt, one actor reported feeling the target emotion "not at all" in her sad trial, and another actor reported feeling below threshold intensities of the target emotions in her angry and anxious trials.

In many of the target emotion trials, actors felt other emotions at the same or higher levels of intensity than the target emotion (Fig. 1). In all of the angry trials, the actors felt contemptuous at levels equal to or greater than angry. In the anxious trials, actors also felt scared. In the sad trials, actors also felt ashamed, anxious, and scared. In all of the positive emotion trials (content, joyful, proud), actors felt content, joyful, and proud, as well as amused, and hopeful. In the content trials, actors also felt love, and in the joyful and proud trials, actors felt interested.

In contrast to the target emotion trials, the mean intensities for all 20 feelings in the neutral trials were below threshold, and the only mean intensity that exceeded "not at all" was content. However, only 2 (33%) of the 6 neutral trials fully satisfied the criterion for neutral, i.e., the intensity of every one of the 20 feelings was less than "moderately". Three of the four trials that failed were very close to criterion, however, in that the intensity of only 1 of 20 feelings exceeded criterion (actors felt "a little bit" or "moderately" content in two trials and "moderately" interested in another trial). The one trial that clearly failed the neutral criterion had above threshold levels of "anxious" and "scared". This was the only 1 of 6 neutral trials in which any discomfort with the laboratory context was apparent.

In this experiment, we showed that actors felt the positive and negative target emotions and neutral during the movement task. Actors reported that they felt the target emotions with at least moderate intensity in 100% of the positive emotion trials and 83% of the negative emotion trials. Not only did the actors feel the target emotions, but they also felt other emotions while knocking, particularly for the positive emotions. Neutral was more difficult to elicit, since only a third of the trials fully met the neutral criterion. We assume that subjective reports of moderately intense feelings indicate that the neurobiological event underlying emotion expression was triggered, and that the emotion was experienced, and not just portrayed, during the movement task. Because the actors sometimes experienced multiple feelings, we cannot separate the potential effects of each of the felt emotions on their body movements.

Experiment 2

The purpose of this experiment was to develop and assess a method for identifying movement trials that were most strongly related to the target emotions. A secondary objective was to provide a preliminary analysis of emotion communication during movement, especially with regard to the relationship between the actors' feelings while moving and the observers' decoding of their feelings.

Method

Thirty-five individuals from the university community (21 female, 14 male; 19.9 $\pm$ 1.9 years) participated as observers. All individuals gave informed consent before participating.

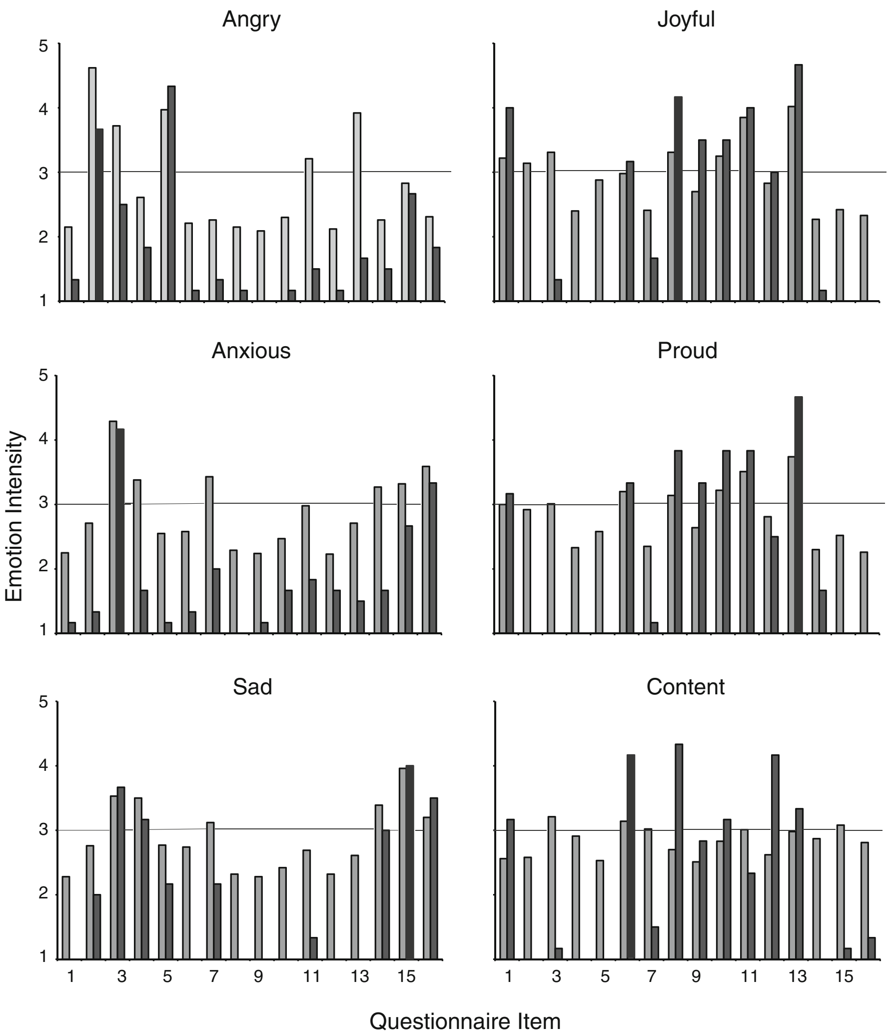

Fig. 1 Actor-reported and observer-rated emotion intensities during knocking. Mean intensity scores for 16 feelings are shown for each target emotion for actors (*dark bars*) and observers (*light bars*). *Black bars* indicate the target emotion items. A score of 5 indicates the greatest intensity ("extremely"); a score of 1 indicates the least intensity ("not at all"). The *horizontal line* indicates the threshold intensity ("moderately"). Questionnaire items were: 1—amused, 2—angry, 3—anxious, 4—ashamed, 5—contemptuous, 6—content, 7—embarrassed, 8—joyful, 9—grateful, 10—hopeful, 11—interested, 12—love, 13—proud, 14—repentant, 15—sad, and 16—scared

The 42 (6 actors × 6 target emotions and 6 actors × 1 neutral) video clips generated in Experiment 1 were used as the emotion stimuli. The videos were edited so that movement started when the actor's arm began to rise and ended when the actor's arm returned to her side. The movement was repeated three times in each video clip. The actors' faces were blurred so that their facial expressions were not observable.

Each observer viewed the 42 video clips presented in one of three randomized orders. After viewing a video clip, observers rated the intensities of the feelings that they thought the actor experienced during the movement. The observers used the same questionnaire that was used by the actors in Experiment 1 except that the text "I felt…" in the actors' questionnaire was replaced by "They felt…" in the observers' questionnaire. To reduce response burden, four items from the actors' questionnaire with low-intensity responses (i.e., awe, flirtatious, surprise, sympathy) were deleted from the observers' questionnaire. Intensity scores for each of the remaining 16 items were averaged across observers to create a mean intensity score for each feeling item for each movement trial.

Emotion communication was assessed for the target emotion and neutral trials separately. For the 36 target emotion trials, the target emotion in a given movement trial was considered *perceived* if it satisfied the threshold intensity criterion, i.e., the mean observer-rated intensity score for the target emotion was rated "moderately" or above. A target emotion was considered *recognized* if it satisfied the threshold intensity criterion and two additional criteria (Gross and Levenson 1995): (1) baseline intensity—the observer-rated intensity score for the target emotion was significantly greater in the target emotion than in the neutral trial, and (2) predominant intensity—the mean observer-rated intensity of the target emotion was at least .5 greater than other intensity scores and was significantly greater than the next highest intensity score. Perception and recognition rates for the target emotion trials were calculated as the percentage of movement trials that satisfied the criteria for perceived and recognized, respectively. The neutral trials were considered perceived if the mean observer-rated intensities for each of the 16 feeling items were less than 3.0 ("moderately"). Recognition was not assessed for the six neutral trials.

To examine the success of emotion communication between actors and observers, the actor-reported intensities from Experiment 1 were compared with the observer-rated intensities (Buck 2005). Trials were categorized as communicated correctly if the target emotions were felt by the actors and perceived by observers, or if they were neither felt nor perceived. Trials were categorized as communicated incorrectly if the actors felt the target emotions but the observers did not perceive them, or if the target emotions were perceived but not felt. Communication in neutral trials was not analyzed because there was not a neutral item on the questionnaires.

Statistical Analysis

First, a mixed-effects model was used to test the fixed effects of video order and observer gender and the random effects of actor and observer on the observer-rated intensity scores for each target emotion. Random effects of observer and actor were assessed by analyzing the variance components. If the intercepts for observer or actor were significant, the Empirical Best Linear Unbiased Predictors were investigated for potential outliers. Neutral trials were not included in this analysis because there was not a "neutral" item on the questionnaire.

Next, the three recognition criteria were evaluated. To assess the threshold criterion, *perception rate* was calculated as the percent of observers who perceived the target emotion, and a one-tailed binomial test was used to determine whether perception rates differed from chance (50%). To evaluate the baseline criterion, a mixed-effects model with random effects of actor and observer was used to test whether the intensity score for the target emotion was significantly greater in the target emotion trial than in the neutral emotion trial for each actor and target emotion; this test controlled for actor and observer effects. To evaluate the predominance criterion, a paired t-test was used to determine whether the target emotion intensity was significantly different than the next highest intensity score for each actor and emotion. Finally, Pearson correlation coefficients were calculated between the actor-reported intensities and observer-rated intensities for the target emotion items across all trials (Ambady and Rosenthal 1993; Buck 2005). The significance level was set at $p < .05$ for all tests.

Results

Video order did not affect mean intensity scores for any of the six target emotions so intensity scores were averaged across orders. Observer gender affected mean intensity scores only for proud trials, in which the mean intensities tended to be slightly higher (.5) for the female than for the male observers ($p = .0357$). Because this gender difference was small and the number of tests was relatively large, the evidence for a gender effect was not overwhelming and the intensity scores were averaged across genders for all emotions.

Neutral Trials

All of the neutral trials were perceived by the observers. Mean intensities for all 16 feelings were below threshold (3.0) in the neutral trials. The feeling items with the highest mean observer-rated intensities were anxious (2.5), sad (2.3) and content (2.0). Thus, the observers perceived neutral in all six trials even though the actors felt neutral in only two of the six trials.

Target Emotion Trials

The target emotions were perceived in less than half (42%; 15 of 36) of the target emotion trials. Although the perceived trials were distributed evenly between positive and negative emotions (7 and 8 trials, respectively), perception rates tended to be greater for the negative emotions (56–78%) than for the positive emotions (33–56%; Table 2). Although perception rates exceeded 50% in an additional seven trials, the trials did not meet the threshold criterion (and thus were not considered perceived) because the perception rates were not significantly different from chance.

Nearly all of the trials that met the threshold intensity criterion also met the baseline intensity criterion (93%; 14 of 15 trials). In the one trial that failed to meet this criterion (anxious), the intensity score for the anxious item in the neutral trial was still less than in the corresponding anxious trial. These results indicated that when the target emotion intensity was sufficient to meet the threshold criterion, in most cases it also exceeded the baseline level, so that the baseline criterion did not add much discriminatory value

Table 2 Perception rates for target emotions

Actor	Angry	Anxious	Sad	Joyful	Proud	Content
1	100[a]	66[a]	40	17	54	54
2	37	63	74[a]	9	23	17
3	54	17	48	14	51	23
4	83[a]	91[a]	74[a]	77[a]	69	69[a]
5	100[a]	66	6	49	71[a]	29
6	91[a]	89[a]	91[a]	69[a]	69[a]	6
Mean	78	65	56	39	56	33

[a] Perception rate exceeded chance level ($p < .05$) and mean observer-rated intensity ≥ 3.0

beyond the threshold criterion in identifying movement trials that encoded the target emotion.

Just over half of the trials that met the threshold and baseline criteria also met the predominant intensity criterion (57%; 8 of 14 trials). Nearly all of the trials (5 of 6) that failed to meet this criterion were associated with positive emotions (i.e., proud, joyful). Because observers scored "proud" and "joyful" with similar intensities in proud and joyful trials, none of the proud and joyful trials were recognized. One negative emotion trial (sad) also failed because the observers perceived an above-threshold level of intensity for anxious.

Taken together, with all three recognition criteria applied, less than a quarter (8 of 36; 22%) of the target emotion trials were recognized by the observers. The recognition rates were 67% for angry (4 of 6 trials), 33% for anxious (2 of 6 trials), 17% for sad and content (1 of 6 trials), and 0% for proud and joyful. One actor generated half of the recognized trials; two actors did not generate any of the recognized trials. Results from Experiment 1 indicated that one actor did not feel the target emotion in one of the eight recognized trials (angry). Thus, target emotions were felt by the actor and recognized by observers in only 7 of the 36 target emotion trials.

Emotion Communication

The relationships between actor-reported and observer-rated emotion intensities were not strong. When evaluated across target trials (e.g., joyful in joyful trials) and non-target trials (e.g., joyful in angry trials), the observer-rated emotion intensities were positively but weakly correlated with the actor-reported intensities (Table 3). These results indicate that both high and low felt intensities could be paired with high or low levels of perceived intensities, and suggest that high levels of felt emotion did not necessarily predict high levels of perceived emotion in the body movements.

Table 3 Correlations of observer-rated with actor-reported intensities in target and non-target emotion trials

Feeling	*r*
Amused, fun-loving, silly	.272***
Angry, irritated, annoyed	.366***
Anxious, apprehensive, tense	.225***
Ashamed, humiliated, disgraced	.086**
Contemptuous, scornful, disdainful	.424***
Content, serene, peaceful	.234***
Embarrassed, self-conscious, blushing	.049
Glad, happy, joyful	.235***
Grateful, appreciative, thankful	.223***
Hopeful, optimistic, encouraged	.265***
Interested, alert, curious	.249***
Love, closeness, trust	.154***
Proud, confident, self-assured	.219***
Repentant, guilty, blameworthy	.112***
Sad, downhearted, unhappy	.205***
Scared, fearful, afraid	.267***

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 4 Percentage of trials in which target emotions were communicated correctly and incorrectly

Target emotion	Correct		Not correct	
	Felt Perceived	Not felt Not perceived	Felt Not perceived	Not felt Perceived
Target trials				
Angry	8	0	6	3
Anxious	6	0	8	3
Content	3	0	14	0
Joy	3	0	11	3
Proud	6	0	11	0
Sad	6	0	8	3
Total	31	0	57	12
Non-target trials				
Angry	1	14	1	1
Anxious	1	11	4	1
Content	1	12	4	0
Joy	1	11	6	0
Proud	3	8	4	2
Sad	1	12	3	1
Total	8	66	21	5

The success of target emotion communication depended on whether it was assessed in target or non-target trials (Table 4). The percent of trials in which the target emotions were communicated correctly in the corresponding target trials (e.g., angry in angry trials) was relatively low (31%) because the percent of trials in which the target emotions were both felt and perceived was small. In contrast, the percent of trials in which the target emotions were communicated correctly in non-target trials (e.g., angry in sad trials) was relatively high (74%) because the percent of trials in which the target emotions were neither felt nor perceived was large. Thus, the test of emotion perception had low sensitivity (32%) but high specificity (90%) across all target emotions and trials. Because the criteria were more stringent for emotion recognition than perception, sensitivity decreased but specificity increased for tests of recognition compared with perception. When only the target emotion trials were considered, sensitivity and specificity were 21 and 67% for recognition, and 41 and 33% for perception, respectively.

Emotion Confusion

Other feelings besides the target emotions were perceived in all the target emotion trials (Fig. 1). Some of these perceived emotions were felt by actors, but others were not. For example, observers perceived and actors felt contempt in the angry trials, fear in the anxious trials, and anxiety, shame, guilt, and fear in the sad trials. Among the positive emotions, observers perceived and actors felt amusement, hope, interest, and pride in the joyful trials, amusement, contentment, joy, hope, and interest in the proud trials, and pride in the content trials.

The observers perceived some emotions that were not felt by the actors. For the most part, the confused emotions were negative in the negative target emotion trials, and were positive in the positive emotion trials (Fig. 1). In angry trials, the observers also perceived anxiety, interest, and pride. In anxious trials, the observers also perceived shame, embarrassment, repentance, sadness, and interest. In sad trials, the observers also perceived embarrassment. In all the positive emotion trials, anxiety was perceived but not felt. Also, anger was perceived in joyful trials, and embarrassment, interest and sadness were perceived in content trials.

In the positive emotion trials, observers failed to perceive some emotions that were felt by the actors. These included gratefulness and love in joyful trials, gratefulness in proud trials, and amusement, joy, hope, and love in content trials.

In this experiment, we demonstrated that observers perceived the target emotions in less than half of the target emotion trials. When the more stringent recognition criteria were applied, less than a quarter of the target emotion trials were recognized. The actor-reported emotion intensities were positively but weakly correlated with the observer-rated emotion intensities. The observers perceived emotions besides the target emotions in all of the target emotion trials, some of which were felt by the actors and some which were not felt. All of the neutral trials were perceived as neutral by the observers.

Experiment 3

The purpose of this experiment was to develop and evaluate a method for qualitatively assessing the effects of different emotions on body movements. The method was evaluated by examining whether or not an Effort-Shape analysis conducted with non-expert observers could discriminate among the target emotions. A secondary objective was to provide a preliminary Effort-Shape analysis of expressive body movements during knocking, regardless of whether the target emotions were felt or recognized during the movement task.

Method

A different set of 31 individuals from the university community participated as observers (21 female, 10 male; 20.6 ± 2.5 years). All individuals gave informed consent before participating. Observers viewed the same 42 video clips, presented in the same three randomized orders that were used in Experiment 2. The observers did not have any special training in Effort-Shape analysis.

Six Effort-Shape factors were used to qualitatively describe the body movements (Dell 1977). Two factors described the form shape of the body (i.e., torso and limb) and four factors described the effort in the body (i.e., space, time, energy, flow) during the movement (Table 5). After viewing a video clip, observers rated the movement quality according to the Effort-Shape factors using a 5-item, Likert scale (1 = *left-anchor quality*; 5 = *right-anchor quality*). The anchor points represented opposite qualities for each factor. For example, for the time factor, a score of 1 (left anchor) indicated that the movement had a "*sustained, leisurely, slow*" quality, and a score of 5 (right anchor) indicated a "*sudden, hurried, fast*" quality. The three intermediate points in the scale indicated a gradient between the left and right anchor qualities. Mean scores for each Effort-Shape factor were calculated for each movement trial.

A mixed-effects ordinal logistic regression analysis was used to determine the fixed effects of emotion, video order, and observer gender and the random effects of observer and actor on the Effort-Shape scores. An ordinal rather than continuous model was used because the Effort-Shape outcome scores were not expected to be distributed normally.

Table 5 Qualities associated with Effort-Shape factors

Effort-Shape factor	Left-anchor qualities[a]	Right-anchor qualities[b]
Torso	Contracted, bowed, shrinking	Expanded, stretched, growing
Limb	Moves close to body, contracted	Moves away from body, expanded
Space	Indirect, wandering, diffuse	Direct, focused, channeled
Energy	Light, delicate, buoyant	Strong, forceful, powerful
Time	Sustained, leisurely, slow	Sudden, hurried, fast
Flow	Free, relaxed, uncontrolled	Bound, tense, controlled

[a] Score = 1

[b] Score = 5

Like in Experiment 2, random effects of observers and actors were assessed by analyzing the variance components. Another ordinal logistic regression analysis was used to determine which Effort-Shape factors contributed significantly to prediction of emotion perception. Finally, Cronbach's alpha was calculated for each emotion and Effort-Shape factor to assess the reliability of the observer scores (Wallbott and Scherer 1986). The significance level was set at $p < .05$ for all tests.

Results

Reliability of Effort-Shape scores among observers for each actor and emotion was good; Cronbach's alpha was .860, for all emotions and Effort-Shape factors. Averaged across emotions, the Cronbach's alpha scores for the energy, flow, space, time, limb and torso factors were .952, .871, .758, .939, .879 and .762, respectively. Video order and observer gender did not affect Effort-Shape scores.

The profiles of mean Effort-Shape scores for each emotion for recognized, perceived, and non-perceived trials are shown in Fig. 2. No two emotions shared the same set of mean Effort-Shape scores, implying that a unique set of Effort-Shape qualities may be associated with each target emotion. The Effort-Shape scores for perceived trials differed from non-perceived trials for each target emotion. The Effort-Shape profiles for recognized trials were similar to the perceived trials (i.e., angry) or they amplified the differences between perceived and non-perceived trials (i.e., anxious, sad).

The set of Effort-Shape factors that best predicted emotion perception was also unique for each of the target emotions (Table 6). Pride was most strongly predicted from the Effort-Shape scores ($r = .439$). In proud trials, energy and time scores were positively associated, and space scores were negatively associated, with emotion perception. Emotion perception was predicted from the Effort-Shape scores next most strongly for the other high activation emotions, angry and joyful ($r = .228$ and .171, respectively). In angry trials, limb and energy scores were positively associated with emotion perception. When emotion recognition rather than perception was predicted for the angry trials, the strength of the relationship increased ($r = .273$). In joyful trials, limb scores were positively related, and flow scores were negatively correlated, with emotion perception. In anxious trials, limb and flow were positively related, and time was negatively related, with emotion perception. Finally, perception of the low activation emotions, sad and content, was most weakly related to the Effort-Shape scores.

In this experiment, untrained observers were able to use an Effort-Shape analysis to detect differences in movement qualities that were associated with different emotions.

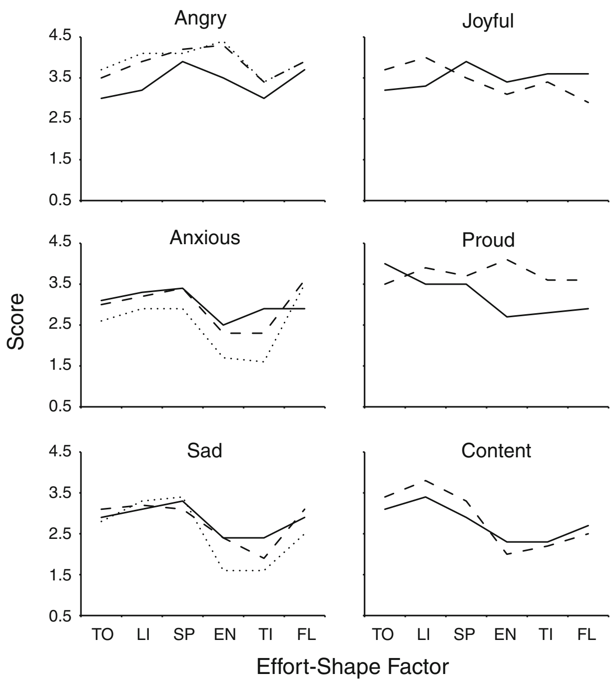

Fig. 2 Effort-Shape profiles for the target emotions. Mean Effort-Shape scores are plotted for trials in which the target emotion was not perceived (*solid line*), perceived (*dashed line*) and recognized (*dotted line*). The largest Effort-Shape scores correspond to the right-anchor qualities for each factor; smallest Effort-Shape scores correspond to the left-anchor qualities for each factor (Table 5). Effort-Shape factors were: *TO* torso shape, *LI* limb shape, *SP* space, *EN* energy, *TI* time, and *FL* flow

Table 6 Effort-Shape factors included in regression models predicting emotion perception

Emotion	Effort-Shape factor						*r*
	Torso	Limb	Energy	Space	Time	Flow	
Angry[a]		+	+				.228***
Anxious[a]		+	ns	ns	−	+	.144***
Sad[a]	ns				−	+	.114***
Joyful[b]	ns	+				−	.171***
Proud[b]			+	−	+		.439***
Content[c]		+	−	+			.078**

* $p < .05$; ** $p < .01$; *** $p < .001$

[a] Perceived trials = 4

[b] Perceived trials = 2

[c] Perceived trials = 1

Unique Effort-Shape profiles emerged for each target emotion. The Effort-Shape profiles differed between trials in which the target emotions were perceived or were not perceived, and these differences were amplified in the recognized trials.

Experiment 4

The purpose of this experiment was to quantify the effects of different emotions on body movements. The method was assessed by examining whether the kinematic analysis could discriminate among the target emotions. Our kinematic analysis included the whole body because even an apparently simple arm movement like knocking generates internal motion-dependent forces that must be stabilized by muscle activity at joints throughout the body. The amount of muscle activity generated to control body posture and limb motions could vary with emotion, thus potentially affecting observable joint motions throughout the entire body. A secondary objective of the study was to provide a preliminary kinematic analysis of expressive body movements during knocking, and to relate the movement kinematics to emotion perception and recognition.

Method

Motion data were analyzed for the same 42 movement trials used in the previous three experiments. Motion data were captured at 120 Hz using a video-based motion analysis system. The three-dimensional coordinate data from the markers were used to model the head/neck, torso, thigh, shank, foot, upper arm, forearm, and hand segments. Joint angles in the sagittal plane (i.e., flexion/dorsiflexion and extension/plantarflexion) were calculated for the neck, shoulder, elbow, knee, and ankle, and a segment angle (angle between the long axis of the segment and vertical) was calculated for the torso. Hand marker data were incomplete so wrist angles could not be calculated. Angular data were filtered using a low-pass, recursive Butterworth filter with cut-off at 8 Hz, and elbow angles were differentiated to calculate elbow angular velocities.

Overall movement time was calculated as the time from onset of arm movement to the time when the arm returned to the side and ceased moving. Overall movement time was subdivided into three component times, and the duration of each component was calculated. The components were: (1) arm ascent (from the beginning of arm movement to the onset of the repetitive knocking motion), (2) knock (the duration of the repetitive knocking motion), and (3) arm descent (the time from the end of the knock phase to the end of the movement). Because elbow motion dominates the knocking movement, a knocking cycle was defined as the interval between adjacent elbow flexion maxima. Multiple knocking cycles occurred during the movement and average knocking cycle durations were calculated for each trial.

Mean and peak joint angles were calculated for the overall movement. Range of motion was calculated as the difference between maximum and minimum values. For the elbow, kinematic values were calculated only for the knocking component of the movement. Maximum angular velocities of the elbow towards (extensor) and away from (flexor) the knocking surface were also calculated. Descriptive statistics were calculated separately for perceived and non-perceived trials.

Results

The actors produced similar knocking movements with the target emotions. The mean movement time was 3.644 ± 1.367 s, the mean number of knocks was 4.4 ± 3.9, and the mean time spent knocking was 1.583 ± .906 s across all the emotions. The relative times spent raising the arm, knocking, and lowering the arm tended to vary with emotion and with perception (Table 7). The longest movement time occurred in the sad

Table 7 Temporal characteristics of knocking movement

Trials	*n*	Movement time (s)	Ascent time (%)	Knocking time (%)	Descent time (%)
Angry					
Perceived	4	2.804 ± .725	23 ± 4	48 ± 1	29 ± 9
Not perceived	2	3.125 ± .153	25 ± 10	35 ± 1	40 ± 11
Anxious					
Perceived	3	4.567 ± .947	17 ± 5	47 ± 3	36 ± 6
Not perceived	3	3.917 ± .874	27 ± 9	39 ± 8	33 ± 12
Content					
Perceived	1	4.500	17	32	52
Not perceived	5	4.000 ± 1.302	24 ± 8	44 ± 16	32 ± 16
Joyful					
Perceived	2	2.550 ± .212	16 ± 3	44 ± 11	41 ± 8
Not perceived	4	3.029 ± .657	18 ± 5	45 ± 16	37 ± 13
Proud					
Perceived	2	2.558 ± .719	18 ± 7	44 ± 0	38 ± 7
Not perceived	4	4.208 ± 2.467	22 ± 9	48 ± 17	30 ± 12
Sad					
Perceived	3	5.522 ± 2.944	30 ± 16	23 ± 8	47 ± 8
Not perceived	3	3.239 ± .337	20 ± 6	42 ± 13	38 ± 10
Neutral					
Perceived	6	3.364 ± .354	19 ± 3	47 ± 7	34 ± 5

trials; the mean movement time increased 70% from the non-perceived to perceived trials. The shortest mean movement times occurred for the angry, joyful, and proud trials. For each of these emotions, the average decrease in mean movement times from non-perceived to perceived trials was 22%. The relative time spent in each of the three component phases of the movement was affected by emotion. The relative time spent knocking was least for perceived sad trials, and decreased 45% from non-perceived to perceived trials. The relative time spent knocking was greatest for perceived angry and anxious trials, and increased on average 29% from non-perceived to perceived trials. The relative descent time was decreased in perceived angry trials, and the relative ascent time was decreased in perceived anxious trials to accommodate the increase in knocking time.

Body motions during the overall movement were similar across the emotions. As expected, the greatest ranges of motion occurred for the elbow and shoulder joints (108 ± 17 and 69 ± 13 deg, respectively). Postural ranges of motion were greater for the neck and torso (21 ± 6 and 22 ± 4 deg, respectively) than for the knee and ankle (6 ± 6 and 5 ± 2 deg, respectively). Some kinematic differences did emerge for emotion and perception. In the perceived angry trials, the mean peak shoulder flexion (raised arm; 71 deg) was at least 17 deg greater than for any other emotion, and was 8 deg greater than in the non-perceived angry trials. Mean peak torso extension (backwards rotation) was at least 7 deg greater in angry and joyful trials than for the other emotions, and increased 10 and 15 deg from non-perceived to perceived trials for angry and joyful

Table 8 Mean elbow joint kinematic data for knocking cycles

Trials	*n*	Frequency (knocks/s)	Cycle duration (ms)	Range of motion (deg)	Max flexor velocity (deg/s)	Max extensor velocity (deg/s)
Angry						
Perceived	4	2.0	489 ± 123	52 ± 16	455 ± 108	699 ± 144
Not perceived	2	2.7	367 ± 6	31 ± 4	315 ± 98	498 ± 76
Anxious						
Perceived	3	2.2	462 ± 252	15 ± 5	216 ± 78	358 ± 145
Not perceived	3	2.4	418 ± 196	19 ± 12	241 ± 56	255 ± 112
Content						
Perceived	1	2.1	473	27	163	305
Not perceived	5	2.4	424 ± 147	23 ± 15	296 ± 64	433 ± 177
Joyful						
Perceived	2	3.5	286 ± 54	25 ± 4	385 ± 34	375 ± 88
Not perceived	4	3.4	293 ± 112	20 ± 10	364 ± 85	411 ± 106
Proud						
Perceived	2	2.7	369 ± 104	36 ± 3	288 ± 76	387 ± 14
Not perceived	4	2.9	335 ± 57	20 ± 8	422 ± 160	475 ± 182
Sad						
Perceived	3	2.2	426 ± 27	14 ± 7	189 ± 56	276 ± 101
Not perceived	3	2.3	405 ± 74	32 ± 13	352 ± 89	539 ± 238
Neutral						
Perceived	6	2.1	479 ± 130	22 ± 8	271 ± 65	409 ± 128

trials, respectively. The torso range of motion was at least 7 deg less in perceived anxious (11 deg) and sad (14 deg) than in the other emotions (21–27 deg), and decreased by 50% from non-perceived to perceived trials for both emotions. The neck was rotated backwards (head upwards) at least 8 deg more in perceived joyful and proud trials than for any other emotions; for proud trials, backwards rotation of the neck was 12 deg greater in perceived than in non-perceived trials.

Some emotion-related differences emerged in the elbow movements during the knocking cycles, and, for some target emotions, elbow movements differed substantially between perceived and non-perceived trials (Table 8). Mean knocking frequency increased 70% from the lowest rate in perceived angry trials to the highest rate in perceived joyful trials. Knocking frequency differed substantially with perception only for angry trials in which the knocking frequency was 26% less in perceived than in non-perceived trials. The mean elbow range of movement in perceived angry trials was at least 44% larger than in any other perceived trials. Elbow range of motion differed substantially between perceived and non-perceived trials for three of the target emotions; elbow amplitude was much greater in perceived than non-perceived angry (68%) and proud (80%) trials, but was much less in perceived sad trials (56%). The mean peak elbow extensor velocity (movement towards the knocking surface) was greatest in perceived angry trials and was least in perceived sad trials. The mean peak elbow flexor velocity tended to be less than the mean peak extensor velocity for all target emotions except joyful.

Joint Coordination

Others have suggested that the relationship between joint motions, rather than just the movement of a single joint, may be important for recognizing emotions during movement (Pollick et al. 2001). To explore the relationship between joint coordination and emotion recognition, we examined angle-angle graphs from one actor who produced movement trials in which observers recognized four of the six target emotions. The percent of observers recognizing the target emotions for this actor were 83, 74, 69, and 91% for angry, sad, content, and anxious, respectively.

For this actor, coordination between the shoulder and elbow joints was similar among the four target emotions (Fig. 3, middle column). Motion began and ended with the shoulder and elbow extended (lower left portion of graphs); the knocking action occurred when the shoulder and elbow were most flexed (upper right portion of each graph). Unlike

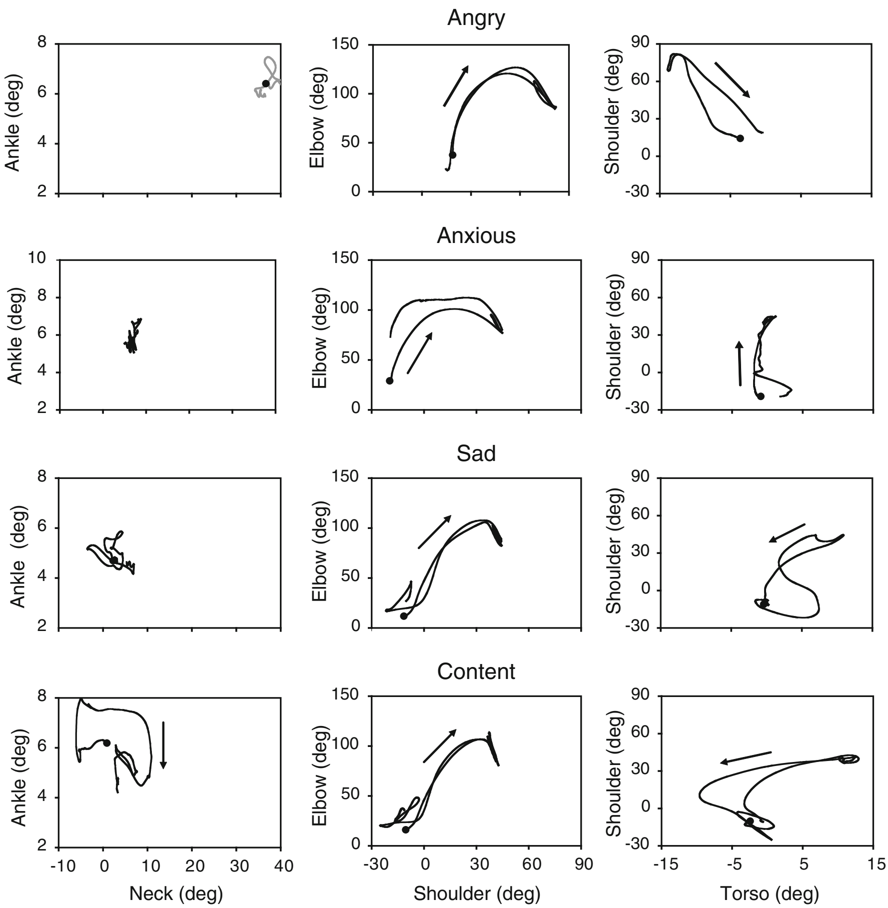

Fig. 3 Joint coordination during knocking in recognized target emotion trials for one actor. Larger (positive) angles indicate joint flexion (i.e., moving towards the knocking surface), smaller (negative) angles indicate joint extension; zero degrees represents anatomical position. Coordination between the ankle and neck, the elbow and shoulder, and the shoulder and torso are shown in the *left*, *middle* and *right* columns, respectively

the other three target emotion trials, the trajectories of the shoulder and elbow joints were different during arm ascent and descent in the anxious.

For this actor, the coordination between the gesturing arm and the torso depended on emotion (Fig. 3, right column). In the angry trial, similar to the perceived angry trials across actors, the torso rotated backwards into an extended position as the shoulder flexed to raise the arm in preparation for knocking. In the sad and content trials, the torso and shoulder joints flexed together to prepare for knocking, and the torso oscillated slightly as the arm was lowered after knocking. In the anxious trial, similar to the perceived anxious trials across actors, the torso moved very little during the task. In contrast, the torso flexed nearly twice as much in the content trial than in any other trials.

The coordination between postural angles also depended on emotion for this actor (Fig. 3, left column). In the angry trial, the neck and ankle trajectories were clustered in the upper right corner of the graph, corresponding to the body pitching forward over the planted feet, with the head down. In the anxious trial, torso rigidity was apparent in the very limited range of motion at the neck. In contrast, neck movement was much greater in sad and content trials. In the content trial, motions of the neck and ankle were decoupled and the excursions were much larger than in any other trial. For this actor, the neck, torso, and ankle motions were literally broadened when experiencing contentment compared to the other emotions.

In this experiment, the number of movement trials was not sufficient to fully characterize the kinematic effects of emotion on body movement. Some trends emerged, however, particularly for angry and sad emotions. For example, angry trials tended to be associated with greater elbow range of motion, elbow extensor velocity, shoulder flexion, and torso extension compared to the other emotions. The emotion-related differences were amplified in the perceived target emotion trials.

General Discussion

The overall goal of this study was to develop and assess methods for identifying movement trials that were strongly related to target emotions so that the movement qualities associated with specific emotions could be characterized. To accomplish this goal, we identified the movement trials in which the actors actually felt the target emotion while moving and the observers recognized the target emotion in the actors' movements. We then examined the qualitative and quantitative characteristics of the body movements, and related those characteristics to the emotion recognition. Although the small number of movement trials in which the target emotions were both felt and recognized limited our ability to fully characterize emotion-specific movement qualities during knocking, the approach developed in this study can be used as a basis for future investigations.

The results of this study highlight factors that are important to consider when designing production studies for bodily expression. Most importantly, a large number of movement trials are needed, and ideally, a relatively large number of actors should generate them. We found that imposing the requirement that the target emotions must be perceived eliminated about half of the movement trials generated by the actors. With the more stringent recognition criteria, the emotion recognition rates decreased further, and were lower for the positive than for the negative emotions. We also found that perception and recognition rates differed among actors, and that even for the same actor, rates differed with emotion. Actors felt, and observers perceived, a range of feelings in the movement trials in addition to the target emotion. By imposing strict recognition criteria, the selection of movement trials was narrowed to those that communicated primarily the target emotion. The net effect of this approach, however, was that only one quarter of the original set of movement trials was available for assessing emotion-related movement qualities. A similar rejection rate emerged in another study that also imposed selection criteria on emotion-related movement trials (Wallbott 1998). In that study, 12 professional actors were videotaped while performing scenarios related to 14 different emotions. The video clips were evaluated by experts (drama students) for naturalness of expression and recognizability of intended emotion; only 224 of 1,344 (17%) video clips were judged as appropriate. Although selection criteria result in higher specificity, the implications for experimental design can be challenging since many trials are potentially eliminated. An important outcome of our study is an indication of the relative number of movement trials needed to analyze movement characteristics associated with different target emotions. If the goal of a production study is to generate sufficient movement trials in which specific target emotions are displayed successfully, our results suggest that many more trials are needed for positive emotions than for negative emotions.

If we had used a forced choice paradigm, or had reduced the number of items on the feelings questionnaire, it is likely that fewer trials would have been eliminated. In a study of affect recognition in arm movements using a forced choice paradigm, overall recognition rate increased from 31 to 59% when the number of affects was decreased by removing the affects that were consistently confused (Pollick et al. 2001). We assume that our threshold intensity criterion (i.e., perception test) was equivalent to a typical forced choice outcome for selecting movement trials. Using the perception assessment resulted in twice as many "recognized" movement trials, distributed evenly across positive and negative target emotions. Whether a forced choice paradigm or a more stringent recognition assessment is used, however, our results suggest that it is very important to impose selectivity on trials included in an analysis of emotion-related movement characteristics.

Even with attention paid to the selection of movement trials tuned to a particular target emotion, more movement trials were needed than were produced in this study to address the kinematic variability inherent in production of movement while experiencing an emotion. Although observers perceived the target emotions in the actors' body movements, we found relatively few emotion-related differences in the kinematics of the gesturing arm or the postural configuration of the body. Even though the knocking task was highly constrained, variability in the dataset due to the individual actors was considerable. These results underscore the importance of using a constrained task for investigating the effect of emotion on bodily expression. Thus, we were not able to fully address the question of which kinematic variable (or variables) were most characteristic of the target emotions and might have contributed to emotion recognition.

Although previous studies of bodily expression have also used a small number of actors to portray emotional body movements (de Meijer 1989; Montepare et al. 1999; Wallbott 1998), our results support the observation that not all actors generate equally recognizable, emotionally expressive body movements. Others have reported similar variability among actors (Montepare et al. 1987; Wallbott 1998) and have suggested that it is important to include a relatively large number of actors to capture the range of expression that is associated with a particular emotion (Atkinson et al. 2004). Although some have suggested that the magnitude of the actor effects are likely smaller than the effects of the target emotions themselves (Wallbott and Scherer 1991), others have shown that actor effects exceeded emotion effects in producing some aspects of facial expressions (Pollick et al. 2003). Our results suggest that actor effects can be substantial and that this potential variability needs to be taken into account when generating a sufficient number of movement trials for subsequent analysis of emotion-associated movement characteristics. The actors' recalled experiences were associated with different circumstances, different appraisals, and ultimately, with different evoked emotions. Because the actors in this study were asked to recall a specific feeling while they produced the movement, the generalizability of these results to movements produced by actors under more typical instruction sets is unknown.

To our knowledge, this is the first study of bodily expression in which the actors' feelings during production of emotion-related movements have been assessed. The actors in this study reported that they felt the target emotions in 92% of the trials. We assume that these subjective reports of moderately intense feelings indicated that the neurobiological events underlying emotion expression were triggered, and that the actors' experienced the target emotions during the movement task. As expected, the target emotions were not the only feelings elicited in the actors. Some of the feelings were quite close (e.g., angry and contemptuous), and it was not possible to elicit one of the feelings without the other. For example, in the joyful and proud trials, all of the actors reported feeling nearly the same intensities of pride and joy. Because the actors experienced multiple feelings while knocking, the multiple feelings may have affected their body movements. Correspondingly, confusion was evident in the observers' responses, particularly for the positive target emotions. By assessing both the actors' feelings and the observers' responses, however, the source of the confusion can be investigated with higher resolution.

The observers may have failed to perceive the target emotions because of errors in production (e.g., the actors did not feel the target emotion or did not feel it exclusively; the actors did not encode the target emotion or did not encode the target emotion exclusively), or errors in perception (e.g., observers did not decode accurately). The great majority of communication errors in this study were of the false negative type in which the actors felt but the observers failed to perceive the target emotions. More of these errors occurred for the positive than for the negative emotions, suggesting that something about the encoding of felt positive emotions is less effective with regards to emotion communication, at least for this task. Our analysis also identified the movement trials in which the target emotions were portrayed, i.e., perceived by the observers but not felt by the actors. It remains to be determined whether the body movements associated with portrayed emotions are the same as those for felt emotions.

Given the paradigm used in this study, it is not possible to determine if the failure of the observers to detect the target emotions in the actors' body movements was due to errors in the encoding by actors or decoding by observers, particularly for the positive emotions. Like this study, others have also reported confusion of pride and happiness in studies of bodily expression of emotion (Montepare et al. 1999; Wallbott 1998). It may be that the positive emotions are less specific in their motor consequences (see Fredrickson 1998, on lesser differentiation among positive vs. negative emotions), resulting in more variability in expression, and thus may be more difficult to recognize from the body movements only. That being the case, it suggests that even more trials are needed for the positive emotions. Regardless of variability in body movements, however, negative emotions may be more salient than positive emotions when observers are asked to evaluate the feelings of others (Baumeister et al. 2001; Rozin and Royzman 2001). Further, we do not know if the actual movement task of knocking interacted with emotion perception in our observers, potentially introducing a bias towards negative emotions.

Using the Effort-Shape analysis, observers were able to detect differences in the qualitative characteristics of the actors' movements. Although angry and joyful were both high-activation target emotions, their Effort-Shape profiles were quite distinct, suggesting that the Effort-Shape analysis was sensitive to differences in valence. The target emotions most confused by observers, joyful and proud, had similar Effort-Shape profiles. When only the perceived trials were considered, however, their Effort-Shape profiles diverged, particularly for energy. Differences in Effort-Shape scores between the low activation emotions (content, sad) were less distinct. Despite relatively small differences in the mean Effort-Shape scores across factors for these two emotions, and the weak predictive relationship between Effort-Shape scores and perception, the differences in movement qualities were sufficient for the observers to distinguish between them.

Although not directly comparable, some qualitative results reported by others are consistent with our Effort-Shape results. Our findings for angry and joyful trials ("strong, powerful, forceful" and "sudden, hurried, fast") were similar to the characterizations of hot anger and elated joy as high "dynamics/energy/power" and "hard, expanded, fast" described by others (Montepare et al. 1999; Wallbott 1998). Our findings for sad trials (i.e., sustained, leisurely, slow) were consistent with the "slow", "slow, soft, and contracted" and "less energetic" qualities observed by others (Brownlow et al. 1997; de Meijer 1989; Montepare et al. 1999; Wallbott and Scherer 1986). Finally, our findings for anxious trials (i.e., bound, tense, controlled) were consistent with the "increased use of shrinking movements" in the improvised movements of individuals with high levels of trait anxiety (Levy and Duke 2003).

A potential limitation of our study was the use of untrained observers rather than individuals trained in Laban movement analysis to generate the Effort-Shape scores. Our purpose was to develop a method for codifying qualitative movement characteristics that could be used broadly by non-experts, but that would take advantage of the systematic approach to qualitative movement description inherent in Laban analysis. Although the untrained observers in this study were able to discern Effort-Shape qualities in the movements, the reliability of observer ratings might improve with some training in the Effort-Shape concepts.

Kinematic characteristics of the knocking movements were consistent with expected movement qualities for each target emotion. Angry movements were expected to be energetic and forceful, and the angry trials were associated with the largest amplitude of elbow motion, the largest elbow extensor velocity (likely generating the most contact force), the highest raised arm (i.e., largest shoulder flexion), and the longest relative time spent in actually knocking. In contrast, sadness was expected to exhibit diminished energy and a paucity of movement, and the sad trials were characterized by the longest overall movement time but proportionately the least time spent actually knocking, the smallest amplitude of elbow motion and the least elbow extensor velocity. Anxious trials were associated with short movement times and constrained torso range of motion. Joyful and proud trials were both associated with extended mean neck angles, i.e., a "chin up" position of the head. In addition, joyful trials had the highest knocking rate and, unlike any other target emotion, had similar peak flexor and extensor elbow velocities. Contentment did not exhibit any distinguishing kinematic characteristics.

Even with the small number of movement trials, differences emerged between perceived and non-perceived trials. The expected movement characteristics associated with the target emotions were enhanced in the perceived trials. For example, in the angry trials, movement time and knocking rate decreased, but shoulder flexion, torso extension, elbow amplitude, and extensor velocity increased with perception. In anxious trials, movement time and torso range of motion decreased with perception. In sad trials, movement time increased, and elbow and torso ranges of motion and relative knocking time decreased, with perception. In proud trials, neck extension tended to increase, and in joyful trials, torso extension tended to increase, in perceived trials compared to non-perceived trials. These results strongly suggest that evaluating movement qualities for perceived movement trials may produce a more definitive description of the effect of emotion on body movements.

Some emotions shared kinematic qualities that may have contributed to confusion in emotion perception and recognition. For example, joy and pride were consistently confused in joy and proud trials, and both target emotion trials exhibited a "chin up" neck posture and a short overall movement time. Anger was confused with pride but not joy in angry trials, and angry and proud trials had the largest elbow amplitudes in perceived trials. Conversely, anger was confused with joy in joyful trials, perhaps due to the extended (upright) torso position associated with both target emotions. Threshold levels of anxiousness were observed for all of the target emotions, but it is not clear which kinematic characteristics might have contributed to this confusion.

Some of the kinematic features were consistent with observer ratings of the Effort-Shape qualities. In the angry trials, the increased elbow amplitude, elbow extensor velocity, and shoulder flexion were consistent with "strong, forceful, powerful" energy and "moves away from the body, expanded" limb shape. In the anxious trials, the decreased torso amplitude was consistent with "bound, tense, controlled" flow. In sad trials, the increased movement time and decreased relative knocking time were consistent with "sustained, leisurely, slow" time. In the joyful trials, the rapid knocking rate and the similarity in peak flexor and extensor elbow velocities were consistent shifts in the Effort-Shape scores towards "sudden, hurried, fast" time and "free, relaxed, uncontrolled" flow. In the content trials, the Effort-Shape scores were shifted towards "light, delicate, buoyant" energy and "moves away from the body, expanded" limb shape, but there were no kinematic characteristics consistent with these qualities. It may be that other kinematic variables that we did not assess are better predictors of the Effort-Shape qualities. For example, in a study of arm movements in dancers, finger-tip accelerations were significantly greater in angry than in joyful or sad movements, and the distance traveled by the fingertip (a measure of indirectness) was greater in joyful than in angry or sad movements (Sawada et al. 2003).

Although very few studies exist that document the effect of emotion on movement kinematics, our results are consistent with reports by others. High activation affects (i.e., angry, happy, excited, strong) were positively correlated with decreased movement duration and increased velocities at the wrist (Pollick et al. 2001), and finger-tip velocities were greater in angry than in sad trials (Sawada et al. 2003). Our increased torso extension, shoulder and elbow range of motion, and elbow extensor velocity in angry trials were consistent with the characterization of angry movements by others as "high movement activity, expansive, and high movement dynamics" (Wallbott 1998). Similarly, the relatively large excursions of the torso and neck in our joyful trials were consistent with the characterization of happy movements as "loose" (Montepare et al. 1999). More studies are needed to establish the relationships between movement characteristics and emotions, particularly when the requirement for perception of emotions in the body movements is imposed.

Together, our results demonstrate the efficacy of selecting movement trials in which target emotions are felt and recognized in assessing bodily expression of emotion. By limiting body movements to a single task, the effect of positive and negative emotions on qualitative and quantitative movement characteristics could be determined more specifically. Even with the relatively small dataset and variability among actors, clear differences emerged in both the qualitative and quantitative measures for the target emotions, especially for the negative emotions. Our data support the supposition that the positive emotions were associated with less distinctive kinematic signatures, and that relatively more trials are needed to fully characterize them.

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