Measures of Emotion: How Feelings are Expressed in the Body and Face During Walking

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Kinesiology)
in The University of Michigan
2009

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Acknowledgements

First, I would like to thank Dr. Melissa Gross for giving me the unique opportunity to work in her biomechanics laboratory. During my years with her as both a Masters and PhD student I was always challenged, she encouraged me to explore new ideas, and never seemed to mind my random trips to the hardware store to find "new things" for the lab. Without question, she bought a girl all the Velcro (every kind!), wooden dowels, toupe tape, unitards and running tights, electrode collars, pieces of plastic, clip lights, unistruct, and wires she could ever want. Most of all, I have appreciated her thoughts, feedback, and ideas that continually guided me throughout this process.

My committee members, Dr. John Laird, Dr. Scott McLean, and Dr. Stephanie Teasely, I always appreciated your expertise, feedback, encouragement, and interest in this thesis. Dr. Teasley, thank you for mentoring me as I decided whether to switch back to Kinesiology to pursue the PhD. The time you have given over the years to brainstorm and to talk about my ideas has been a highlight of this experience. Dr. Laird, thank you for helping provide a framework for thinking about the applications of this work. Dr. McLean, thank you for your detailed reviews of the biomechanics methodology in this thesis.

This dissertation was additionally possible because of the support of many students who worked in the lab. Special thanks to Becca Edgeworth who helped me through the long days of data collection, data processing, and endless validation studies. Zara Schulman was also a joy to work with as I was testing methodology and in the early stages of data collection. Although not a student, Alex Flick was always available to help with Matlab code and technical issues that came up in the lab. I appreciated his talent for helping me turn my ideas into functional items that I could actually use during data collection.

Thanks to Brady West for always answering when I asked "can you explain it another way". Because of Brady, I learned more about statistics than I ever thought possible. Likewise, thanks to Ed Rothman for such enthusiastic displays of excitement over my data. Thanks to my accountability group, Julia Looper and Antoinette Domingo. It was always nice knowing you were there to brainstorm or to just chat. Jen Michaels, I will never forget all the conversations you were willing to have about this work. I appreciated your interest and thoughtful comments.

Last but not least, my family and friends. This would not have been possible without your support over the years. My parents who always supported and encouraged me to pursue my interests. My husband, Glenn, who has been at my side every step of the way and one of my biggest cheerleaders. Thanks for all the support, I truly couldn't have done it without you. My brother, Jamie, who kept it real and Beth Tompkins for our weekly phone chats. Finally, a special thanks to my grandfather for demonstrating genuine curiosity and enthusiasm for the world around us.

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Chapter 1

Introduction

Expressive behavior provides insights into many aspects of emotion from social processes to emotion disorders (Cohn, Ambadar, & Ekman, 2007; Hess & G, 2000; Sloan, Strauss, Quirk, & Sajatovic, 1997). Facial and vocal expressions, in particular, are expressive behaviors that are important and have established behavioral assessment methods in emotion research (Bachorowski, 1999; Banse & Scherer, 1996; Ekman, 1993; Ekman, Friesen, & Hager, 2002). Using facial and vocal expressions in emotion research is possible because of the validated methods for assessing expressive behavior in these modalities. In contrast, bodily expression has received the least amount of attention despite ample evidence suggesting that bodily behaviors may be associated with specific emotions (Coulson, 2004; de Meijer, 1989; Kleinsmith, De Silva, & Bianchi-Berthouze, 2006; Wallbott, 1998). Additionally, not all emotions are communicated equally well through each expressive modality (Castellano, Kessous, & Caridakis, 2008; Meeren, van Heijnsbergen, & de Gelder, 2005; Scherer & Ellgring, 2007a, 2007b) and interactions between modalities may also be associated with specific emotionally expressive behaviors (Scherer & Ellgring, 2007b). Thus, comprehensive and validated methods for assessing both bodily expression and interactions between modalities are critical for completing the assessment tools available for furthering insights into emotion.

Established methods for characterizing and assessing expressive behaviors in the face and voice include the Facial Action Coding System (Ekman et al., 2002) and signal processing techniques (Owren & Bachorowski, 2007). Results of studies assessing facial and/or vocal expression are used in clinical practice and well as computer applications. The auto industry, for example, has begun exploring applications that recognize specific behaviors associated with emotions such as anger so that the car can respond appropriately with the aim of avoiding road rage (Jonsson & Harris, 2008). Not only does this application need to recognize behavior associated with emotion, the vocal response produced by the car must be expressed appropriately to elicit the desired reaction from the driver. Recognition and production of emotionally expressive behavior is essential for natural interaction between human and machine. Effective integration depends on successfully characterizing each expressive modality in addition to the interactions between modalities. Therefore, until methods are available for characterizing expressive bodily movement and the interactions between modalities, successful development of applications ranging from the gaming industry to educational tools, is severely limited.

The field of biomechanics has well established and validated methods for assessing and describing human movement (Cappozzo, Della Croce, Leardini, & Chiari, 2005; Chiari, Della Croce, Leardini, & Cappozzo, 2005; Della Croce, Leardini, Chiari, & Cappozzo, 2005; Leardini, Chiari, Della Croce, & Cappozzo, 2005). Yet, the use of biomechanics (including comprehensive methods for capturing and analyzing movement data) has not been exploited as a technique for describing expressive bodily movement. By applying biomechanical methods to this question, progress on answering questions about emotion can be further explored in addition to advancing development of complex applications that need to respond to and/or produce expressive behavior.

Although biomechanics offers comprehensive and reliable methods, specialized knowledge and expensive equipment are needed for capturing and assessing human movement. Therefore, biomechanical methods have not fully been applied in psychology or computer science to quantitatively characterize bodily expression. The range of behavioral coding schemes used in psychology for qualitatively characterizing expressive bodily behavior (Montepare, Koff, Zaitchik, & Albert, 1999; Wallbott, 1998) exemplifies the complexity of human movement. Therefore, combining established methods from psychology and quantitative methods from biomechanics will provide new methods for capturing, assessing, and characterizing emotionally expressive bodily movement.

The goal of this dissertation was to investigate emotion-related multimodal behavioral patterns of the body and face. To do this, methodological limitations were addressed to allow comprehensive qualitative and quantitative characterizations of emotion-related movement. This dissertation addressed four specific aims to accomplish this goal. First, the feasibility of using specialized equipment for capturing facial expression during an unconstrained whole body movement task was validated. Validated methods for simultaneously capturing facial and bodily expression were not previously available yet are necessary for studying multimodal behavior. Second, qualitative movement characteristics associated with emotions that are both felt and recognized were assessed. Because previous qualitative characterizations of emotionally expressive behavior emphasize specific movement behaviors rather than the characteristic ways in which the movements are performed, a task-independent method for describing expressive bodily behavior does not exist. Third, methods from biomechanics were used to quantitatively characterize the bodily expression of five target emotions during a walking task. Use of these methods provided a comprehensive and systematic assessment of quantitative movement features. Finally, facial expressions that occurred during the walking task were characterized, providing the data necessary for the multimodal analysis. The multimodal analysis explored whether there is evidence for multimodal patterns of emotion-related behavior. Together, the methods used in this dissertation provide a novel set of assessment tools for investigating questions about the psychology of emotion and provides a comprehensive description of emotion-related movement characteristics.

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Chapter 2
Background

2.1 Overview

Emotions are expressed nonverbally using an integrated combination of signals from the body, face, and voice (Castellano et al., 2008; Ekman, 1964; Scherer & Ellgring, 2007b; Van den Stock, Righart, & de Gelder, 2007). However, methodological challenges have limited the ability to assess the expressive characteristics of multimodal behavior. In fact, only one study has systematically assessed multimodal expression (Scherer & Ellgring, 2007b). Therefore, little is known about how expressive signals combine to characterize specific emotions.

Before multimodal expression of emotion in the body and face can be characterized, methodology is needed for simultaneously capturing these modalities and comprehensive methods for assessing subtle expressive bodily behavior are needed. Thus, the three main goals of this dissertation are to validate the feasibility of new methodology for simultaneously capturing multimodal behavior in the body and face, to systematically identify qualitative and quantitative signs in body movement that may be associated with specific emotions, and to assess the signals in the body and face that combine to characterize emotionally expressive behavior. To provide the necessary foundation for addressing these goals, this chapter covers the fundamentals of expressive behavior, methodological considerations relevant to expressive behavior in the face, voice, and body, and finally multimodal expressive behavior.

2.1.1 Fundamentals of expressive behavior

The study of emotionally expressive behavior is guided by the implicit assumption that emotion affects motor behavior resulting in characteristic changes in expressive modalities such as the face, body, and the voice. Relatively new to emotion research are fMRI studies, which provide some of the first neurological evidence that emotion affects motor behavior. In these studies, brain regions associated with both emotion processing and motor responses are both activated when subjects view images of emotional body postures (Beatrice de Gelder, 2006; Pichon, de Gelder, & Grezes, 2007). Although the technology to conduct these studies has only recently been applied to emotion studies, the existing empirical evidence resulting from fMRI studies firmly supports the assumption that emotion affects motor behavior, which is a crucial assumption made by researchers studying emotionally expressive behavior.

The results from brain imaging studies are consistent with the empirical evidence from observer recognition studies and analyses of expressive behavior. Frijda (1986) associates emotion and motor behavior by explaining emotions as coordinative structures associated with a tendency to act. For example, anger has been associated with an urge to attack, sadness with a tendency to withdraw from action, and fear with the urge to flee (Frijda, 1986). Levenson (1994) represents such emotion manifestations as multifaceted processes that include antecedent events, emotion prototypes, action tendencies, and measurable responses (R. W. Levenson, 1994) (Figure 1). Further, Larsen and Fredrickson (1999) provide a working definition of emotion embodying the concepts necessary for this dissertation: emotion affects motor behavior and behavior is multimodal. This working definition provides three relevant assumptions about emotion: (1) emotions are multifaceted processes that unfold over time, (2) emotions manifest themselves in multiple channels, and (3) emotion channels are loosely coupled and may interact in complex ways.

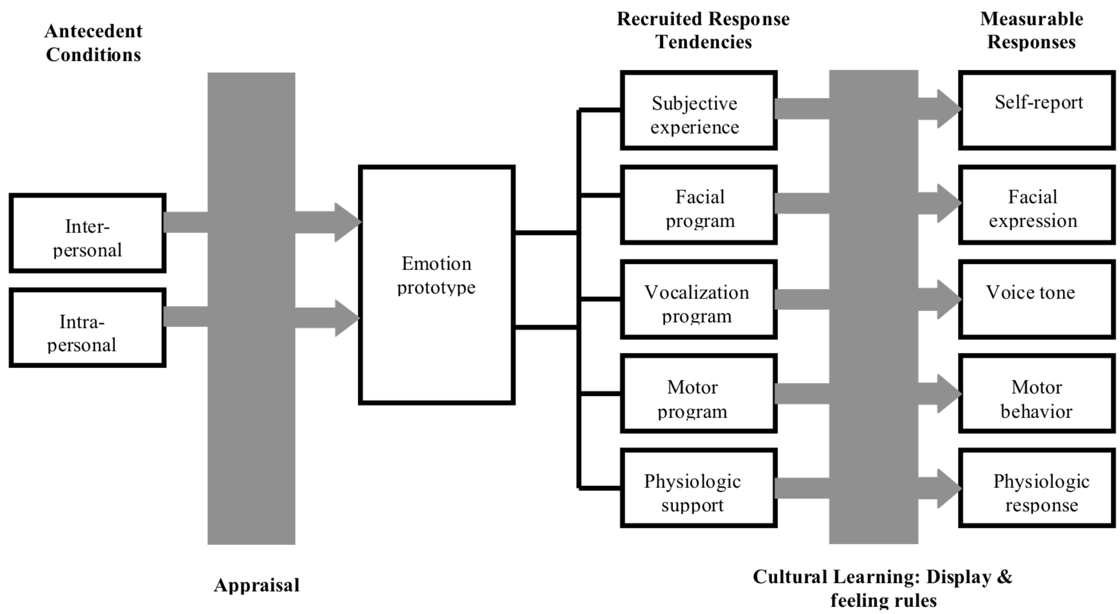

Figure 1. Model of emotion (Levenson, 1994).

Empirical evidence from recognition studies establishes that observers can accurately recognize emotions from both static images of emotion-related body postures (Atkinson, Dittrich, Gemmell, & Young, 2004; Coulson, 2004; Kleinsmith et al., 2006) and dynamic displays of prototypical emotion-related gestures (Atkinson, Tunstall, & Dittrich, 2007; Costanzo & Archer, 1989; Grezes, Pichon, & de Gelder, 2007; Montepare et al., 1999; Rozin, Taylor, Ross, Bennett, & Hejmadi, 2005; Scherer & Ellgring, 2007b; Wallbott, 1998; Wallbott & Scherer, 1986) and stylized movements (Camurri, Lagerl, & Volpe, 2003; Dahl, 2007; Dittrich, Troscianko, Lea, & Morgan, 1996; Sawada, Suda, & Ishii, 2003). *Observer recognition studies* are commonly used in studies of expressive behavior to gain social consensus about what the person performing the movement was feeling. The person performing the movement will be referred to as the *encoder*; terminology often used in studies of expressive behavior (Scherer, 2003; Wallbott, 1998). *Prototypical gestures* are movements made with the intent to communicate and have been the primary source of expressive stimuli used in observer recognition studies. *Stylized* *movements* are found in dance, for example, where specific movement patterns suggestive of specific emotions are used. Prototypical gestures and stylized movements will collectively be referred to as *emblematic movements*. Overall, recognition studies suggest that motor behavior changes are both observable and characteristic for specific emotions.

To describe the changes associated with specific emotions, analyses measure the emotionally expressive behavioral characteristics. This type of study is referred to by Scherer (2007b) as a *production study***,** a term that will be used throughout this dissertation to describe analyses that aim to either qualitatively or quantitatively characterize expressive behavior. Accurately measuring and describing expressive behavior using production studies requires two key components. First, one must identify the behavior that they are going to measure. Second, evidence must be provided that suggest the behavioral characteristics associated with specific emotions.

The first component required to gain a detailed understanding of expressive behavior is identifying the channel that carries the expressive signal. In semiotics (a branch of philosophy and communication), the terms sign and sign vehicle are used (Hager & Ekman, 2003). The *sign* is a symbol of the actual signal and the sign vehicle is the *channel* used to carry and transmit the sign. In facial expression research, the sign is a symbol of the emotion and the sign vehicle is the visible changes produced by muscular actions (buldges, bags, pouches, wrinkles, shapes etc. (Hager & Ekman, 2003). Making this distinction is important because we do not have the technology available to measure the actual signal (the emotion). Therefore, we must mind the gap. The task, then, is to capture behavioral changes (the sign vehicle) and determine the changes that are associated with specific emotions (the sign). For the purpose of this dissertation, the sign vehicle will be referred to as a channel. For example, in facial expression, the face is the modality, the visible changes in the face (buldges, bags, wrinkles etc.) is the channel, and the specific visible characteristics associated with an emotion is the emotion sign. Hager and Ekman (2003) strongly note that research trying to measure behaviors involved in communication should measure the sign vehicles.

While the goal of the first component is to identify a sign vehicle and determine how to measure it, the goal of the second component is to identify a relationship between the measured signs and specific emotions. The significance of this is to ensure that the sign vehicle is not just creating a reliable pattern for a specific behavior, but that it is also the pattern that reliably indicates the presence of a specific emotion. In other words, the goal in this step is to validate the emotional meaning of the measured behavior. Because whole body movement is so complex, movement kinematics have not been thoroughly explored as a sign vehicle for the emotion signal. Thus, a systematic exploration of qualitative and quantitative aspects of movement is necessary to determine whether emotion affects movement characteristics and whether these effects are reliable indicators of emotion.

2.1.2 Conclusions

Several methodological issues have impeded the study of multimodal expressive behavior, primarily related to both the ability to simultaneously capture multiple modalities and to how emotionally expressive body movements are generated and quantified. Characterizing multimodal expression in the body and face will only be possible if methods are developed and validated for simultaneously capturing expressive behavior in these modalities and methods for characterizing expressive behavior in the body are systematically assessed. To begin, the following section reviews a validated and comprehensive system for characterizing facial expression.

2.3 Facial expression

Facial expression is recognized as a valid indicator of emotion and can be described using the Facial Action Coding System (FACS) (Cohn et al., 2007; Cohn & Ekman, 2005; Ekman & Rosenberg, 2005). As characterized by Cohn et al. (2007), FACS has emerged as the most widely used, comprehensive, and psychometrically rigorous coding system for describing facial expression(Cohn et al., 2007; Cohn &

Ekman, 2005; Ekman & Rosenberg, 2005). FACS coding is most effective when images are unobstructed frontal views. Yet, capturing images suitable for FACS coding is not possible unless participants remain in a single position and directly face the camera. Consequently, facial expression analysis is not currently possible when the experimental methodology allows free movement, thus limiting the ecological validity of results and the variety of hypotheses that can be tested. Nonetheless, while FACS is an appropriate methodology for assessing facial expression, the procedure for capturing images suitable for FACS analysis limits potential experimental designs. The goals of this section are to briefly describe FACS coding and how it was developed, and then to discuss methodological considerations for analyzing and collecting expressive facial behavior.

An important feature of FACS is that it is purely descriptive and makes no inferences about emotions. In this respect, FACS can be thought of as a measurement system from which inferences about emotion can be made based on the observed behavior. To code facial behavior, trained FACS coders view videos of facial expressions and manually code each frame. Facial expressions are described in action units (AUs), which are the smallest visually discriminable facial movements. Based on empirical research, associations between specific combinations of AUs and emotions are made. A general list of these is available in the FACS Investigators' Guide (Ekman et al., 2002), the FACS interpretive database (Hager, 2003), and in empirical research.

To determine the visual change in the face that occurs when each muscle is activated, Ekman and Friesen electrically stimulated each muscle in themselves, learned to control them voluntarily, and documented appearance changes (Cohn et al., 2007). If more than one muscle produced the same appearance change, only one action unit was assigned to the appearance. The final set of action units is a result of this analysis and includes the set of all visually distinguishable movements. In the most current version of FACS (Ekman et al., 2002), there are 9 AUs specified for the upper face and 18 for the lower face. Each AU is assigned a numerical code, given a description, and is associated with facial muscle(s). For example, AU 1 is the inner brow raiser and is activated by the Frontalis and Pars Medialis muscles. In addition to the upper and lower face, FACS includes 23 codes for head and eye movement, 5 miscellaneous AUs, 9 action descriptors, 9 gross behaviors, and 5 visibility codes (Cohn et al., 2007).

There are two approaches to FACS coding: comprehensive and selective coding. In comprehensive coding, the coder checks each AU in every frame of the video. In selective coding, a predetermined set of codes is checked in every frame. There are advantages and disadvantages to each type of coding. A trained FACS coder takes approximately 100 minutes to code 1 minute of video with comprehensive coding (Cohn et al., 2007). Therefore, for long video segments it can be more feasible to make assumptions a priori about the AUs that are important for the particular analysis. However, with selective coding it is harder to interpret null results, make new discoveries about facial behavior associated with emotions, or to discriminate subtle facial expressions. Therefore, unless studies are assessing specific actions units, comprehensive coding is recommended.

Besides deciding whether to code comprehensively or selectively, coders must also decide whether to code the intensity of the AUs. There are five possible levels of intensity for each AU, but manually coding intensity is still very subjective and reliability is difficult to establish. Despite this limitation, testing hypotheses related to discriminating emotions or describing facial configurations associated with specific emotions, coding action units without intensity is sufficient (Scherer & Ellgring, 2007a, 2007b). Newer, automated methods such as the Automated Facial Analysis system under development at CMU Pitt (Cohn & Kanade, 2007) aim to address this methodological limitation. Until these new methods are fully developed and validated, studies of facial expression are generally limited to coding whether AUs are activated or not, which is an important precursor to investigating AU intensity.

To code facial AUs, a clear unobstructed frontal view of the face is needed. This has presented a significant challenge to researchers interested in facial expression because a study participant cannot be engaged in activities that move the face away from the camera. Due to this limitation, capturing facial expression while concurrently capturing full body dynamic movement where the person is allowed to move freely has not yet been done. Without the ability to capture facial expression during dynamic movement tasks, studies on multimodal behavior are limited.

2.3.1 Conclusions

Despite a comprehensive and validated system for characterizing facial expression, use of FACS is limited by the ability to capture an unobstructed view of the face. In addition to the need for validated methodology for capturing facial expression during dynamic tasks, methods for collecting bodily movement are also necessary for the assessment of multimodal behavior. Although methods for facial expression analysis are not directly applicable to the study of bodily expression, methods used in vocal expression research provide techniques for identifying expressive qualities in continuous signals that are affected by both task and emotion. The following section provides a brief review of vocal expression analysis because its methods are well established and also offer insights into methodology for studying bodily expression.

2.4 Vocal expression

The study of vocal expression relies on established methods for assessing vocal acoustics (Bachorowski, 1999; Banse & Scherer, 1996; Owren & Bachorowski, 2007; Scherer, 2003) that are appropriate for use in the assessment of bodily expression. Vocal and bodily expressions are similar in that the acoustical signal carries information about the task (the words, sentences, or movement) in addition to expressive content. Vocal expression researchers have successfully separated task from expressive content and have associated specific acoustic properties with emotions (Owren & Bachorowski, 2007). Research associating specific movement properties with emotion has much to gain by using previously established methodology for voice. Therefore, the purpose of this section is to review the basic acoustic signal properties and the key methodological design allowing expressive signals to be associated with emotion.

Sound is typically represented mathematically as a continuous sine or cosine function with a particular frequency (Owren & Bachorowski, 2007). When represented as a quantitative function, a number of parameters can be derived using techniques from signal processing and statistics. These parameters are often associated with specific perceptual qualities of sound such as pitch, intensity, voice quality / timber, and tempo (Table 1) (Bachorowski & Owren, 1995; Laukka, 2004). The total number of such parameters that can be derived and studied in vocal expression analyses is quite large. For example, pitch is characterized as the fundamental frequency of the signal. Fundamental frequency is the frequency with which the vocal folds vibrate and can be described by the mean, range, and contour of the signal. One key difference between voice and face signals is that the voice is measured as a continuous signal and typically parameterized into a number of variables that are associated with known perceptual qualities of acoustic signals.

Table 1. Perceptual qualities associated with acoustic signal parameters.

Perceptual Quality	Associated acoustic signal parameter
Pitch	Pitch is modulated by changes in the frequency with which the vocal folds vibrate. This is quantified as the fundamental frequency (F0).
Intensity	Intensity is also referred to as loudness and reflects the effort required to produce speech.
Quality	Quality of speech is determined by the vocal tract resonance of the pharyngeal, oral, and nasal cavities. Quality is typically quantified as the frequencies of the first two formants (i.e. vocal tract resonances).
Tempo	The temporal sequence of the production of sound. Typically quantified as speech rate and pausing.

Studies of vocal expression typically use standardized and often meaningless sentences (Scherer, 2003; Scherer, Banse, Wallbott, & Goldbeck, 1991), with the speakers in the studies being asked to say the same sentence for all emotions. The purpose of standardizing the sentence is to ensure that differences in acoustic variables can be attributed to emotion rather than to the use of different words. Further, some studies use meaningless sentences that give the impression of listening to an unknown foreign language (Wallbott, 1998). For recognition studies, using meaningless sentences ensures that listeners are using expressive cues in the signal to determine the emotion that the speaker is feeling rather than making a judgment based on the meaning of the sentence. For production studies, signals can be compared and differences can be attributed to expression rather than task. Therefore, when the goal is to identify and associate expressive style with specific emotions, using a constrained task is recommended.

2.4.1 Conclusions

In summary, procedures used to characterize vocal expression can be borrowed for use in the study of bodily expression despite the differences in the types of signals (one being acoustic and the other visual). The main reason for this is that the signal from the voice has been treated as a continuous signal that is then parameterized into a number of variables that are associated with perceptual qualities. Because signals from the body collected using motion capture technology are also continuous signals that can be parameterized, it is important to use a constrained movement task when studying expressive body movement. This will allow differences in the movement signals to be attributed to emotion rather than task – therefore, task and emotion will not be confounded.

2.5 Bodily expression

Despite the attention both facial and vocal expression have received in the literature, production studies related to expressive bodily movement are comparatively underrepresented. Further, the existing research on this topic is not standardized or comprehensive making comparisons between studies difficult or irrelevant. This issue can be attributed to the complexity of whole body movement indicating a need to reduce the scope of the problem. The first step is to give proper methodological consideration to the procedures used to capture and assess bodily expression. As with facial and vocal expression production studies, bodily expression can be characterized using observer-based coding. In contrast, an alternative method is to capture 3D joint kinematics and use quantitative methods similar to those described for acoustical analyses to assess continuous signals. This section describes (1) methods used to collect bodily expression data, (2) observer-based recognition and behavioral analyses, and (3) quantitative methods for collecting and analyzing whole body movement.

2.5.1 Methods for collecting bodily expression data

There are four primary methodological considerations to address prior to collecting whole body emotion expression stimuli. First, should actors or untrained participants be used? Second, should the expressive task be constrained, or should the encoders be free to express the emotion that they feel best represents the emotion? Third, how many encoders should be used? Finally, which emotions should be included?

2.5.1.1 Use of actors versus untrained participants

The first methodological consideration is whether to use actors or untrained participants as encoders. Typically, studies of emotion expression, including bodily expression, have used actors to portray the emotion (Atkinson et al., 2004; Montepare et al., 1999; Wallbott, 1998). One reason actors are considered as an alternative to untrained participants is because of the practical difficulty and ethical constraints involved in obtaining spontaneously occurring expressions in a laboratory setting. Scherer and Ellgring (2007a) rationalize the use of actors using four assumptions, which collectively suggest that actors, when used appropriately, can produce expressions that generalize to natural and spontaneously occurring expressions. First, although actors may use prototypical displays, Scherer and Ellgring (2007a) assume that there is some truth to the display. Second, it is assumed that good actors will base their portrayals on previous memories or recalled observations of another person's behavior during a specific emotion. By basing performances on recalled portrayals, it is expected that there will be more variability in the repertoire that should generalize to real experiences. Third, when acting techniques such as the Stanislavski approach or method acting are used, the expressions produced should be close to what naturally occurs for that particular person. Finally, when actors are asked to express an emotion by immersing in the scenario, it is expected that they are embodying the emotion rather than purposely trying to manipulate one specific affective channel. For further discussion on the rationale for using actors see Scherer and Ellgring (2007a) and Banse and Scherer (1996).

The underlying assumption these arguments depend on is that emotionally expressive movement is qualitatively and quantitatively the same for felt and portrayed emotions, yet no empirical evidence exists to support this assumption. The implications of the assumption are under explored creating three possible methodological issues. First, because studies with actors have not evaluated whether the target emotion was felt or portrayed, the assumption that actors embody the emotion is untested and may result in the study of movements that do not accurately represent the target emotion. Second, acting may tend to produce exaggerated movements. Existing literature suggests that exaggerated movement has positive implications for observer recognition. For example, a study of tennis serves demonstrated that exaggerated movement improves accurate recognition of movement style (Pollick, Paterson, Bruderlin, & Sanford, 2001) . Likewise, similar results (with the exception of the emotion sad) were found regarding exaggeration in a study of portrayed emotions (Atkinson et al., 2004). However, it remains unclear what the relationship is between an actor's exaggerated emotion and whether the emotion was truly felt by the actor. Finally, acting quality is also an important consideration when using actors. Although it is assumed that "good" actors embody emotions and produce natural behavior, it is not clear what constitutes a good actor – that is, a standard for the acting quality has not been suggested or evaluated. Therefore, the use of actors for production studies raises serious concerns about the validity of the expressive movement with respect to felt emotions.

In contrast to using actors, validated methods from psychology exist for inducing and evaluating felt emotions using non-actors. In particular, using an autobiographical memories paradigm is an effective method for emotion induction (Ekman, Levenson, & Friesen, 1983; Labouvie-Vief, Lumley, Jain, & Heinze, 2003; R. W. Levenson, 2007; R. W. Levenson, Carstensen, Friesen, & Ekman, 1991). Using this method, each participant completes a worksheet prior to data collection asking them to describe a time in their own life when they felt a specific emotion. For example, for eliciting joy, they may be asked to complete the following information:

> *Think of a time in your life when you felt exhilarated, for instance, when you felt euphoric or very playful, or felt like you wanted to jump up and down. Using only a few words, please indicate: a) ....where you were: b) ...who you were with: c) ....what caused the feeling/what was it about?*

Before performing the required task for the study, participants should be provided with an opportunity to review their notes to help them recall the emotion and to feel it as strongly as possible. Therefore, when properly used, the autobiographical memories paradigm is a good choice for emotion induction when a variety of emotions are being studied as it is a relatively effective method for emotion induction across a wide range of emotions.

For studies that assume neurobiological changes due to emotion, it is especially important to ensure that the experience of emotion and the associated bodily changes are captured. Two assessment methods could complement each other to establish that the emotion was felt and to ensure that the expressive signal is in the movement: (1) self-report by the encoder and (2) social consensus among observers (discussed in detail in 2.4.2). Self-reports of subjective experience are a common method for assessing felt emotion. While a number of different types of self-report questionnaires are available (Larsen & Fredrickson, 1999), one type of questionnaire called the multi-item Differential Emotions Scale (DES) (Gray & Watson, 2007; Izard, 1991; Izard, Libero, Putnam, & Haynes, 1993; Larsen & Fredrickson, 1999) is particularly suited for experiments that need a relatively simple and easily understood assessment of emotion experience. The purpose of this scale is to assess multiple discrete emotions with the assumption that participants may feel more than one emotion during an experience with each emotion being experienced at different intensity levels. Participants rate the intensity that they felt each of the emotions on the questionnaire using a 5-item likert scale (0 = not at all; 1 = a little bit; 2 = moderately; 3 = a great deal; 4 = extremely). One way in which this type of questionnaire is different from single item questionnaires is that respondents are asked to rate clusters of three emotion words (for example, glad / happy / joyful, angry / irritated / annoyed). Providing participants with three emotions words that are closely related ensures that they connect with at least one of the words. These questionnaires offer the advantage that they are easy to construct, simple and brief to administer, and easily understood by respondents, making them a good choice for experiments that require a lot of self-reports to be quickly filled out.

While it may seem that collecting self-report data and obtaining social consensus is labor intensive and unnecessarily costly when actors can be used instead, the rationale for ensuring that emotion is felt is that evidence suggests a neurological basis for emotion affecting body movements in characteristic ways. It is not known whether portrayed emotions are qualitatively and quantitatively the same, making it even more important to validate that emotion was felt. Empirical evidence from recent fMRI studies demonstrates that brain regions associated with both emotion processing and motor responses activate when observers view images of emotional body postures (Beatrice de Gelder, 2006; Pichon et al., 2007). Validating that emotion is felt during whole body movement tasks allows qualitative and quantitative aspects of motor behavior that are affected by an emotion to be assessed. Therefore, insight into the coordinative structures associated with a particular emotion can be made. Thus, the motor behaviors must be captured while the neurobiological processes are active, that is, during felt emotion. In conclusion, unless future empirical evidence suggests no qualitative or quantitative difference between the movements of actors and untrained participants, untrained participants should be used in studies that aim to characterize emotionally expressive body movement.

2.5.1.2 Selection of free versus constrained movement task

The second methodological decision is to determine whether study participants should perform a constrained task or respond freely. There are advantages and disadvantages to both and the selection should depend on the research questions being studied. Although prototypical bodily behaviors are often associated with specific emotions (i.e., an emblematic gesture such as punching a wall), expressive bodily behaviors 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). Wallbott (1998), for example, demonstrated that movement qualities are associated with specific, different emotions. For example, he noted high movement dynamics associated with hot anger (Wallbott, 1998). 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 performed with the emotion recognizable. This is analogous to vocal expression, where an emotion can be communicated using specific words or by changing the vocal characteristics with which an emotionally neutral sentence is spoken (Banse & Scherer, 1996; Scherer & Ellgring, 2007b). Having encoders perform a constrained movement task is preferable for analyses where the expressive content (style) and task need to be separated so that changes in the signal can be attributed to emotion differences.

Task selection may also affect the ability to capture the expressive style for positive emotions. While action tendencies for specific emotions tend to be associated with specific motor behavior, there tends to be a stronger association between motor behavior and negative emotions than motor behavior and positive emotions. Typically a non-specific "do anything" motor program is associated with positive emotions (Fredrickson & Levenson, 1998) suggesting that positive emotions may not be as closely associated with specific actions (Fredrickson, 1998). Consequently, it may be particularly important to study the effect of emotion on performance of non-emblematic movements to capture expressive movement style while participants experience positive emotions.

2.5.1.3 Encoder sample size

The third methodological decision is to determine how many encoders are necessary given that previous studies indicate significant variability in participants' ability to communicate a specific emotion. Wallbott and Scherer (1986) identified and documented this problem in a study that assessed actor differences in behavior cues. They demonstrated that, for bodily expression, actors differed in terms of the types of movements and the amount of movement activity. In addition, observer judgments in the study by Wallbott and Scherer (1986) revealed that actors might also differ in terms of movement velocity, expansiveness, energy, activity, and pleasantness. Interestingly, they found that the actor effects were only main effects. That is, they did not find an interaction effect between emotion and actor and concluded that actor differences do not depend on the type of emotion but were general styles of the actor. In addition to the findings by Wallbott and Scherer (1986) other studies assessing emotion-related expressive movement also suggest encoder variability (M. M. Gross, E. A. Crane, & B. L. Fredrickson, Submitted; J. M. Montepare, S. B. Goldstein, & A. Clausen, 1987; Pollick et al., 2001; Wallbott, 1998; Wallbott & Scherer, 1986). That is, some encoders are better than others at expressing target emotions. For example, of the five walkers studied in Montepare's (1987) study, accurate classification for pride ranged from 0 to 100 percent. Similar results can be found in Wallbott and Scherer (1986) and Pollick et al. (2001). In our own studies, we have also observed that some encoders are better than others at communicating specific emotions (M. M. Gross et al., Submitted). Overall, these studies suggest that encoders have individual movement styles and some encoders more effectively communicate specific emotions.

Because of the amount of work involved with capturing expressive whole body data and the significant work involved with processing and analyzing data, typically only a few participants are used in production studies (see Table 2). Wallbott and Scherer (1986) suggest that production studies often rely on the assumption that actors are able to express emotions in a standardized way, eliminating the need for a large number of encoders. This assumption is challenged, however, by evidence suggesting that actors have their own styles and that some are better than others at communicating specific emotions. Until variability of expressive movement style is well documented and understood, the more encoders the better.

2.5.1.4 Selecting emotions for expressive behavior studies

The final methodological consideration is to select the emotions that will be studied. While this depends largely on the research questions, for studies assessing expressive behavior there are important considerations. For instance, while negative emotions are associated with specific action tendencies (e.g., the tendency to flee when frightened), positive emotions have been associated with non-specific action tendencies (Frijda, 1986). For example, joy has been characterized as having "free activation" (Frijda, 1986). Because the positive emotions may not be as closely associated with specific actions (Fredrickson, 1998), it may be particularly important to study the effect of emotion on performance of non-emblematic movements to understand bodily expression across a range of emotions. In addition, when little is known about whether emotion differences in motor behavior are measurable, selecting emotions that are very different from one another is a reasonable place to start. Therefore, when a range of emotions is needed, two main theories of emotion can help guide the selection of emotions.

Two established theories of emotion, discrete theory and dimensional theory, differ significantly in their approaches for capturing the structure of emotion. The discrete theory claims the existence of universal "basic emotions" (e.g. Ekman (1992a; 1992b) and Plutchik (1980)), while the dimensional theory, assumes the existence of two or more major dimensions. These dimensions are believed to both describe emotions and to distinguish between them (Russell, 1980). However, the approach that best captures the structure of emotion is still widely debated, even though attempts have been made to conflate the dimensional and discrete approaches (Russell & Barrett, 1999).

Table 2. Representative studies on emotion expression demonstrating the number of encoders used in emotion expression experiments.

Study	Emotion	Movement	Encoders	Emotions
Dahl (2007)	Portrayed	Constrained	1	4
Hejmadi, Davidson, & Rozin (2000)	Portrayed	Free	1	11
Castellano, Camurri, Mazzarion, & Volpe (2007)	Portrayed	Free	2	n/a *
Dittrich et al. (1996)	Portrayed	Free	2	6
Montepare et al. (1999)	Portrayed	Free	2	4
Pollick et al. (2001)	Portrayed	Constrained	2	10
de Meijer (1989)	Portrayed	Free	3	12
Atkinson et al. (2007)	Portrayed	Free	4	6
Camurri et al. (2003)	Portrayed	Free	5	4
Montepare et al. (1987)	Portrayed	Constrained	5	4
Gross, Crane, Fredrickson (Submitted)	Felt	Constrained	6	7
Wallbott & Scherer (1986)	Portrayed	Free	6	4
Atkinson et al. (2004)	Portrayed	Free	10	5
Castellano et al. (2008)	Portrayed	Free	10	8
Sawada et al. (2003)	Portrayed	Free	10	3
Grezes et al. (2007)	Portrayed	Free	12	2
Scherer & Ellgring (2007b)	Portrayed	Free	12	14
Wallbott (1998)	Portrayed	Free	12	14

Central to discrete emotion theories is the existence of historically evolved basic emotions that are universal and can therefore be found in all cultures (Ekman, Sorenson,

& Friesen, 1969). Theories differ on the number of basic emotions, but they typically range from 2 to 18 categories. However, there is considerable agreement on the following six: anger, disgust, fear, happiness, sadness and surprise. Arguments for basic emotions include the existence of universal facial expressions recognized independent of culture(Ekman, 1992b; Ekman et al., 1969), as well as the presence of facial expressions in primates (Parr, Waller, & Heintz, 2008; Parr, Waller, Vick, & Bard, 2007). Basic emotion models imply that there are prototypical expressions that can be observed in the face, body, voice, and physiological reactions. One limitation to selecting emotions from the short list of basic emotions is that positive emotions are generalized as one emotion into a category referred to as happy. Generalizing positive emotions into one category does not allow inferences to be made about subtle expressive differences between positive emotions.

Dimensional emotion theories use dimensions rather than discrete categories to describe emotions. Emotions are typically characterised by their valence (pleasure), arousal (activation), and dominance (control, social power) with arousal and valence suggested as the two most important dimensions (Russell, 1983). Russell (1980) described the dimensions in terms of the Circumplex of Affect model (Figure 2). Selecting a balanced set of discrete emotions based on their pleasantness and activation can allow comparisons to determine whether differences in expression are due to pleasantness or to activation.

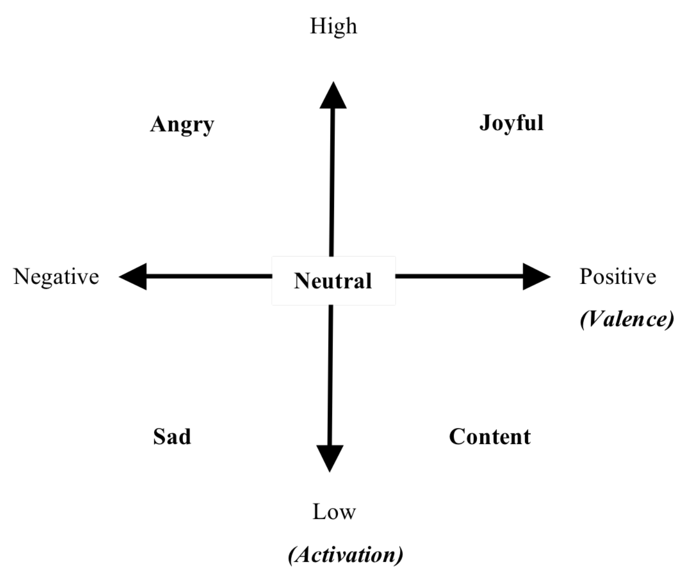

Figure 2. Example of four balanced emotions on the circumplex model.

For studies that aim to characterize expressive behavior across a range of emotions, particularly when little is known about how emotion affects behavior in a specific modality, it is important to select emotions that are very different from one another. The selection of specific discrete emotions is most effective when the emotions are balanced with respect to activation and valence. This way, if differences do exist and are detectable through a specific channel, then the differences have the best chance for showing up and, when needed, for comparisons to be made about activation and intensity. Therefore, because so little is known about expressive multimodal behavior a range of balanced emotions should be used in multimodal production studies.

2.5.1.5 Summary

In summary, for work that aims to characterize expressive bodily movement with emotions, it is important to consider whether to use actors or untrained participants as encoders, whether the movement task should be constrained or free, to determine the number of encoders needed, and to select appropriate emotions. For production studies, when the assumption is that there is a neurological basis for emotion to affect bodily movement in characteristic ways, assessment of whether the emotion was felt or not should be done whether actors or non-actors are used. Because of possible issues related to actors producing exaggerated movements and not having standards for determining the quality of the actors, using validated emotion induction methods and assessment of felt emotion with non-actors is a good alternative. When a goal of the study is to quantify movement characteristics associated with emotion a constrained movement task such as walking must be used. If encoders are allowed to move freely, the movement task will be confounded with the expressive style in the movement. As many coders as possible should be used because of the large amount of variability in human movement. Finally, while emotion selection largely depends on the research questions, when possible, a set of balanced emotions is preferable. Once felt emotion has been established, it is also important to establish whether observers are able to accurately recognize emotion in the movement trials so that when behavioral analyses are done, there is a high probability that the emotion signal is in the data being studied.

2.5.2 Observer-based recognition and behavioral analyses

Besides the methodological issues related to collection of expressive stimuli, there are additional considerations worth reviewing related to observer studies. In recognition studies, observers are used for social consensus to determine if the target emotion is recognizable in a particular trial. Additionally, behavioral analyses are conducted where coding of specific movements is performed to associate behaviors with specific emotions.

2.5.2.1 Recognition studies

One goal of observer-based recognition studies is to identify movement trials for subsequent analysis of emotion-related movement characteristics. Typically the purpose of such social consensus studies is to identify trials that best represent the expressive signal of the target emotion. The standard for social consensus studies is to use forced-choice questionnaires. One methodological concern for many social consensus recognition studies is the use of forced-choice paradigms with only the target emotions as response options. While the forced-choice methodology is valid, by using only the target emotions as possible choices, the questionnaire implies that the encoder either felt an emotion that is represented on the list or had no emotion at all. Additionally, when the questionnaire only includes a few items the probability of accurately guessing the correct item is quite high. The probability of a correct guess is determined by dividing the number of questionnaire items by 100. This probability is often referred to in the literature as the chance recognition rate. It is generally accepted that a trial was accurately recognized if the observer recognition rate is greater than the chance recognition rate (for example, see Atkinson et al. (2004; 2007) and Montepare et al. (1999)). Thus, recognition rates may be artificially inflated, and some trials may be identified for subsequent analyses even if they are only marginally related to the target emotion.

As evidence of the artificial inflation effect, two studies that assessed movement behavior associated with emotion during a constrained movement task reported very different ranges of recognition accuracy. Montepare et al. (1987) studied movement style qualities in gait associated with four target emotions: anger, sadness, happiness, and pride. The mean recognition rates of ten observers were .90, .74, .94, and .56 respectively. In contrast, Pollick et al. (2001) reported an overall recognition rate of 30% when assessing arm movements. This study did not, however, report recognition rates for each target emotion. One possible explanation for the higher recognition rates in the Montepare et al. (1987) study is that the forced-choice questionnaire only included four emotions compared to Pollick et al. (2001) questionnaire, which included ten emotions. Therefore, the recognition rates reported by Montepare et al. (1987) may be artificially inflated. Because emotion expression in non-emblematic movement is expected to be subtle, it is reasonable to expect that recognition rates will also be lower than those reported for prototypical gestures or stylized movement. Overall recognition rates for emblematic movements have been reported, for example, at 88% (Dittrich et al., 1996), approximately 80% (Atkinson et al., 2004), 55% (Sogon & Masutani, 1989), and 84% (Atkinson et al., 2007). Further studies using forced-choice questionnaires with low chance rates are necessary to determine normative recognition rates for non-stylized movements.

When only a few emotions are studied, providing a distracter item for each target emotion that is similar in terms of valence and intensity can decrease the probability of chance recognition. Additionally, options for no-emotion / neutral and none of the above will further ensure that when an emotion is selected, it is most likely because the observer actually recognized the emotion rather than guessed. One consequence of more stringent criteria for recognized trials is that fewer trials will likely meet the criteria for subsequent analyses. This provides further rationale for larger samples of encoders so that a large enough sample of trials is available for analyses. In conclusion, while recognition rates may decrease, including enough emotions on the questionnaire to decrease chance recognition is preferable because it increases confidence that the trials selected for analyses are representative of the target emotions.

2.5.2.2 Behavioral analyses

Besides being used in observer-based recognition studies, observers have been used in a variety of qualitative analyses to describe the effects of emotion on body movements. Wallbott and Scherer (1986), for example, developed a body coding system to describe body posture, the types of movements performed, and the overall movement qualities. Identifying specific behaviors of the upper body, shoulders, head, arms, and hands captured body posture and types of movements. Joy, for example, was characterized as having the shoulders up, head backward, and arms stretched out (Wallbott & Scherer, 1986). In contrast to this system, Montepare et al. (1999) used six fundamental characteristics of movement to capture the dimensions of form, tempo, force, and direction. Overall, results from these studies demonstrate that there are emotion-specific body behaviors. However, neither system provides a comprehensive scheme for coding body movement, which is important for describing movement qualities in a task independent way.

In contrast to the behavioral coding systems of Wallbott and Scherer (1986) and Montepare et al. (1999), a comprehensive system for describing movement called Laban Movement Analysis (Cecily Dell, 1977) (LMA) is used to describe the body motions of individuals engaged in a variety of tasks, including factory workers and dancers (Laban & Ullmann, 1988). LMA is a notation system made up of specific terminology and symbols for documenting movement. Just as music notation includes not only musical notes but also symbolic instructions about how to play those notes, LMA notation includes information both about the body movement and the way in which that body movement is performed. Indeed, one goal of this system was to provide notation for the smallest units of bodily movement. What makes this notation unique is that it allows documentation of the movement task along with descriptors of how to perform the task (i.e. the movement style).

LMA has two primary components for describing the movement style: effort and shape, The shape component captures how the body changes shape during a movement task. Shape is divided into three subcategories: the form of the body itself (towards or away from the body center), the directional path in space (spoke or arc-like), and how the body shapes itself with respect to the environment (gathering or scattering). Effort is used to capture movement dynamics describing how exertion is concentrated during movement. Effort is divided into four subcategories: space (indirect or direct), energy (forceful or light), time (sustained or quick), and flow (bound or free). Another distinctive feature of Effort-Shape is that each category is defined as a continuum between two extremes.

While Effort-Shape analyses have not been used in studies to assess movement qualities associated with expressive behavior, principles of Effort-Shape have been used to produce natural looking behavior in computer graphics (Chi, 1999). The important distinction between Effort-Shape and behavioral coding methods of Wallbott and Scherer (1986) and Montepare et al. (1999) is that Effort-Shape captures the movement quality in contrast to capturing specific movements. The two most prominent and respected methods for qualitatively assessing human movement are Wallbott and Scherer's (1986) coding scheme and Effort-Shape analysis. The advantage of Wallbott and Scherer's (1986) scheme is the use of specific body movements. The disadvantage is that Wallbott and Scherer's (1986) scheme, which associates specific gesticulatory behaviors with specific emotions, may prove too narrow and thereby result in missed behaviors that could be associated with emotion. Effort-Shape analysis provides a method for assessing bodily movement that is based on dynamic qualities of movement that reveal expressive behavior in the system as a whole. Therefore, Effort-Shape analysis has strong potential as a comprehensive assessment tool for qualitatively describing expressive whole body movements associated with specific emotions.

2.5.2.3 Summary

The purpose of this section was to review methods for collecting bodily expression data and to describe two different coding schemes for qualitatively describing expressive bodily movement. While there is evidence that emotions are associated with detectable differences in body movement patterns, generalizations about the underlying qualities associated with emotion are limited because of the methodological issues involved. First, the studies typically lack rigorous checks to ensure that emotions were felt rather than portrayed. In fact, many of studies use actors to display emotional movements. We do not currently have enough evidence about whether movement associated with felt emotions is quantitatively different from movement in which emotion is portrayed, even if recognition rates suggest no difference. Second, emotion recognition studies often use forced choice paradigms that may artificially inflate the recognition rates, leading to potential false positive results, confounding a description of movement qualities associated with a particular emotion. Therefore, these are important issues to consider before addressing quantitative methods for describing expressive bodily movement.

2.5.3 Quantitative methods for collecting and analyzing whole body movement

While qualitative methods do provide insight into behaviors and movement qualities associated with emotions, they are not sufficient for building quantitative models of emotionally expressive behavior. Because of the challenges associated with quantifying whole body movement, methods for describing bodily expression have been more similar to the coding methods of facial expression than to the quantitative methods used to study vocal expression. Kinematic methods, however, describe body position and how it changes over time from 3-dimensional coordinate data generated with a motion capture system. Therefore, kinematic methods can provide a quantitative description of movement qualities associated with emotion. To better understand the potential contribution of kinematic methods, this section describes the similarities to vocal expression analyses and the methodological considerations for analyzing kinematic data.

Similar to vocal expression, where the acoustic signal has both a linguistic component and an expressive component, bodily expression can also be characterized by task and style components. The task component of bodily expression is analogous to the linguistic component in speech and the style component is analogous to the expressive component that affects how the words are spoken. An important distinction between studying vocal expression and bodily expression is that while there is only one acoustical signal to capture to properly assess vocal expression, there are numerous signals that can be captured to properly assess bodily expression. For example, using motion capture technology, we can capture continuous signals for each joint. Furthermore, many parameters can be calculated for each of the joint signals. For example, we can describe joint kinematics by calculating the joint position, velocity, and acceleration. We can further parameterize these by, for example, assessing the means, calculating joint range of motion, or by identifying peak velocities. Unlike vocal expression, none of these kinematic parameters have been empirically associated with emotionally expressive movement. Therefore, there are hundreds of possible parameters that may be associated with emotionally expressive movement when one considers the number of kinematic parameters available to study multiplied by the number joints. The first step to reducing the scope of this problem so that future studies may be considered comprehensive and comparable is to systematically determine the joints kinematic parameters that are affected by emotion.

In order to effectively capture affective movement patterns three criteria must be met. First, simultaneous posture and limb movements must be recorded and quantified. Second, emotion should be felt and recognized to help ensure that the expressive signal is in the movement data. Third, the movement task must be controlled between emotions so that inferences can be made about style difference between the movement trials. Because of the specialized equipment and knowledge necessary to capture and analyze kinematic data very few studies have used these methods to describe emotion-related movement characteristics. Two studies (Pollick et al., 2001; Sawada et al., 2003) that have used kinematic methods only reported the kinematics of single joints or segments, but these studies did not provide any information on postural variables or on coordination of multiple body segments. Therefore, the methods used to identify the effect of different emotions on body movement have been flawed, both because simultaneous posture and limb movements have not been quantified and because the movement task has not been controlled between emotions.

2.5.4 Conclusions

In summary, bodily expression changes in characteristic ways with specific emotions. However, studies on bodily expressions tend to use actors, free responses, and observer-based coding schemes to associate movement types and qualities with specific emotions. These methodological issues, related to how emotionally expressive body movements are generated and quantified, limit the study of bodily expression of emotion. The use of biomechanical methods to describe the complex, 3-dimensional characteristics of body movement have only been used in a handful of studies investigating bodily expression. To establish the relationship between body movements and emotional experience, an effective procedure would be to use a combination of qualitative and quantitative methods that capture the characteristics of dynamic, expressive movement.

In this methodology, it is important that 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. This novel approach to the study of emotionally expressive bodily movement is expected to further advance our understanding of the physical manifestation of emotion in body movement.

2.6 Multimodal expression

Expressive behaviors of the face, voice, and body are typically studied in isolation. However, there is reason to suspect that there are interactions between these expressive modalities that also play an important role in the recognition of emotionally expressive behavior. Ekman (1964) provided some of the first systematic evidence for observer sensitivity to interactions between modalities during interview behavior. More recently, Van den Stock et al. (2007) found that expressions in the body influence observer recognition of emotions in the face and voice. To date, the few studies that have investigated multimodal expressive behavior have focused on recognition while only one study has attempted to describe multimodal patterns in the face, body, and voice associated with target emotions. Thus, a subtle yet potentially powerful indicator of emotion is underexplored. This section reviews the relevant recognition and production studies.

2.6.1 Recognition studies

There are two methods for studying emotion recognition from expressive behavior: (1) using observers and (2) using automatic classification methods. Typically recognition rates from observer studies are used as a gold standard by which we can compare recognition rates from automatic classification methods. In this section we review both observer and automatic classification methods.

Observer recognition studies that have investigated multiple modalities suggest that recognition accuracy tends to improve with multiple modalities compared to individual modalities. In addition, recognition accuracy seems to be dependent on both emotion and modality. Indeed, some emotions tend to be communicated better through some modalities than others. One of the first studies to investigate multimodal emotion recognition compared observer recognition of expressive behavior from video, audio, and audiovisual stimuli (Wallbott & Scherer, 1986). In this study, observer judgments based on visual stimuli resulted in more accurate recognition than audio for anger and sadness while joy and surprise were approximately the same (Table 3). Interestingly, judgments based on the combined audiovisual stimuli only increased recognition accuracy for joy and surprise while accuracy for anger and sadness increased compared to the audio stimuli but decreased compared to the visual stimuli.

If recognition rates are an indicator of possible signal congruency—that is, the signals are about the same strength and communicate the same emotion—these results may not be so surprising. Observer judgments of emotion may be more accurate and made faster with combined and congruent modalities (Meeren et al., 2005). Further, Van den Stock et al. (2007) replicated this finding with a different set of emotions and further indicated that the influence of body expression in the perception of facial expression depended on the ambiguity of the facial expression. These results suggest that there are interactions between channels that may become especially important when there is ambiguity in one of the modalities. Taken together, evidence from recognition studies indicates that potentially important interactions between modalities may influence emotion recognition accuracy. Thus, developing methods for studying multimodal behavior is especially important.

Table 3. Summary of multimodal observer recognition results from Wallbott (1986).

Emotion	Audiovisual	Video	Audio
Anger	.52	.56	.44
Sadness	.77	.83	.47
Joy	.70	.65	.65
Surprise	.43	.35	.31

In contrast to observer recognition studies, a few studies have used automatic classifiers to determine recognition accuracy from multiple modalities. In a recent study by Castellano (2008) a Bayesian classifier was used to train and test a model to recognize emotion from multimodal input including expressions from the face, body, and voice. Classification accuracy was determined for each modality individually and compared to all three combined (Table 4). Both feature-level and decision-level fusion of the multimodal data were compared. Overall Castellano (2008) concluded that emotion recognition was best for gestures, followed by speech and facial expression. However, using feature-level fusion to combine all modalities significantly improved the overall performance of the classification model compared to any of the unimodal models. These results indicate that measures from multiple modalities should improve emotion classification. However, the classification methods used do not allow insight into the specific measures or combination of measures that are important for emotion classification.

Table 4. Multimodal classification results from Castellano (2008).

Emotion	Face	Gesture	Speech	Feature	Decision
Anger	56.67	80	93.33	90	96.67
Despair	40	56.67	23.33	53.33	53.33
Interest	50	56.67	60	73.33	60
Irritated	53.33	63.33	50	76.67	60
Joy	53.33	60	43.33	93.33	86.67
Pleasure	53.33	66.67	53.33	79	80
Pride	33.33	96.67	56.67	86.67	80
Sad	46.67	56.67	76.67	83.33	80
Model performance	48.3	67.1	57.1	78.3	74.6

In a related study, Scherer and Ellgring (2007a) used statistical discriminant methods to classify facial expressions as one of 14 emotions (Table 5). The same face stimuli were used in a subsequent multimodal analysis by Scherer and Ellgring (2007b) that combined data from the face, body, and voice to classify the trials. Table 5 provides a comparison of recognition accuracy for the face and multimodal analyses. A unimodal recognition analysis using the body was not done and is therefore, not included in the table. Interestingly, for the two positive emotions, recognition rates significantly improved when information from multiple modalities was used compared to face alone. Recognition accuracy remained the same for four emotions (cold anger, contempt, sadness, despair), increased with multimodal information for four emotions (hot anger, elated joy, happiness, and anxiety), and decreased with multimodal information for seven emotions (disgust, panic, fear, shame, interest, pride, and boredom). The results for these classification studies provides further evidence of emotion-specific interactions between multiple modalities. However, testing hypotheses about these interactions is particularly challenging because these methods do not reveal the specific behaviors associated with accurate emotion classification. Therefore, emotion classification methods that also allow identification of the relevant features associated with classification are needed.

Table 5. Comparison of two individual studies by Scherer (2007a) and Scherer (2007b) using the same stimuli.

Emotion	Multimodal	Face
Cold anger	37.50	37.50
Hot anger	50.00	43.75
Elated joy	93.75	62.50
Happiness	87.50	68.75
Disgust	68.75	93.75
Contempt	50.00	50.00
Sadness	62.50	62.50
Despair	62.50	62.50
Anxiety	68.75	31.25
Panic fear	25.00	31.25
Shame	18.75	37.50
Interest	0.00	25.00
Pride	25.00	56.25
Boredom	56.25	68.75

In summary, results from automatic classification methods are consistent with findings from observer recognition studies suggesting that, in general, combining modalities can improve emotion recognition. These studies, however, also indicate that some modalities are better than others for emotion recognition. However, neither observer recognition nor automatic classification studies reveal (1) what the important features are in each of the modalities that contributed to emotion recognition or (2) important interactions between modalities. Therefore, we still don't know which features are associated with emotions in each individual modality or what the interactions are between features that contribute to emotion recognition.

2.6.2 Behavioral pattern analysis

While a few studies have begun assessing the importance of multimodal information for emotion recognition, only two studies have assessed multimodal behavioral patterns associated with specific emotions. These studies provide the first evidence for correlated patterns in multiple modalities and features used to discriminate emotions.

One of the earliest multimodal studies assessed coordination of facial actions, head movement, and eye movement (Cohn et al., 2004). Moderate within subject correlations of behaviors were found between these features. The conclusion of the study was that the correlated behaviors suggest that there are coordinated movement structures.

A more extensive examination of multimodal behavioral patterns was completed by Scherer and Ellgring (2007b) assessing the co-occurrences of facial, vocal, and bodily behaviors (Table 6). In this exploratory study, FACS was used to code facial behavior, Wallbott and Scherer's (1986) coding scheme was used to code bodily behavior, and acoustic analyses were used to characterize vocal behavior. A stepwise discriminant analysis was used to determine how variables combine to discriminate between emotions. For example, AU12 and AU13 can be used to discriminate between elated joy, happiness, and pride. With a set of only 10 multimodal variables used as input into the model, the cross-validated prediction accuracy was 50.4%, which was quite a bit higher than the unimodal prediction accuracies.

The findings in this exploratory study are limited because emblematic movements and actors were used. More studies that explore multimodal interactions are necessary to understand this complex phenomenon. The next steps for furthering this work are to use emotion portrayals that are felt and recognized and to examine the influence of individual channels in addition to multimodal interaction on the perception of emotion.

Table 6. Co-occurrence of facial, vocal, and bodily characteristics associated with specific emotions identified by Scherer and Ellgring (2007b).

	Multimodal behavioral characteristics			
Emotion	AU 4 + HiF0 + UBC	AU12 + AU13	AU14 + HiDur	HiF0 + HiAmp
Cold anger				
Hot anger				X
Elated joy		X		X
Happiness		X		
Disgust	X			
Contempt				
Sadness	X			
Despair	X			X
Anxiety				
Panic fear	X			X
Shame			X	
Interest				
Pride		X		
Boredom			X	

Note: AU = Action unit, HiF0 = High fundamental frequency, HiDur = Slow speech tempo, HiAmp = High amplitude in the voice, UBC = Upper body collapsed

2.6.3 Conclusions

In summary, recognition studies indicate that (1) emotion classification tends to improve for both observers and statistical models with congruent affective information from multiple modalities, and (2) some modalities are better than others at individually communicating specific emotions. However, classification systems do not indicate which information is used to make predictions about felt emotion. Therefore, methods for identifying the multimodal features of emotionally expressive behavior are needed and may have important consequences for development of applications involving emotionally expressive behavior and for providing new insights into the psychology of emotion.

2.7 Chapter conclusions

Expressive behavior has provided important insights into emotion and new technologies are beginning to take advantage of expressive behavior as a method for human-machine interaction. Although expressive behavior occurs in multiple modalities and important interactions may occur between modalities, the face, voice, and body have primarily been studied in isolation. Thus, little is known about how expressive modalities combine to characterize specific emotions. Progress on characterizing expressive multimodal behavior has been limited by methodological issues related to simultaneously capturing behavior from multiple modalities (specifically the face and body) and methods for characterizing expressive bodily behavior. Thus, methodological limitations need to be addressed to allow comprehensive qualitative and quantitative characterizations of emotion-related body movement.

First, specialized equipment needs to be developed and validated for capturing facial expression during a movement task. To overcome limitations with respect to the emotion portrayals, a set of stimuli generated using non-actor subjects, a constrained whole body movement task, emotion elicitation procedures to induce target emotions in the subjects, and a balanced set of positive and negative emotions is needed. Before assessing the qualitative and quantitative behavioral characteristics in the emotion portrayals, an emotion recognition study is needed to determine whether the emotion signal was present in the emotion portrayal. A forced-choice questionnaire that includes distractor items in addition to the target emotion items can help ensure that the emotion selected was not due to chance.

In addition to the methodological needs related to generating the emotion stimuli, several advancements are also necessary related to assessing the behavioral characteristics. These included systematic methods for qualitatively and quantitatively assessing movement characteristics associated with emotions. Finally, methods that allow identification of multimodal features of emotionally expressive behavior are necessary to understand the complex emotion-related interactions between modalities.

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Chapter 3

Specific Aims

Specific Aim 1: To determine the feasibility of using a head-mounted camera to capture facial expressions during body movement.

Research Questions & Hypotheses

RQ 1.1: Does wearing a head-mounted video camera affect emotion elicitation?

Hyp 1.1.1: There is no difference between the proportion of trials reported as felt between the group that did not wear the head-mounted camera (non-HM) and HM groups for sad, anger, joy, and content emotions or neutral.

Hyp 1.1.2: Self-reported intensities for sad, anger, joy, and content are not different between the non-HM and HM groups.

RQ 1.2: Does wearing a head-mounted video camera affect emotion recognition?

Hyp 1.2.1: There is no difference in observer recognition of emotion between HM and non-HM groups for sad, anger, joy, content, and neutral emotions.

RQ 1.3: Does the head-mounted camera affect observer recognition of the qualitative aspects of movements?

Hyp 1.3.1: There are no significant differences between the non-HM and HM groups for the Effort-Shape scores for sad, anger, neutral, joyful, and content emotions.

RQ 1.4: Does wearing the hear-mounted camera affect quantitative aspects of movement?

Hyp 1.4.1: Joint angular kinematic measures are the same for both groups for emotion that are both felt and recognized.

Hyp 1.4.2: Gait cycle descriptors are the same for both groups for emotions that are both felt and recognized.

Specific Aim 2: To determine the Effort-Shape characteristics of emotion-related body movement.

Research Questions & Hypotheses

RQ 2.1: Do the emotion-portrayals have external validity?

Hyp 2.1.1: Emotion portrayals are accurately decoded at levels greater than chance.

RQ 2.2: What Effort-Shape qualities are associated with each target emotion?

Hyp 2.2.1: Observer ratings of Effort-Shape qualities are not due to chance.

Exp 2.2.2: Provide numerical profiles for each emotion based on the six Effort-Shape qualities.

Hyp 2.2.3: Emotions differ with respect to movement style characteristics.

Exp 2.2.4: Determine whether individual encoders, observers, encoder gender, or observer gender affect judgments of movement characteristics.

RQ 2.3: Are specific Effort-Shape characteristics associated with decoding accuracy?

Hyp 2.3.1: Movements that do not correspond to the emotion profiles identified in 2.2.1 are associated with low recognition accuracy.

Exp 2.2.3: Determine whether individual encoders, observers, encoder gender, or observer gender affect movement characteristics.

Specific Aim 3: To determine kinematic characteristics of emotion-related body movement.

Research Questions & Hypotheses

RQ 3.1: What kinematic qualities are associated with each target emotion?

Exp 3.1.1: Provide kinematic profiles for each target emotion.

Hyp 3.1.2: Emotions differ with respect to kinematic characteristics.

Exp 3.1.3: Determine whether individual encoders or gender affect movement kinematics.

RQ 3.2: Are specific kinematic characteristics associated with decoding accuracy?

Exp 3.2.1: Kinematics that do not correspond to the emotion profiles identified in 3.1.1 are associated with low recognition accuracy.

Specific Aim 4: To determine multimodal patterns of emotion in body and face.

Research Questions & Hypotheses

RQ 5.1: For the face, determine whether each target emotion is associated with a specific set of FACS action units?

RQ 5.2: For the body, determine whether each target emotion is associated with a specific set of kinematic characteristics?

RQ 5.3: Does evidence exist for the presence of multimodal patterns when an emotion is experienced?

Hyp 5.3.1: More emotion-portrayals will cluster together for each target emotion with the multimodal data compared to either of the individual modalities.

Chapter 4
Data Collection Methods

4.1 Overview

This chapter describes the methods used to generate five unique datasets necessary to address the specific aims of this dissertation. Table 7 summarizes the datasets and the studies in which they will be used. Each dataset was derived from either walker or observer participants and was categorized as either walker or observer data. Thus, this chapter is divided into two sections corresponding to walker and observer data. Each section first describes the data collection methods, and then describes the data reduction procedures used to construct each of the datasets.

Table 7. Dataset summary.

DATASET	**TYPE**	**DESCRIPTION**	**Specific Aim**			
			1	2	3	4
Elicitation	Walker	Self-report of emotion during movement trial	X			
FACS	Walker	Assessment of facial expressions during gait				X
Motion	Walker	Movement kinematics and gait descriptors	X		X	X
Recognition	Observer	Observer recognition of emotion	X	X		
Effort-Shape	Observer	Qualitative assessment of movement trials	X	X		

4.2 Walker data

4.2.1 Data collection methods

The following methods were used to collect emotion elicitation data, as well as face and side-view video and motion data from walker participants. Walkers (n = 42, 52% female) were recruited from the University of Michigan undergraduate student population. Ages ranged from 18-32 years (20.1 $\pm$ 2.7 yrs.). All participants were able-bodied and no special skills were required. Half of the participants were randomly assigned to a group that wore a head-mounted camera (HM group) to record video of facial expressions (non-HM: n=21, 57% female, HM: n=21, 48% female). The difference in gender distribution was not significant ($X^2_{(1)} = 0.4$, $p = 0.54$). Prior to data collection, participants reviewed a description of the study and signed a consent form approved by the Institutional Review Board (IRB).

Upon arrival, the participants were informed that the study was about the expression of emotion and that video and motion capture data would be recorded during walking. They were informed that their faces would be blurred in the whole-body videos and these videos would be shown to peers in another study. The HM participants were additionally informed that only the study investigator would view the face videos.

Because one goal of this dissertation was to study felt emotion, an autobiographical memories paradigm was used to elicit emotions in participants. Participants were given as much time as needed to complete an autobiographical memories worksheet. They were informed that the worksheet was for their use only, to help feel emotions, and would remain confidential. On the worksheet, participants were asked to describe times in their own life when they felt two negative emotions (angry and sad), two positive emotions (content and joyful), and neutral emotion (Table 8). Using only a few words, they were asked to indicate: a) where they were, b) who they were with, and c) what caused the feeling/what was it about?

After completing the worksheet, participants changed into a special motion capture suit, and thirty-one passive retro-reflective markers (2 cm diameter) were placed on specific anatomical landmarks on the body in preparation for collection of motion capture data. The placement of the markers allowed the body to be demarcated into eight linked segments, each segment representing a bony segment of the musculo-skeletal system.

Table 8. Autobiographical memories worksheet.

Anger	Think of a time in your life when you felt very offended, for instance, when you felt furious or enraged, or felt like you wanted to explode.
Sad	Think of a time in your life when you felt in despair, for instance, when you felt low or depressed, or felt like you wanted to withdraw from the world.
Neutral	Think of a time in your life when you did not feel any emotion, for instance, when you put gas in your car or did your laundry.
Content	Think of a time in your life when you felt fulfilled, for instance, when you felt satisfied or comfortable, or felt like you wanted to relax and savor life.
Joy	Think of a time in your life when you felt exhilarated, for instance, when you felt euphoric or very playful, or felt like you wanted to jump up and down.

To capture a consistent image of the face during movement, participants assigned to the HM group were fitted with the specialized head-mount custom designed in our laboratory to support a small video camera (Adventure Cam II, Viosport). The camera weighed 80 grams, was 76 mm in length by 22 mm in diameter, and had a resolution of 380 TV lines. The camera rested on the head-mount approximately 30.5 cm from the face. After the head-mount was placed on the participant, the camera was adjusted to ensure that the participant's field of view was not obstructed and that a full view of the face was captured (Figure 3 & Figure 4).

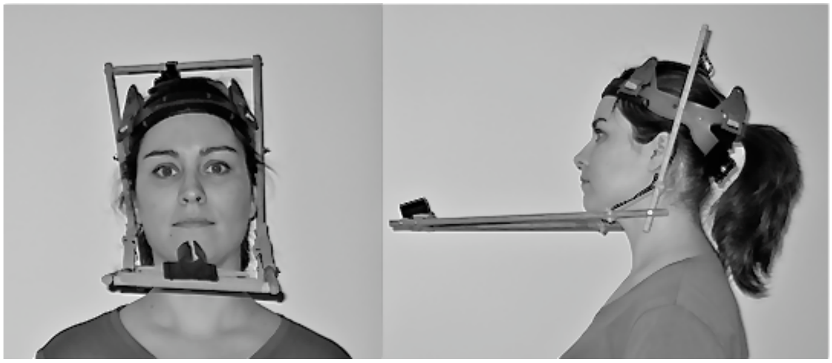

Figure 3. Head mount apparatus used to support video camera for recording facial expression. The adjustable mount for the camera is located at the tip of the horizontal strut.

Figure 4. Face view captured from the head-mounted camera.

Once the set-up was complete, participants were asked to walk at a self-selected pace approximately 5 meters after recalling a memory from their worksheet. Before each walking trial, the participants read their notes to help recall the specific memory. Memories were referred to as numbers rather than emotions to help ensure that a bias was not introduced. Participants began walking when they felt the recalled emotion as strongly as possible; they did not wait for a cue from the experimenter to begin and they did not have to provide a cue to indicate they were ready to walk. As each participant walked, side-view video and whole body 3-D motion capture data were recorded for both the non-HM and HM groups, and face-view video was recorded for the HM group.

Participants performed three trials for each memory in a block to increase the probability that at least one trial would have usable video and motion capture data and the target emotion would be felt. Subjective experience of emotion was assessed after each walking trial using a self-report questionnaire (Table 9) to report emotion intensity. The questionnaire included the four target emotions and four non-target, distracter emotions. The non-target emotions were selected for inclusion based on their similarity, in terms of valance and intensity, to the target emotions. After each walking trial, participants rated the intensity that they felt each of the eight emotions using a 5-item likert scale (0 = not at all; 1 = a little bit; 2 = moderately; 3 = a great deal; 4 = extremely). After each emotion block, the walker was also asked to indicate the trial they felt was their best trial for that memory. The memory order was randomized for each participant.

Table 9. Self-report questionnaire.

Target Emotion	Non-Target Emotion	"…how you felt while walking:"
Angry		I felt angry, irritated, annoyed.
Content		I felt content, serene, peaceful.
Joyful		I felt glad, happy, joyful.
	Awe	I felt awe, wonder, amazement.
Sad		I felt sad, downhearted, unhappy.
	Fear	I felt scared, fearful, afraid.
	Surprise	I felt surprised, amazed, astonished.
	Disgust	I felt disgusted, repulsed, revolted.

4.2.2 Elicitation dataset

The measures included in the dataset were: walker, emotion, trial number, gender, age, HM group, and target emotion intensity rating. In addition, a binary variable was created to code the target emotion as felt or not felt. The variable was coded as "felt" when the self-reported intensity score for the target emotion was greater than or equal to two ("moderately"). Because an item for neutral was not included on the questionnaire, a neutral trial was considered "felt" if all eight items on the questionnaire were scored less than two.

One observation for each walker for each emotion was selected for inclusion in the final emotion elicitation dataset (42 walkers x 5 emotions = 210 total observations). To be selected for inclusion in the dataset, a trial needed to have (1) usable kinematic data, and (2) usable side-view video and face-view video (if applicable). If more than one emotion trial met these criteria for an individual walker-emotion, the trial with the highest score for the target emotion item on the self-report questionnaire was selected. When two or more trials had the same score for the target self-report item, the self-selected best trial was used. If the self-selected best trial was not available, the trial with the lowest scores for all other questionnaire items was selected.

4.2.3 Motion dataset

The measures included in the dataset were: walker, emotion, trial, gender, age, HM group, and joint angles (Table 10). The 210 trials selected for the final elicitation dataset were the same trials included in the motion dataset. For each of the included walking trials, one gait cycle was selected (Heel strike or Toe off) and the data were time-normalized to 100 samples per trial. Motion data were filtered to reduce noise in the signal with a 6Hz low pass Butterworth filter. For each trial the neck, trunk, shoulder, elbow, wrist, hip, knee, and ankle joint 3D kinematics were calculated, in addition to four 2D postural angles. All calculations were completed using C-Motion Visual 3D software package.

Table 10: Limb and torso angles included in kinematic analyses.

Limb angles	**Torso angles**
Shoulder Flexion	Neck Extension
Elbow Flexion	Neck Right Tilt
Wrist Flexion	Neck Left Rotation
Hip Flexion	Trunk Flexion
Hip Abduction	Trunk Right Tilt
Hip External Rotation	Trunk Left Rotation
Knee Extension	Lumbar Lordosis
Ankle Plantarflexion	Shoulder Retraction
	Shoulder Depression
	Thoracic Lordosis

To compute the 3D joint angles, a link-based model was used with the joints defined by the segments in Table 11. Segments are defined by the markers / anatomical landmarks in Table 12. The 2D postural angles were calculated as the included angle between segments defined using coordinate data from three markers (Table 13). The angles were defined relative to the laboratory coordinate system using 3-point angle calculations in the Visual 3D software. Shoulder girdle retraction was defined in the XY (transverse) plane, shoulder girdle depression was depression was defined in the XZ (frontal) plane, thoracic and lumbar lordosis were defined in the YZ (sagittal) plane. Marker definitions can be found in Table 14.

Table 11. Segments used to define joints.

3D Angle	**Segment**	**Reference**
Shoulder	Left Upper Arm	Thorax / Abdomen
Elbow	Left Forearm	Left Upper Arm
Wrist	Left Hand	Left Forearm
Hip	Left Thigh	Pelvis
Knee	Left Shank	Left Thigh
Ankle	Left Shank	Left Foot
Neck	Head	Thorax / Abdomen
Trunk	Thorax / Abdomen	Pelvis

Table 12. Anatomical landmarks used to define segments.

Segment	Proximal Markers		Distal Markers		Tracking Markers
	Lateral	Medial	Lateral	Medial	
Head	R Acromion *	L Acromion*	HR	HL	HL,HR,HT
Thorax/Ab	ICR	ICL	R Acromion*	L Acromion*	AL, AR, C7, IJ, L3, ST, T6
Upper Arm	L. Acromion *	Shoulder *	ALE	AME	UA1, UA2, UA3 (Cluster plate used)
Forearm	ALE	AME	RS	US	FA1, FA2, FA3 (Cluster plate)
Hand	RS	US	MC2	MC5	MC2, MC3, MC5
Thigh	L Trochanter*	HH_Left_Hip*	LLE	LME	TH1, TH2, TH3 (Cluster plate)
Shank	LLE	LME	LM	MM	SH1, SH2, SH3 (Cluster plate)
Foot	LM	MM	MT5	MT1	HEEL, MT1, MT5

* See Table 9 for offset

Table 13. Definition of 2D postural angles.

2D Angle	Point 1	Point 2	Point 3	Plane
Thoracic Lordosis	L3	T6	C7	YZ
Lumbar Lordosis	T6	L3	SA	YZ
Shoulder Retraction (Shrink)	Al	IJ	AR	XY
Shoulder Depression (Shrug)	AL	IJ	AR	XZ

Table 14. Motion capture marker definitions.

Remove for Tracking	Marker #	Marker Name	Anatomical Position
	1	HT	Top of Head
	2	HR	Right Side of Head
	3	HL	Left Side of Head
	4	C7	Spinous Process C7
	5	IJ	Jugular Notch
	6	T6	Spinous Process T6
	7	ST	Sternum 3rd Rib
	8	AR	Right Acromion
	9	AL	Left Acromion
	10	L3	3rd Lumbar Vertebrae
**	11	ICR	Right Iliac Crest
**	12	ICL	Left Iliac Crest
	13	ASISR	Right Anterior Superior Iliac Spine
	14	ASISL	Left Anterior Superior Iliac Spine
	15	SA	Sacrum (Line up with PSIS)
**	16	GTR	Right Greater Trochanter
**	17	GTL	Left Greater Trochanter
	18	UA1	Upper Arm Plate Superior
	19	UA2	Upper Arm Plate Posterior
	20	UA3	Upper Arm Plate Anterior
**	21	ALE	Arm Lateral Epicondyle
**	22	AME	Arm Medial Epicondyle
	23	FA1	Forearm Plate Superior
	24	FA2	Forearm Plate Posterior
	25	FA3	Forearm Plate Anterior
**	26	RS	Radial Styloid Process
**	27	US	Ulnar Styloid Process
	28	MC3	3rd Metacarpal
	29	MC2	2nd Metacarpal
	30	MC5	5th Metacarpal
	31	TH1	Thigh Plate Superior
	32	TH2	Thigh Plate Posterior
	33	TH3	Thigh Plate Anterior
**	34	LLE	Leg Lateral Epicondyle
**	35	LME	Leg Medial Epicondyle
	36	SH1	Shank Plate Superior
	37	SH2	Shank Plate Posterior
	38	SH3	Shank Plate Anterior
**	39	LM	Lateral Maleolus
**	40	MM	Medial Maleolus
	41	HEEL	Heel
	42	MT1	1st Metatarsal
	43	MT5	5th Metatarsal

In some cases, offsets were necessary to define the joint center. Table 15 provides the offsets applied to calculate shoulder, elbow, and hip. Additionally, to define the hip joint, a standard Helen Hayes marker set and regression equations available in the software package were used.

Table 15. Offsets used to calculate joint centers.

Landmark Name	**Starting Point**	**Ending Point**	**Offset from Starting Point**
Shoulder	L Acromion	Elbow	10.40%
Elbow	ALE	AME	50%
R Acromion	AR	n/a	Z = - 0.019 m
L Acromion	AL	n/a	Z = - 0.019 m
R Trochanter	GTR	n/a	X = - 0.019 m
L Trochanter	GTL	n/a	X = 0.019 m
HH_Left_Hip *			

* HH_Left_Hip joint center was calculated automatically in the software using Helen Hayes Regression Equations. The joint markers used to define the Helen Hayes Pelvis were ASISL, SA, and ASISR.

4.2.4 FACS dataset

The facial action coding system (FACS) was used to code facial behavior, using the face videos from the group that wore the head-mounted camera. The trials selected for inclusion were a subset of the 210 trials used in the elicitation and motion datasets, because only half of the walkers were in the HM group. The dataset included a total of 105 trials (21 walkers x 5 emotions).

FACS, a comprehensive system for coding the smallest units of movement in the face (Ekman, Friesen, & Hager, 1978), divides the face into action units (Table 16). Action units are based on the muscular anatomy of the face and they indicate the muscle or group of muscles required to generate a specific facial action.

Only the frames corresponding to the gait cycle selected for analysis were coded. All action units for every frame were coded as on or off. The measures included in the final dataset were: walker, emotion, trial, gender, age, time, and each of the action units.

Table 16. FACS action units (Ekman et al., 1978).

AU	Description	Muscular Basis
AU1	Inner brow raiser	Frontalis, Pars Medialis
AU2	Outer brow raiser	Frontalis, Pars Lateralis
AU4	Brow lowerer	Depressor Glabellae; Depressor Supercilli; Corrugator
AU5	Upper lid raiser	Levator Palpebrae Superioris
AU6	Cheek raiser	Orbicularis Oculi, Pars Orbitalis
AU7	Lid tightener	Orbicularis Oculi, Pars Palebralis
AU9	Nose wrinkler	Levator Labii Superioris, Alaeque Nasi
AU10	Upper lip raiser	Levator Labii Superioris, Caput Infraorbitalis
AU11	Nasolabial furrow	Deepener Zygomatic Minor
AU12	Lip corner puller	Zygomatic Major
AU13	Cheek puffer	Caninus
AU14	Dimpler	Buccinnator
AU15	Lip corner depressor	Triangularis
AU17	Chin raiser	Mentalis
AU18	Lip Puckerer	Labii Superioris; Incisivii Labii Inferioris
AU20	Lip stretcher	Risorius
AU22	Lip funneler	Orbicularis Oris
AU23	Lip tightener	Orbicularis Oris
AU24	Lip Pressor	Orbicularis Oris
AU25	Lips apart	Depressor Labii, or Relaxation of Mentalis or Orbicularis Oris
AU26	Jaw drops	Masetter; Temporal and Internal Pterygoid Relaxed
AU27	Mouth stretches	Pterygoids; Digastric
AU28	Lip Suck	Orbicularis Oris
AU38	Nostril Dilator	Nasalis, Pars Alaris
AU39	Nostril Compressor	Pars Transversa and Depressor Septi Nasi
AU41	Lids droop	Relaxation of Levator Palpebrae Superioris
AU42	Slit	Orbicularis Oculi
AU43	Eyes Closed	Relaxation of Levator Palpebrae Superioris
AU44	Squint	Orbicularis Oculi, Pars Palpebralis
AU45	Blink	Relaxation of Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis
AU46	Wink	Orbicularis Oculi

4.3 Observer data

4.3.1 Data collection methods

Side-view video clips from the 210 trials (42 walkers x 5 emotions) selected in the walker protocol were shown to observers in two different emotion assessment studies (Recognition and Effort-Shape). The walkers' faces were blurred to ensure that observers were not using information from facial expression to assess emotion, and the movement clips were looped three times. Two sets of observers (n=60 in each set) from the University of Michigan student population were recruited for participation in each study. Participants (n=60, 48% female) in the Recognition study ranged in age from 18-30 years (20.9 $\pm$ 2.7 yrs). Participants (n=60, 52% female) in the Effort-Shape study ranged in age from 19-30 years (22.0 $\pm$ 2.6 yrs). No special skills were required. However, participants were excluded if they participated as a walker and could not participate in both the Recognition and Effort-Shape studies. The protocol used was the same in both studies, with the exception of the questionnaire that the participants filled out. The following section describes the protocol, as well as the construction of each of the resulting Recognition and Effort-Shape datasets.

Upon arrival, participants reviewed a description of the study and signed a consent form approved by the IRB. They were informed that the study was about the expression of emotion in movement, that they would be watching a series of short video clips of people walking, and that after each clip they would fill out a questionnaire.

The large number of video clips used in this experiment required them to be divided between two groups of observers so that a single observer did not see more than 110 clips. Observers were randomly assigned to one of two observer groups with 30 observers in each group. The video clips of the walkers were shown to the observers in one of three different randomized sequences. After viewing each video clip, observers filled out an emotion assessment questionnaire.

In the Recognition study, observers selected one of 10 emotions that they thought the walker experienced during the trial. The forced choice items included the 4 target emotions, 4 non-target emotions, neutral/no emotion, and none of the above (Table 17). In the Effort-Shape study, observers completed a six-item Effort-Shape questionnaire. On the questionnaire, two items – torso shape and limb shape – were related to the shape of the body and four items – space, time, energy, flow – were related to the effort quality during the movement (Table 18). The observers rated the qualities using a 5-item Likert scale (1 = left-anchor quality; 5 = right-anchor quality). The anchor points represented opposite qualities for each Effort-Shape factor. Observers were instructed to think of the scale as a continuum, rather than 5 discrete points on a scale. They were shown a bar with a gray-scale gradient from white on the left to black on the right. The gradient bar had five evenly spaced points from which they could select.

Table 17. Recognition study feelings questionnaire.

Target Emotion	**Non-Target Emotion**	**"…how they felt while walking:"**
Angry		They felt angry, irritated, annoyed.
Content		They felt content, serene, peaceful.
Joyful		They felt glad, happy, joyful.
	Awe	They felt awe, wonder, amazement.
Sad		They felt sad, downhearted, unhappy.
	Fear	They felt scared, fearful, afraid.
	Surprise	They felt surprised, amazed, astonished.
	Disgust	They felt disgusted, repulsed, revolted.
Neutral		They felt neutral.
	None of the above	None of the above.

Table 18. Effort-Shape study questionnaire.

1 = Left-anchor Quality	**Effort-Shape Quality**	**5 = Right-anchor Quality**
Contracted, bowed, shrinking	Torso Shape	Expanded, stretched, growing
Moves close to body, contracted	Limb Shape	Moves away from body, expanded
Indirect, wandering, diffuse	Space	Direct, focused, channeled
Light, delicate, buoyant	Energy	Strong, forceful, powerful
Sustained, leisurely, slow	Time	Sudden, hurried, fast
Free, relaxed, uncontrolled	Flow	Bound, tense, controlled

4.3.2 Recognition dataset

The measures in the dataset were: observer, observer gender, observer age, observer group, video sequence, walker, walker gender, walker age, target emotion, walking trial number, and the observed emotion (score ranging from 1-10 from the forced-choice feelings questionnaire). In addition, each observation was coded as recognized if the observed emotion agreed with the target emotion. The total number of observations for each target emotion is 1260 (42 walkers x 30 observations for each clip).

4.3.3 Effort-Shape dataset

The measures in the dataset were: observer, observer gender, observer age, observer group, video sequence, walker, walker gender, walker age, target emotion, walking trial number, and the reported score for each of the six Effort-Shape qualities. The total number of observations for each target emotion was 1260 (42 walkers x 30 observations for each clip).

4.4 References

Ekman, P., Friesen, W. V., & Hager, J. C. (1978). *Facial Action Coding System Investigator's Guide*. Salt Lake City: Research Nexus.

Chapter 5

Study Design

5.1 Specific Aim 1 – Feasibility Study

Purpose: To determine the feasibility of using a head-mounted camera to capture facial expressions during body movement.

Research Question 1.1: Does wearing a head-mounted camera affect emotion elicitation?

Dataset: Elicitation

	Hypothesis	**Measures**	**Analysis**
1.1.1	There is no difference between the proportion of trials reported as felt between the non-HM and HM groups for sad, anger, joy, and content emotions or neutral.	IV: ▪ Group ‣ HM, Non-HM ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Walker (n = 42) ▪ Walker age ▪ Walker gender ▪ Group x Emotion ▪ Group x Gender DV: ▪ Felt emotion ‣ 1 = Felt ‣ 0 = Not felt	A generalized linear mixed model with random walker effects was used to model the probability of the binary response variable (felt emotion) with a logit link. Approximate likelihood ratio tests were used to determine if the interaction effects were significant.

	Hypothesis	Measures	Analysis
1.1.2	Self-reported intensities for sad, anger, joy and content are not different between the non-HM and HM groups.	IV: ▪ Group ‣ HM, Non-HM DV: ▪ Emotion intensity ‣ 0 = not at all ‣ 1 = a little bit ‣ 2 = moderately ‣ 3 = quite a bit ‣ 4 = extremely	The distributions of the self-reported intensity scores were compared using Fisher's exact test. The analysis was performed separately for each emotion.

Research Question 1.2: Does wearing a head-mounted video camera affect emotion recognition?

Dataset: Recognition

	Hypothesis	Measures	Analysis
1.2.1	There is no difference in observer recognition of emotion between HM and non-HM groups for sad, anger, joy, content, and neutral emotions.	IV: ▪ Group ‣ HM, Non-HM ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Video sequence ‣ A, B, C ▪ Video set ‣ 1, 2 ▪ Observer (n = 60) ▪ Observer gender ▪ Observer age ▪ Walker ▪ Walker gender ▪ Walker age DV: ▪ Recognized emotion ‣ 1 = Recognized* ‣ 0 = Not recognized * Recognized if observed emotion = target emotion	A generalized linear mixed model with crossed random effects of walkers and observers was used to model the probability of the binary response variable (recognized emotion) with a logit link. The analysis was performed separately for each emotion.

Research Question 1.3: Does the head-mounted camera affect observer recognition of qualitative aspects of movements?

Dataset: Effort-Shape

	Hypothesis	Measures	Analysis
1.3.1	There are no significant differences between the non-HM and HM groups for the effort-shape scores for sad, anger, neutral, joyful and content emotions.	IV: ▪ Group ‣ HM, Non-HM ▪ Video sequence ‣ A, B, C ▪ Video set ‣ 1, 2 ▪ Observer ▪ Observer gender ▪ Observer age ▪ Walker ▪ Walker gender ▪ Walker age DV: ▪ Effort-Shape scores ‣ Torso shape ‣ Limb shape ‣ Energy ‣ Time ‣ Space ‣ Flow	Effort-Shape scores were treated as continuous variables. A linear mixed model with crossed random walker and observer effects was used to model means on the response variables (i.e., Effort-Shape scores). The analysis was performed separately for each emotion.

Research Question 1.4: Does wearing the head-mounted camera affect quantitative aspects of movements?

Dataset: Motion

	Hypothesis	Measures	Analysis
1.4.1	Joint angular kinematic measures are the same for both groups for emotions that are both felt and recognized.	IV: ▪ Group ‣ HM, Non-HM ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Walker ▪ Walker gender DV: ▪ Kinematic measures ‣ Mean joint angles ‣ Joint RoM	A linear mixed model with random walker effects was used to model means on the response variable (kinematic measures).
1.4.2	Gait cycle descriptors are the same for both groups for emotions that are both felt and recognized.	IV: ▪ Group ‣ HM, Non-HM ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Walker ▪ Walker gender DV: ▪ Gait cycle descriptors ‣ Cycle duration ‣ Normalized stride length ‣ Normalized gait velocity	A linear mixed model with random walker effects was used to model means on the response variable (gait cycle descriptors).

5.2 Specific Aim 2 – Movement Style Study

Purpose: To determine the Effort-Shape characteristics of emotion-related body movement.

Research Question 2.1: Do emotion portrayals of walking have external validity?

Dataset: Recognition

	Hypothesis	Measures	Analysis
2.1.1	Emotions are recognized at levels greater than chance. Note: Chance is defined as 10% because we have ten items on our questionnaire. Observers selected one item from the questionnaire for each video clip.	IV: ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Walker ▪ Observer DV: ▪ Recognized emotion ‣ 1 = Recognized* ‣ 0 = Not recognized * Recognized if observed emotion = target emotion	A logistic regression model was used to model the probability of recognized emotion using the technique of generalized estimating equations (GEE). GEE allows binary recognition outcomes from the same walker/emotion combinations to be correlated, which would be expected if a walker was effective at expressing an emotion. The predicted probabilities of recognized emotion for each target emotion were calculated based on the model in addition to calculating a 95% confidence interval for each predicted emotion. An emotion was considered recognized if the predicted probability was greater than chance and the 95% confidence interval did not include the value corresponding to chance recognition (0.10).

Research Question 2.2: What Effort-Shape qualities are associated with each target emotion?

Dataset: Effort-Shape (Note: Only trials that were both felt and recognized were included in the analyses)

	Hypothesis	**Measures**	**Analysis**
2.2.1	Observer ratings of Effort-Shape qualities are not due to chance.	DV: ▪ Effort Shape scores ‣ Torso shape ‣ Limb shape ‣ Energy ‣ Time ‣ Space ‣ Flow	A chi-square test, adjusted for clustering (Jann 2008) by observer, was performed separately for each target emotion for each Effort-Shape quality. The null hypothesis that the distribution of Effort-Shape responses was uniform was tested. This would be expected if observers responded by random chance. The MGOF command (Jann, 2008) was used in Stata version 10.

	Hypothesis	Measures	Analysis
2.2.2	Exploratory: Provide numerical profiles for each emotion based on the 6 ES Qualities.	▪ Effort-Shape scores ‣ Torso shape ‣ Limb shape ‣ Energy ‣ Time ‣ Space ‣ Flow ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad	Calculated means for each ES Qualities for each emotion. Represented the data in tables.
2.2.3	Emotions differ with respect to movement style characteristics.	IV: ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Video sequence ‣ A, B, C ▪ Video set ‣ 1, 2 ▪ Observer ▪ Observer gender ▪ Walker ▪ Walker gender DV: ▪ Effort-Shape scores ‣ Torso shape ‣ Limb shape ‣ Energy ‣ Time ‣ Space ‣ Flow Effort-Shape scores were treated as continuous variables.	Tested to determine if there were significant differences between mean effort-shape scores for anger, content, joyful, neutral, and sad emotions. A linear mixed model with crossed random walker and observer effects was used to model means on the response variables (i.e., Effort-Shape scores). The analysis was performed separately for each Effort-Shape quality. Post-hoc pairwise comparisons of the means were examined to determine what the differences are between emotions. The lmer function in R version 2.5.0 were used for this analysis.

2.2.4	Exploratory: To determine whether individual encoders, observers, encoder gender or observer gender affects judgments of movement characteristics.		Evaluated base on previous model.

Research Question 2.3: Are specific Effort-Shape characteristics associated with decoding accuracy?

Dataset: Recognition and Effort-Shape

	Hypothesis	Measures	Analysis
2.3.1	Movements that do not correspond to the emotion profiles are associated with low recognition.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Mean Effort-Shape scores (mean from 30 observers was calculated for each trial) ‣ Torso shape ‣ Limb shape ‣ Energy ‣ Time ‣ Space ‣ Flow	Tested for significant correlations between mean Effort-Shape scores and percent recognition.

	Hypothesis	Measures	Analysis
2.3.2	Exploratory: To determine whether additional factors affect decoding accuracy.	IV: ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Video sequence ‣ A, B, C ▪ Video set ‣ 1, 2 ▪ Observer (n = 60) ▪ Observer gender ▪ Walker ▪ Walker gender ▪ Walker gender * emotion ▪ Observer gender * emotion DV: ▪ Recognized emotion ‣ 1 = Recognized* ‣ 0 = Not recognized * Recognized if observed emotion = target emotion	A generalized linear mixed model with crossed random effects of walkers and observers was used to model the probability of the binary response variable (recognized emotion) with a logit link.

5.3 Specific Aim 3 – Quantitative Assessment

Purpose: To determine the kinematic characteristics of emotion-related body movement.

Research Question 3.1: What kinematic qualities are associated with each target emotion?
Dataset: Motion

	Hypothesis	Measures	Analysis
3.1.1	Exploratory: Provide kinematic profiles for each target emotion.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Kinematic measures ‣ Joint RoM ‣ Angles at HS	A linear mixed model with random walker effects was used to model means on the response variable.
3.1.2	Joint angular kinematic measures are affected by emotion.	IV: ▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Walker ▪ Walker gender DV: ▪ Kinematic measures ‣ Joint RoM ‣ Angles at HS	A linear mixed model with random walker effects was used to model means on the response variable.
3.1.3	Exploratory: To determine whether individual encoders or encoder gender affects movement kinematics.		Evaluated based on previous model.

Research Question 3.2: Are specific kinematic characteristics associated with decoding accuracy?
Dataset: Motion

	Hypothesis	Measures	Analysis
3.2.1	Kinematics that do not correspond to the emotion profiles identified are associated with low recognition accuracy.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Kinematic measures ‣ Joint RoM ‣ Angles at HS	Tested for significant correlations between mean Effort-Shape scores and percent recognition.

5.4 Specific Aim 4 – Multimodal Analysis

Purpose: To determine multimodal patterns of emotion in the body and face.

Research Question: Determine whether each target emotion is associated with a specific set of FACS action units?

Dataset: FACS

	Hypothesis	Measures	Analysis
4.1.1	Exploratory: Identify facial patterns associated with each target emotion.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ AU score ‣ Coded as on (1) or off (0).	A cluster analysis was performed on the FACS dataset. The two-step cluster algorithm in SPSS version 16 was used. The distance measure was computed using the log-likelihood method. In addition, the number of clusters was fixed to five, since five target emotions were investigated in this analysis.

Research Question 4.2: Determine whether emotion portrayals cluster together for each target emotion using kinematic data?

Dataset: Body

	Hypothesis	Measures	Analysis
4.2.1	Exploratory: Identify whether emotion portrayals cluster together for each target emotion.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Kinematic measures ‣ Joint RoM ‣ Angles at HS	The two-step cluster algorithm in SPSS version 16 was used. The distance measure was computed using the log-likelihood method. In addition, the number of clusters was fixed to five, since five target emotions were investigated in this analysis.

Research Question 4.3: Does evidence exist for the presence of multimodal patterns when an emotion is experienced?

Dataset: FACS & Body

	Hypothesis	Measures	Analysis
4.3.1	More emotion portrayals will cluster together for each target emotion with the multimodal data compared to either of the individual modalities.	▪ Emotion ‣ Anger ‣ Content ‣ Joy ‣ Neutral ‣ Sad ▪ Kinematic measures ‣ Joint RoM ‣ Angles at HS ▪ AU score ‣ Coded as on (1) or off (0).	A cluster analysis was performed on the FACS dataset. The two-step cluster algorithm in SPSS version 16 was used. The distance measure was computed using the log-likelihood method. In addition, the number of clusters was fixed to five, since five target emotions were investigated in this analysis.

Chapter 6

Feasibility of Using a Head-Mounted Camera to Capture Facial Expressions During Body Movement

6.1 Abstract

In this study, we tested the feasibility of capturing video of facial expressions while concurrently capturing motion capture and video of bodily expressions. To collect facial expression data, we used a custom designed head-mount for a video camera that provided images for facial expression microanalysis but did not limit freedom of movement. We assessed the effect of the head-mount on emotion elicitation, emotion recognition, qualitative aspects of body movement, and quantitative aspects of body movement. The results indicate that while the head-mount may slightly constrain arm movement, wearing the head-mounted camera during motion capture is a valid method for collecting facial and bodily data.

6.2 Introduction

Many studies have documented that emotions can produce measurable changes in expressive modalities, including the face (Ambadar, Schooler, & Cohn, 2005; Ekman, 1993; Scherer & Ellgring, 2007a), voice (Bachorowski, 1999; Banse & Scherer, 1996; Ellgring & Scherer, 1996), and body (Atkinson et al., 2004; Coulson, 2004; J. M. Montepare et al., 1987; Pollick et al., 2001; Wallbott, 1998). Although studying each modality independently has advanced our understanding of emotion and social behavior, emerging studies are beginning to require simultaneously captured signals from multiple modalities, such as the face and body (Scherer & Ellgring, 2007b). The challenge for multimodal studies is that current methods for capturing facial video limit the range of movement tasks that may be used to assess expressive behavior. Indeed, in one of the first studies to assess multimodal expressive patterns and the relationship with emotion, the authors acknowledge the importance of the behaviors studied and conclude that their results may be limited by the behaviors in their analysis (Scherer & Ellgring, 2007b). Therefore, methodology to simultaneously capture signals from multiple modalities that allows freedom of movement is needed so that a range of expressive behaviors can be studied. The primary objective of this study was to overcome this technical constraint by testing the feasibility of capturing video of the face during a movement task in which a subject changes location.

Previous studies of expressive behavior have captured face video by placing a stationary camera directly in front of the subject. However, for experiments that require the subject to change location or engage in tasks that take their face away from the camera, one camera is not sufficient to capture a continuous and unobstructed frontal view. Although multiple cameras placed around the experimental space could provide a continuous view, the video image of the face would have to be assembled from multiple cameras with differing angles and distances, thereby affecting face size or shading. Such a compromised view of the face impairs the ability to use well-established methods, such as the Facial Action Coding System (FACS) (Ekman & Friesen, 1978), to document and characterize the expressive facial behaviors. An alternative to using multiple, stationary cameras is to fix a single camera to the subject's head so that a continuous and unobstructed video of the face can be captured. However, wearing a head-mounted camera could potentially interfere with the production of expressive behavior by affecting emotion elicitation, emotion recognition, or body movements. If the method for capturing the expressive stimuli interferes with the expressive behavior, then the multimodal signals captured may not accurately represent target emotions. Therefore, methods for capturing expressive stimuli are valid only if they do not interfere with expressive behavior.

The purpose of this study was to assess the feasibility of collecting face video during an expressive movement task in which the subject changes location. Face video was collected simultaneously with whole-body video and motion capture data to qualitatively and quantitatively assess body movements. To determine whether wearing a head-mounted camera interfered with expressive behavior, this study was divided into four parts assessing the effect of the head-mount on (1) emotion elicitation, (2) emotion recognition, (3) qualitative aspects of body movement, and (4) quantitative aspects of body movement.

6.3 Part 1 – Emotion elicitation

The first aim was to test whether wearing a head-mounted camera to record facial expressions affected emotion elicitation during a movement task in which a subject changes location. Walking was studied because it is a well-documented movement task in biomechanics, it is an emotionally neutral task, and it is a task that requires subjects to move from one location to another. Additionally, the fact that emotions are recognizable in walking (Janssen et al., 2008; J. M. Montepare et al., 1987) suggests characteristics modifications in this task are associated with specific emotions. Thus, walking is an ideal task for future studies to explore the characteristic movement styles associated with specific emotions.

Two negative emotions (anger and sad), two positive emotions (joy and content), and neutral were selected for the study because these emotions are balanced in terms of pleasantness and intensity. Two of the emotions included in the present study, anger and sadness, were included in a study by Montepare et al. (1987) demonstrating differences between emotions are observable in walking. In contrast to Montepare et al. (1987), we chose to include two positive emotions with opposite intensities (joy and content) rather than the more general emotion referred to as happiness. To determine whether wearing the head-mounted camera affects emotion experience, self-reports of emotion experience from participants wearing the head-mounted camera are compared to a control group that did not wear the head-mounted camera.

To address this aim, we tested (1) whether the proportion of movement trials in which the target emotions were felt was different between head-mount (HM) and non-HM groups, and (2) whether the self-reported intensities of the target emotions were different between the groups.

6.3.1 Walkers

Walkers were recruited from the University of Michigan undergraduate student population and gave informed consent before participating. Walkers (n = 42, 52% female) ranged in age from 18-32 years (20.1 $\pm$ 2.7 yrs.). All participants were able-bodied and no special skills were required. They were randomly assigned to the non-HM (n = 21, 57% female) and HM groups (n = 21, 48% female). The difference in gender distribution was not significant ($X^2_{(1)} = 0.4$, p = 0.54).

6.3.2 Materials and procedure

Head-mounted camera. To capture a consistent image of the face during movement, a head mount was custom designed in our laboratory to support a small video camera (Adventure Cam II, Viosport). The camera weighed 80 grams, was 76 mm in length by 22 mm in diameter, and had a resolution of 380 TV Lines. The camera rested on the head mount approximately 30.5 cm from the face and was adjusted to ensure that the participant's field of view was not obstructed and that a full view of the face was captured (Figure 5).

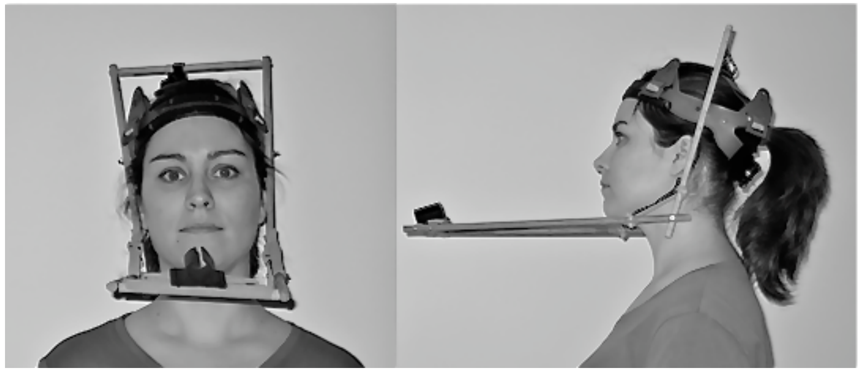

Figure 5. Head mount apparatus used to support video camera for recording facial expression. The adjustable mount for the camera is located at the tip of the horizontal strut.

Procedure. Walkers completed an autobiographical memories worksheet (Labouvie-Vief et al., 2003; R. Levenson, Cartensen, Friesen, & Ekman, 1991). They described times in their own life when they felt two negative emotions (anger and sad), two positive emotions (joy and content), and neutral emotion.

Walkers wore a motion capture suit and thirty-one light-weight spherical markers (2 cm diameter) were placed over specific anatomical landmarks. They walked 5 meters at a self-selected pace after recalling a memory from their worksheet. Side-view video and 3-D motion capture data were recorded, and face-view video was additionally recorded for the HM group.

Participants performed three walking trials of each memory in a block; memory order was randomized. To determine if the target emotion was felt, walkers completed a self-report questionnaire after each trial to indicate what they felt while walking. After each emotion block, walkers indicated which trial was their best trial for that memory.

Measures. Subjective experience of emotion was assessed using a self-report questionnaire to report emotion intensity (Gray & Watson, 2007; Larsen & Fredrickson, 1999). The questionnaire included the four target emotions and four non-target, distracter emotions (awe, disgust, fear, and surprise). Walkers rated the intensity that they felt each emotion using a 5-item likert scale (0 = not at all; 1 = a little bit; 2 = moderately; 3 = a great deal; 4 = extremely).

A binary variable was created to code the target emotion as felt or not felt. The variable was coded as "felt" when the self-reported intensity score for the target emotion was greater than or equal to two ("moderately"). Because an item for neutral was not included on the questionnaire, a neutral trial was considered "felt" if all eight items on the questionnaire were scored less than two.

Data analysis. 210 walking trials (5 emotions x 42 walkers) were selected for evaluation. To be selected, a trial needed to have (1) usable kinematic data, and (2) usable side-view video and face-view video (if applicable). If more than one emotion trial was available for an individual walker, the trial with the highest score for the target emotion item on the self-report questionnaire was selected. When two or more trials had the same score for the target self-report item, the self-selected best trial was used. If the self-selected best trial was not available, the trial with the lowest scores for all other questionnaire items was selected.

A generalized linear mixed model with random walker effects was used to model the probability of the binary response variable (felt emotion) with a logit link. Fixed effects of group, emotion, walker gender, and walker age, and the interactions between group - emotion and group - gender were tested. Fixed effects were significant if the absolute value of the t-ratio of the estimate to its standard error was greater than 2. Approximate likelihood ratio tests were used to determine if the interaction effects were significant: effects with a p-value greater than .05 were removed from the model. To determine if emotion intensity was affected by wearing the head-mounted camera, the distributions of the self-reported intensity scores were compared using Fisher's exact test for each emotion.

6.3.3 Results

Proportions of felt trials. There were no significant differences in the proportion of trials coded as felt between the HM and non-HM groups for each emotion. The difference between groups for each emotion, except neutral, was less than 5% and the emotions were coded as felt in more than 95% of the trials in each group. Our success in eliciting neutral trials was less effective, however, and the criterion for felt neutral trials was met in only 68% of the trials. In the majority of "failed" neutral trials, walkers reported feeling either content or anxious at a moderate level. Although the average percentage of felt neutral trials tended to be greater for walkers wearing the head-mounted camera (non-HM = 60%, HM= 76.2%), the difference was not significant.

Fixed effects of emotion, walker gender, and walker age did not significantly effect felt emotion. Likewise, there were no interaction effects for group and emotion or group and gender.

Intensities of felt emotions. There were no significant differences in the distributions of the self-reported intensity scores between the HM and non-HM groups for any of the target emotions. The largest difference in reported intensities between groups was for content in which the HM group had a greater percentage of the highest intensity scores (76.2% vs. 57.1%) but the difference was not significant.

Post-hoc power analysis. Because the observed differences between the non-HM and HM groups for each target emotion were so small (0-5% for anger, sad, content, joy; 16.2% for neutral), an unrealistic number of walkers in each group would be necessary to achieve 80% power (i.e. 169 for anger, joy and sad; and 129 for neutral; over 700,000 for content).

6.4 Part 2 – Emotion recognition

The second aim was to determine whether the head-mounted camera worn by the walkers affected emotion recognition by observers. Social consensus studies are often used prior to behavioral analyses to select trials that accurately represent the target emotions. Therefore, to address this aim, we tested whether observer recognition of emotion in the body movements of the walkers differed between HM and non-HM groups.

6.4.1 Observers

Observers (n = 60, 48% female) ranged in age from 18-30 years (20.9 $\pm$ 2.7 yrs). They provided informed consent prior to beginning the study. No special skills were required. However, observers were excluded if they had participated as a walker.

6.4.2 Materials and procedure

Video clips. Side-view video clips from the 210 trials were shown to the observers to determine if the target emotion was recognizable in the body movements of the walkers. The walkers' faces were blurred and the movement clips were looped three times.

Procedure. The large number of video clips used in this experiment required them to be divided between two groups of observers so that a single observer did not see more than 110 clips. Observers were randomly assigned to one of two groups with 30 observers in each group. The video clips were shown in one of three different randomized sequences. After viewing each video clip, observers selected one of 10 emotions that they thought the walker experienced during the trial. The forced choice items included the same 4 target emotions and 4 non-target emotions as in the Elicitation study. In addition, observers could select from neutral/no emotion and none of the above.

Measures. The total number of emotion observations for each group for each emotion was 630 (21 walkers x 30 observations for each clip). Each emotion observation was coded as recognized if the observed emotion agreed with the target emotion.

Data analysis. A generalized linear mixed model with crossed random effects of walkers and observers was used to model the probability of the binary response variable (recognized emotion) with a logit link. The analysis was performed separately for each emotion and the model included fixed effects of head-mount group, walker gender, observer gender, walker age, observer age, video sequence and observer group. Fixed effects were determined as significant if the absolute value of the t-ratio of the estimate to its standard error was greater than 2. To check for random observer effects, a likelihood ratio test was used to determine if the variance of the random observer effect was significantly greater than zero.

6.4.3 Results

Recognition. Emotion recognition was not significantly different between the HM and non-HM groups. The differences in the number of observations that were recognized between the two groups were small, ranging from 19 observations for sad (3% of the total observations) to 4 observations for neutral (0.06% of total).

Additional measures. Fixed effects of head-mount group, walker gender, observer gender, walker age, observer age, video sequence and observer group were not significant for any emotion. Random observer effects were observed, however, indicating that the observer effects should remain in our statistical model.

Post-hoc power analysis. Because the observed differences between the non-HM and HM groups for each target emotion were so small, an unrealistic number of total observers (i.e., 310 for joy, 297 for anger, 3903 for neutral, 204 for sad, 227 for content) would be necessary to achieve 80% power.

6.5 Part 3 – Effort-Shape analysis

The third aim was to determine if wearing the head-mounted camera affected qualitative characteristics of the walkers' body movements. Most previous studies that qualitatively describe the effects of emotion of body movement document the behaviors associated with specific emotions. Wallbott and Scherer (1986), for example, developed a body coding system to describe body posture, the types of movements performed, and the overall movement qualities. For example, using this system joy, was characterized as having the shoulders up, head backward, and arms stretched out (Wallbott & Scherer, 1986). Although documenting the behaviors associated with specific emotions is an important aspect of emotionally expressive movement, an alternative and perhaps complementary approach to studying expressive body movement is to describe the characteristic modifications that make any movement performed with emotion recognizable.

Despite evidence that certain movement styles are associated with specific emotions, studies such as Montepare et al. (1987), Pollick et al. (2001), and Dahl (2007) have used qualitative movement style descriptions unique to their respective studies. Thus, comparisons between studies are difficult. Therefore, the study of expressive behavior needs a comprehensive and task-independent system for qualitatively describing movement style characteristics. Gross et al. (Submitted) propose using an existing, comprehensive, and task-independent system for qualitatively describing movement called Effort-Shape analysis. Effort-Shape analysis is a component of Laban Movement Analysis Analysis (Cecily Dell, 1977) which is used to describe the body motions of individuals engaged in a variety of tasks, including factory workers and dancers (Laban

& Ullmann, 1988). The benefit of Effort-Shape analysis is that it provides a method for assessing the dynamic qualities of whole-body movement that reveal expressive behavior. However, before future studies on multimodal expression can use this system to characterize movement style, it must be determined whether wearing a head-mounted camera affects the qualitative aspects of expressive body movement.

In this part of the study, we used an Effort-Shape analysis to assess the qualitative characteristics of the body movements and we tested whether Effort-Shape scores differed between the groups.

6.5.1 Observers

Observers ($n = 60$, 52% female) ranged in age from 19-30 years (22.0 ± 2.6 yrs). No special skills were required. However, participants were excluded if they participated in as a walker or in the recognition study.

6.5.2 Materials and procedure

The same video clips and procedures used in the recognition study were used in this study. However, observers completed a six-item Effort-Shape questionnaire after viewing each video clip. Two questionnaire items were related to the shape of the body (i.e., torso shape and limb shape), and four items were related to the effort quality during the movement (i.e., space, time, energy, flow) (Table 19).

Table 19. Effort-Shape Questionnaire Items

1 = left-anchor quality	Effort-Shape Quality	5 = right-anchor quality
Contracted, bowed, shrinking	Torso Shape	Expanded, stretched, growing
Moves close to body, contracted	Limb Shape	Moves away from body, expanded
Indirect, wandering, diffuse	Space	Direct, focused, channeled
Light, delicate, buoyant	Energy	Strong, forceful, powerful
Sustained, leisurely, slow	Time	Sudden, hurried, fast
Free, relaxed, uncontrolled	Flow	Bound, tense, controlled

The observers rated the qualities using a 5-item Likert scale (1 = left-anchor quality; 5 = right-anchor quality). The anchor points represented opposite qualities for each Effort-Shape factor. Observers were instructed to think of the scale as a continuum rather than 5 discrete points on a scale. They were shown a bar with a gray-scale gradient from white on the left to black on the right. The gradient bar had five evenly spaced points from which they could select.

Measures. Scores for each item on the Effort-Shape questionnaire were used to characterize movement qualities. The Effort-Shape scores were treated as continuous variables since observers were asked to think of the scale as a continuum rather than 5 discrete points.

Data analysis. A linear mixed model with crossed random walker and observer effects was used to model means on the response variables (i.e., Effort-Shape scores) for each emotion. The model included fixed effects of walker gender, observer gender, walker age, observer age, video sequence, and observer group. Fixed effects were determined as significant if the absolute value of the t-ratio of the estimate to its standard error was greater than 2. To check for random observer effects, a likelihood ratio test was used to determine if the variance of the random observer effects was significantly greater than zero.

6.5.3 Results

Effect of HM. In general, wearing the head-mounted camera did not affect qualitative characteristics of body movements. 93% of all mean differences for the Effort-Shape scores between groups were 0.4 or less and 57% were 0.2 or less. The head-mount did, however, have statistically significant emotion-specific effects on limb shape and time qualities. For content and neutral emotions, the mean limb shape scores were 0.46 and 0.45 less in the HM group, shifting the limb shape quality towards "close to the body". For neutral emotion, the mean time score was 0.35 less in HM group shifting the time quality towards "slow, sustained, leisurely". Overall, all differences between groups were less than 0.5 on a five point scale but we do not know if this relatively small difference should be interpreted as a meaningful, expressive difference in movement quality.

Additional measures. While observer group and observer age did not have any significant emotion-specific effects for any of the Effort-Shape qualities, all other measures (i.e., sequence, walker gender, walker age, and observer gender) had at least one significant emotion specific effect for at least one of the Effort-Shape qualities. In these cases, mean differences were 0.30 or less ($t > 2$) with some differences as small as 0.08 ($t=2.099$). These differences were accounted for by including these measures in all our statistical analyses.

6.6 Part 4 – Kinematic analysis

The fourth aim was to determine whether wearing the head-mounted camera affected the quantitative aspects of body movement. Specifically, kinematic methods from biomechanics can be used to quantitatively describe body position and how it changes over time. The use of quantitative biomechanical methods to describe the complex, 3-dimensional characteristics of body movement have begun to be used in a small set of studies (Janssen et al., 2008; Ma, Paterson, & Pollick, 2006; Pollick et al., 2001; Sawada et al., 2003); yet, they have not been used in multimodal studies that require other modalities, such as facial expression, to be concurrently captured. Therefore, it must be determined whether wearing a head-mounted camera affects the quantitative aspects of expressive body movement before multimodal studies can use a head-mounted camera concurrently with motion capture technology to collect facial and bodily expression data. To do so, we tested whether there were significant differences in gait cycle descriptors or joint angular kinematics between HM groups.

6.6.1 Materials and procedure

Kinematic data. Motion capture data from trials selected for analysis were included in the kinematic analysis if the target emotion was both felt and recognized (138 of 210 trials; non-HM trials: n = 66, 50% female; HM trials: n = 72 trials, 49% female). One gait cycle (i.e., when the left heel strikes (toe-off) to the next left heel strike (toe-off)) was selected for analysis for each walking trial. Joint angles were calculated for the neck, trunk, shoulder, elbow, wrist, hip, knee, and ankle for each walking trial using C-Motion Visual 3D software package.

Measures. Gait cycle descriptors included cycle duration (time to complete a gait cycle), normalized stride length (distance traveled in one gait cycle normalized by walker height), and normalized gait velocity (meters / seconds, normalized by walker height). Joint angular kinematic measures included the mean angle and range of motion of each joint during the gait cycle.

Data analysis. A linear mixed model with random walker effects was used to model means on the response variables (i.e., gait cycle descriptors and joint angular kinematic measures) for each emotion. The model included fixed effects of emotion, group, walker gender, and the interaction between group – emotion. Fixed effects were determined as significant if the absolute value of the t-ratio of the estimate to its standard error was greater than 2. To check for significant interaction effects, a likelihood ratio test (LRT) was used; only significant interactions ($p > 0.05$) were included in the model.

6.6.2 Results

Gait cycle descriptors. Wearing the head-mounted camera did not affect any of the gait cycle descriptors nor were there any significant interaction effects between wearing the head-mount and emotion. However, the fixed effect of walker gender was significant for cycle duration ($t=2.699$) and there were significant differences among emotions (independent of head-mount) for cycle duration and normalized gait velocity.

Joint angular kinematics. Wearing the head-mounted camera affected elbow range of motion in anger and content. The elbow flexed 10.3 deg (22.6%) and 12.8 deg (32.3%) less in anger and content, respectively.

Significant gender effects were also observed for some angular measures. To understand these effects we ran a post hoc analysis to determine if there was an interaction between gender and wearing the head-mounted camera. The mean angle of shoulder flexion was reduced less in males (1.2 deg) than in females (10.2 deg) when wearing the HM. However, significant gender effects, independent of wearing the head-mounted camera, were also observed for the mean angles of elbow and hip flexion. Finally, there were significant differences among emotions (independent of head-mount) for most joint angular measures studied.

6.7 Discussion

This study validates the feasibility of collecting facial and bodily expression data concurrently using a head-mounted video camera and motion capture technology. We tested four aspects of emotion expression that could have been affected by wearing a head-mounted camera, including self-report of emotion, observer recognition of emotion, observer assessment of qualitative aspects of the walkers' body movements, and the quantitative aspects of body movements assessed with a kinematic analysis. We found that wearing a head-mounted camera did not affect emotion elicitation or recognition in regard to self-report and observer recognition of emotion.

Some aspects of the walkers' body movements, assessed either qualitatively or quantitatively, were slightly affected by wearing the head-mounted camera. The small differences in movement characteristics associated with wearing the HM are consistent with what might be expected from wearing such a device. The limb shape quality differences corresponded to joint angular differences, particularly in the shoulder and elbow. These results suggest that when wearing the head-mounted camera the walkers held their arms slightly closer to their torso (particularly in females) and they did not move as much at the elbow. This more constrained upper body position is consistent with what we might expect from walkers wearing an unfamiliar device on their head. We conclude that adding a warm up session to help the walkers become more comfortable wearing the head-mounted camera may mitigate these small effects. Additionally, with rapid advances in technology we can also expect that cameras will decrease in both size and weight, thereby reducing this effect.

Because the differences between the HM and non-HM groups were minimal in the emotion elicitation and recognition parts of this study, post-hoc power analyses suggest that we were underpowered. However, an unrealistic number of participants would be necessary to achieve 80% power with such small differences between groups. Additionally, the number of walkers included for the generation of expressive movement ($n = 42$) and the number of observers included in the recognition study ($n=60$) are at least as large as the number used in studies that assess recognition of expressive movement (Atkinson et al., 2004; Atkinson et al., 2007; Coulson, 2004; Pollick et al., 2001; Sawada et al., 2003; Wallbott, 1998). We conclude that the number of subjects was sufficient given the small differences between groups.

Overall, we recommend wearing the head-mounted camera as a valid method during concurrent collection of facial and bodily data. While we recognize that the head-mount may slightly constrain arm movement, the benefits to collecting quantitative multimodal data are significant enough that we recommend these methods for future multimodal analyses.

6.8 References

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Chapter 7

Effort-Shape Characteristics of Emotion-Related Body Movement

7.1 Abstract

The purpose of this study was to characterize the of movement style of five target emotions and assess whether individual movement style characteristics were associated with decoding accuracy. We used an autobiographical memories paradigm for elicitation, observer judgments of emotion for recognition, and Effort-Shape analyses for movement description. Observers were able to accurately decode the target emotions at levels greater than chance. Although the combination of movement characteristics for the six Effort-Shape qualities was unique for each target emotion, three general categories of movement style emerged. In addition, a specific range on the continuum for each Effort-Shape quality together with a specific combination of Effort-Shape characteristics may be important for recognizing emotions, particularly for positive emotions.

7.2 Introduction

It is well documented that expressive cues in body movement communicate emotion-related meaning (de Gelder, 2006; de Meijer, 1989; Dittrich, Troscianko, Lea, & Morgan, 1996; Montepare, Koff, Zaitchik, & Albert, 1999; Pollick, Paterson, Bruderlin, & Sanford, 2001). Despite the number of studies that have investigated this relationship, the coding systems used to characterize movement qualities associated with emotion have typically been unique to each individual study. As a result, the comparison, replication, and further exploration of results from individual studies are limited. Two studies have suggested that Effort-Shape analysis presents a promising alternative to study-dependent coding schemes (Gross, Crane, & Fredrickson, Submitted; Levy & Duke, 2003). While Effort-Shape analysis has strong potential as a valid, comprehensive, and standard method for characterizing expressive body movement, it has not yet been used to document the characteristic changes in body movement associated with specific emotions in a large number of encoders. Thus, the purpose of this study is to assess the whole body movement style characteristics associated with emotions using an Effort-Shape analysis to provide a comprehensive description of qualitative whole-body movement characteristics associated with emotions.

Effort and Shape are two components of Laban Movement Analysis (LMA), an existing and well-established system for describing body movement developed for choreography (Cecily Dell, 1977) (LMA). LMA is a comprehensive notation system made up of specific terminology and symbols for describing the body motions of individuals engaged in a variety of tasks (Laban & Ullmann, 1988). Just as music notation includes musical notes as well as symbolic instructions about how to play those notes, LMA notation includes information about specific body movements as well as instructions about how the movements should be performed. Thus, LMA allows documentation of the movement task along with descriptors of the movement style. Because the Effort-Shape components of LMA characterize the expressive style of the movement, they are ideal for qualitatively describing emotion-related expressive qualities in body movement. The shape component captures how the body changes shape during a movement task. Shape is divided into three subcategories: the form of the body itself (towards or away from the body center), the directional path in space (spoke or arc-like), and how the body shapes itself with respect to the environment (gathering or scattering). Effort is used to capture movement dynamics describing how exertion is concentrated during movement. Effort is divided into four subcategories: space (indirect or direct), energy (forceful or light), time (sustained or quick), and flow (bound or free). Another distinctive feature of Effort-Shape is that each category is defined as a continuum between two extremes.

An important distinction between Effort-Shape analysis and other behavioral coding methods is that Effort-Shape captures the movement quality in contrast to describing specific movements. Although previous systems have demonstrated changes in body movement that are associated with emotions (Montepare, Goldstein, & Clausen, 1987; Wallbott, 1998; Wallbott & Scherer, 1986), these systems tend to associate gesticulatory behaviors with specific emotions. Effort-Shape analysis provides a method for assessing bodily movement dynamics that reveal expressive movement style. Indeed, De Meijer (1989) incorporated qualities from the Effort component of LMA into a study that identified specific features associated with emotion-related attributions. Therefore, Effort-Shape analysis has strong potential as a comprehensive assessment tool for qualitatively describing expressive whole body movements associated with specific emotions.

Although Levy et al. (2003) examined the use of LMA in documenting expressive body movement related to anxiety and depression and De Meijer (1989) incorporated Effort features of LMA into analyses associated with emotion-related behavior, this system is still not used regularly in expressive body movement research. LMA typically requires certified movement analysts (CMA) to code the body movements, and the specialized training and certification necessary may be prohibitive for some studies. However, Gross et al. (Submitted) demonstrated that untrained observers could judge the Effort and Shape components of LMA with reasonable reliability in expressive body movements. In addition, their results suggested emotions might be associated with a unique Effort-Shape profile. Besides emotion-related profiles, the study provides further evidence that specific Effort-Shape qualities tend to be associated with an observers ability to accurately decode specific emotions. Therefore, in addition to CMAs, untrained observers can be used to qualitatively assess Effort and Shape movement style characteristics.

De Meijer's (1989) use of Effort qualities to choreograph emotion-related movements and Levy's (2003) use of a full scope of Effort-Shape qualities to evaluate movement characteristics provide examples of the potential value and range of uses of

Effort-Shape qualities. Gross et al. (Submitted) further demonstrated the exciting potential of assessing a single un-choreographed movement task using untrained observers to judge the Effort-Shape qualities displayed by each encoder. Together these studies open the possibility to study the effects of a range of emotion on whole body movement style.

The purpose of this study was to provide a comprehensive characterization of movement style using Effort-Shape analysis for five target emotions and to assess whether movement style characteristics were associated with observers' ability to accurately decode the emotion felt by the encoder. First, we describe the procedure used to elicit and assess felt emotion in 42 encoders. Second, we describe the study used to assess whether observers recognized the experienced emotion in an emotion portrayal. Third, trials that were considered both felt and recognized were included in the analysis to characterize the movement style qualities for each of the target emotions. Finally, we assessed whether specific emotion-related movement style characteristics were associated with decoding accuracy.

7.3 Methods

7.3.1 Emotion portrayals

The emotion portrayals in this study were generated in a previous study (Crane, Gross, & Fredrickson, Submitted). Briefly, fourty-two encoders (52% female; ages 18-32 years, mean = 20.1 $\pm$ 2.7 yrs.) were recruited from the University of Michigan undergraduate student population and gave informed consent before participating. The encoders were asked to walk while feeling an emotion. Side-view video was recorded while encoders walked approximately 5 meters at a self-selected pace.

An autobiographical memories paradigm (Labouvie-Vief, Lumley, Jain, & Heinze, 2003; Levenson, Cartensen, Friesen, & Ekman, 1991) was used to elicit the five target emotions, including two negative emotions (anger and sad), two positive emotions (joy and content), and neutral. The four negative/positive target emotions were chosen because they are balanced in terms of pleasantness and arousal. Neutral was included as a control and is referred to as a target emotion for the purpose of this study. To determine if the target emotion was felt, walkers completed a self-report questionnaire after each emotion portrayal to indicate the emotion(s) they felt while walking (Crane et al., Submitted). The questionnaire included the four negative/positive target emotions and four non-target emotions. Walkers rated the intensity that they felt each emotion using a 5-item Likert scale. An emotion was considered *felt* when the self-reported intensity score for the target emotion was greater than or equal to two ("moderately"). However, because an item for neutral was not included on the questionnaire, a neutral trial was considered felt if all eight items on the questionnaire were scored less than two.

The final set of emotion portrayals included 210 video clips (42 participants x 5 target emotions = 210 emotion portrayals). Of the 210 emotion portrayals, 191 (91%) were considered felt. For anger, joy, and sadness, 41 of 42 emotion portrayals (97.6%) were considered felt. For content, 40 (95.2%) were considered felt. For neutral, only 28 of 42 (66.7%) emotion portrayals were considered felt.

7.3.2 Decoding accuracy

The external validity of each emotion portrayal was examined by asking observers which emotion they thought the encoder experienced. We determined whether each of the target emotions was accurately decoded at levels greater than chance. In addition, factors affecting decoding accuracy were assessed. We hypothesized that if expressive style is sufficient for recognizing emotion, then observers using a forced-choice questionnaire would accurately choose the target emotion at levels greater than chance.

Decoding data were generated in the same study as the emotion portrayals (Crane et al., Submitted). Briefly, observer participants (n = 60, 48% female) ranged in age from 18-30 years (20.9 $\pm$ 2.7 yrs). They provided informed consent prior to beginning the study. No special skills were required. However, encoders were not permitted to participate as observers. To avoid observer fatigue, the 210 video clips of emotion portrayals were divided into two groups so that a single observer viewed no more than 110 emotion portrayals. Although not all emotion portrayals were considered felt, to ensure a balanced design in which an observer viewed a single encoder five times all 210 portrayals were included in this analysis. Observers were randomly assigned to one of two groups with 30 observers in each group. The video clips of the emotion portrayals were shown to each participant in one of three different randomized sequences. The encoders' faces were blurred in the side-view videos and each movement clip was looped three times. After viewing each emotion portrayal, observers selected one of 10 emotions that they thought the encoder experienced while walking. The forced-choice items included the same emotions as the self-report questionnaire used for the encoders, as well as neutral/no emotion and none of the above items.

The total number of judgments for each target emotion was 1260 (42 walkers x 30 judgments for each emotion portrayal). An emotion judgment was considered accurately decoded if the judged emotion agreed with the target emotion. To determine if each of the target emotions was accurately decoded at levels greater than chance, a logistic regression model was used to model the probability of recognized emotion using the technique of generalized estimating equations (GEE). GEE allows binary recognition outcomes from the same walker/emotion combinations to be correlated, which would be expected if a walker was effective at expressing an emotion. We calculated the predicted probabilities of decoding accuracy for each target emotion based on the model in addition to calculating a 95% confidence interval for each predicted emotion. The predicted probability of decoding accuracy was considered greater than chance if it was greater than .10 and the 95% confidence interval did not include .10. Chance was considered .10 because there were 10 questionnaire items. This *GENLIN* command is SPSS version 16 was used for this analysis.

Next, to determine whether decoding accuracy was affected by emotion, video sequence, observer group, a generalized linear mixed model was used to model the probability of the binary response variable (accurately decoded / inaccurately decoded) with a logit link. The model controlled for random effects of observers and walkers and fixed effects of observer and walker gender. Since emotion had the potential to interact with observer gender and/or walker gender, the analysis was repeated separately for each emotion. Fixed effects were determined as significant if the p-value was less than .05. To check for random walker and observer effects, likelihood ratio tests were used to determine if the variance of each random effect was significantly greater than zero. The *lmer* function in R version 2.5.0 was used for this analysis.

7.3.3 Emotion-related movement style characteristics

An Effort-Shape analysis (C. Dell, 1977; Gross et al., Submitted) was used to describe the movement style characteristics associated with each of the target emotions. The Effort-Shape data were generated in a pervious study (Crane et al., Submitted). Briefly, the same emotion portrayals for the social consensus procedures were used in the Effort-Shape analysis except that observers completed a six-item Effort-Shape questionnaire after viewing each emotion portrayal. Observer participants (n = 60, 52% female) ranged in age from 19-30 years (22.0 $\pm$ 2.6 yrs). No special skills were required. However, participants were excluded if they participated as a walker or in the social consensus study. Effort components were used to characterize movement dynamics describing how exertion was concentrated during movement, and shape components were used to characterize how the torso and limbs of the body changed form during the movement task.

Observers rated each Effort-Shape quality using a 5-item Likert scale (1 = left-anchor quality; 5 = right-anchor quality) with anchor points representing opposite qualities for each Effort-Shape factor (Table 20). Observers were instructed to think of the scale as a continuum rather than 5 discrete points on a scale. Observer judgments of the Effort-Shape qualities were used to characterize movement style.

Table 20. Anchor descriptions for Effort-Shape qualities.

1 = left-anchor	Effort Quality	5 = right-anchor
Indirect, wandering, diffuse	Space	Direct, focused, channeled
Light, delicate, buoyant	Energy	Strong, forceful, powerful
Sustained, leisurely, slow	Time	Sudden, hurried, fast
Free, relaxed, uncontrolled	Flow	Bound, tense, controlled
	Shape Quality	
Contracted, bowed, shrinking	Torso	Expanded, stretched, growing
Moves close to body, contracted	Limb	Moves away from body, expanded

To assess the validity of the Effort-Shape judgments, we determined whether observers' responses were due to chance and whether there was interobsever agreement. A chi-square test adjusted for clustering by observer (Jann 2008) was performed separately for each Effort-Shape quality for each target emotion. We tested the null hypothesis that the distribution of Effort-Shape responses was uniform, which would be expected if observers responded by random chance. The *MGOF* command (Jann, 2008) was used in Stata version 10. Observer ratings of Effort-Shape qualities were not due to chance. To assess reliability, the interobserver agreement rate was calculated using Cronbach's alpha for each Effort-Shape quality. Reliability of Effort-Shape scores was good; the average Cronbach's alpha across qualities was .93. Scores for individual qualities ranged from a high of .98 for time and a low of .86 for flow.

To characterize the movement style associated with each target emotion, a mean for each Effort-Shape quality was calculated for each emotion. Individual observer judgments of the Effort-Shape qualities were included in the calculation of the mean score if the emotion portrayal was felt by walkers and recognized by observers. A *recognized* emotion portrayal was defined as an emotion portrayal in which the proportion of accurately decoded judgments from the social consensus study was greater than chance (.10), the assumption being that if observers recognize the target emotion in a portrayal, a signal that represents the target emotion was observed in the portrayal. Based on the mean score, a movement style characteristic was assigned. Because the Likert scale ranged from one to five, the authors interpreted a mean greater than three as tending toward the right anchor characteristic and a mean less than three as tending toward the left anchor characteristic. Therefore, left or right anchor characteristics were assigned depending on which anchor the mean tended toward. For example, a mean greater than 3 for the torso quality was assigned the right anchor characteristic for torso shape (expanded, stretched, growing). If the mean score was $3 \pm .1$, it was not interpreted as tending toward either anchor. The degree to which an individual Effort-Shape quality tended toward and anchor for an emotion was assessed using a linear regression analysis with post-hoc pairwise comparisons.

We also determined whether video sequence, observer group, individual walkers, or individual observers affected judgements of movement style characteristics. A linear mixed model was used to model means on the response variables (i.e., Effort-Shape judgments) for each Effort-Shape quality. The model included fixed effects of emotion, walker gender, observer gender, video sequence, and observer group, and crossed random effects of walker and observer. Likelihood ratio tests using the method of Maximum Likelihood were used to assess whether each of the effects was significant. A full model including all of the effects was compared to a reduced model in which a single effect was removed. Effects were determined to be significant if the p-value was less than .05. Post-hoc pairwise comparisons of the means using a Tukey HSD adjustment were examined to determine what the differences were between emotions. The *lmer* function in R version 2.5.0 was used for this analysis.

A similar data analysis procedure was used to assess whether observer gender or walker gender affected judgements of Effort-Shape qualities. However, because these effects had the potential to interact with emotion, the analysis was performed for each Effort-Shape quality for each emotion. Therefore, the model included fixed effects of walker gender and observer gender, as well as random effects of walker and observer.

7.3.4 Movement style qualities associated with decoding accuracy

Based on the movement style qualities that emerged for each emotion, we determined whether each of the qualities was important for observer recognition of the target emotion. We predicted that emotion portrayals that displayed the emotion-specific movement characteristics would be associated with high decoding accuracy and those that did not display the characteristics would be associated with low decoding accuracy. To test this, we first calculated a mean score for each Effort-Shape quality for each emotion portrayal (recall that there are 30 observer responses for each emotion portrayal). Next, we determined whether there was a significant correlation between the overall decoding accuracy of an emotion portrayal (i.e. recognition) and the mean Effort-Shape score associated with the portrayal by calculating Pearson correlation coefficients for each Effort-Shape quality for each target emotion.

7.4 Results

7.4.1 Decoding accuracy

Overall, observers accurately decoded target emotions at levels greater than chance (Figure 6). The proportion of accurate observations was highest for sadness (.43) followed by neutral (.25), joy (.24), and anger and content (.23). Decoding accuracy was not affected by walker gender, observer gender, video sequence, or observer group for any emotion. However, for all emotions the variance of the random observer effect was significantly greater than zero. This indicates that some observers were better than others at accurately decoding emotion from body movement. Investigation of the observer effect is beyond the scope of this study but including observers in the statistical models controlled for this effect.

Some walkers communicated specific emotions more effectively than other walkers, thereby affecting decoding accuracy. For all emotions, the variance of the random walker effect was significantly greater than zero, indicating that individual walkers differed with respect to observer ability to accurately decode the emotion. Further investigation of this effect revealed considerable variability in the proportion of accurately decoded judgements for individual walkers. The proportion of judgements accurately decoded ranged for an individual encoder from a low of 0 for each of the emotions to a high of .93, .73, and .67 for sadness, anger, and joy, respectively, and .53 for both neutral and content (Figure 6). Of the 210 emotion portrayals, 152 (72%) were considered recognized. The percent of emotion portrayals considered recognized was highest for neutral (83%) followed by sadness (76%) and content (74%), joy (67%), and anger (62%). Additionally, 138 (66%) of the emotion portrayals were considered both felt and recognized (Table 21).

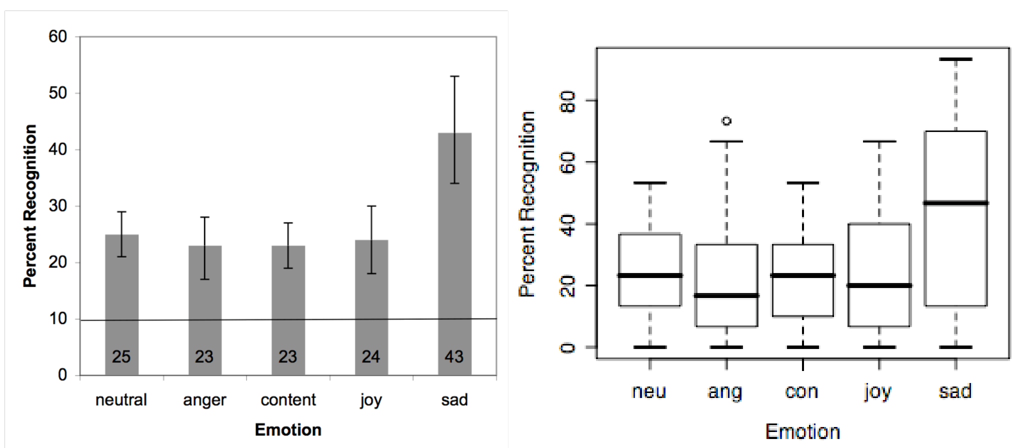

Figure 6. Proportion of emotion portrayals accurately decoded (left) and range of accurate recognition rates (right).

Table 21. Number of emotion portrayals considered felt by walkers, recognized by observers, and both felt and recognized.

	Target Emotion				
	Anger	Joy	Sad	Content	Neutral
Felt	41	41	41	40	28
Recognized	26	28	32	31	35
Felt & Recognized	26	28	32	29	23

Note. The total number of portrayals for each emotion is 42.

7.4.2 Emotion-related movement style characteristics

Mean Effort-Shape scores were calculated for each target emotion based on the observer judgments corresponding to the 138 felt and recognized emotion-portrayals (Table 22). Based on the mean scores for the Effort-Shape qualities, three general movement styles emerged (Table 23). The high arousal emotions, anger and joy, shared the same characteristics for five of the six Effort-Shape qualities: torso, limb, space, energy, and time. Content and neutral were judged as having the same characteristics for four of the six Effort-Shape qualities: torso, limb, time, and flow. The movement style characteristics for the low arousal emotion sadness contrasted with all target emotions for each Effort-Shape quality. Therefore, descriptions of the emotion-related movement style characteristics will be described in these groups.

Table 22. Means for recognized portrayals for each target emotion.

	Target Emotions				
Quality	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Torso	3.3	3.6	2.5	3.3	3.2
Limb	3.5	3.6	2.4	3.0	2.9
Space	3.9	3.7	2.4	3.2	3.0
Energy	3.7	3.3	2.5	2.9	2.8
Time	3.7	3.6	1.9	2.7	2.5
Flow	3.5	3.1	2.7	2.8	2.8

Table 23. Movement style characteristics for each emotion.

Quality	Target Emotions				
	Anger	Joy	Sad	Content	Neutral
Torso	Expanded, stretched, growing	Expanded, stretched, growing	Contracted, bowed, shrinking	Expanded, stretched, growing	Expanded, stretched, growing
Limb	Moves away from body, expanded	Moves away from body, expanded	Moves close to body, contracted	Neither contracted nor expanded	Neither contracted nor expanded
Space	Direct, focused, channeled	Direct, focused, channeled	Indirect, wandering, diffuse	Direct, focused, channeled	Neither indirect nor direct
Energy	Strong, forceful, powerful	Strong, forceful, powerful	Light, delicate, buoyant	Neither strong nor light	Light, delicate, buoyant
Time	Sudden, hurried, fast	Sudden, hurried, fast	Sustained, leisurely, slow	Sustained, leisurely, slow	Sustained, leisurely, slow
Flow	Bound, tense, controlled	Neither free nor bound	Free, relaxed, uncontrolled	Free, relaxed, uncontrolled	Free, relaxed, uncontrolled

Anger and joy tended toward the right anchor of the scale for all Effort-Shape qualities except flow, for which anger tended toward the right anchor quality and joy did not tend toward either anchor. For both anger and joy, the torso was expanded, the limbs moved away from the body, the walker moved directly through space with strong energy, and the movement timing tended to be sudden or fast.

Content tended toward the same anchors as neutral with a few exceptions: neutral did not tend toward either anchor for space, and content did not tend toward either anchor for energy. For both neutral and content, the torso shape was expanded, the limbs were considered neither contracted nor expanded, the movement timing was sustained and leisurely, and the flow tended to be free and relaxed.

Sad was characterized by very different Effort-Shape characteristics than the other target emotions. Overall, sad had a contracted torso shape; the limbs moved close to the body; movement through space was indirect, wandering, and diffuse with light energy; the timing of movements was slow; and movements were considered free, relaxed, and uncontrolled.

Although individual Effort-Shape qualities tended toward the same anchor for two or more emotions, the degree to which the quality tended toward an anchor was different among emotion. For example, the mean torso shape scores for anger, content, joy, and neutral were all greater than three suggesting that torso shape was expanded for all four of the emotions. However, the mean score for each emotion reveals that the mean was the highest for joy (3.6), the same for anger and content (3.3), and the lowest for neutral (3.2). To identify whether mean scores for an Effort-Shape quality were different, post-hoc pairwise comparisons of the means were examined.

Although anger and joy both tended toward the right anchor of the scale for most Effort-Shape qualities, there were significant differences between the mean scores for the torso, space, energy and flow qualities (Table 24). Observers judged joy as having a more expanded torso than anger, while anger was judged as having a more direct use of space and a stronger energy than joy. Additionally, the tendency for anger to be judged as bound, tense, and controlled was significantly greater than for joy, which was judged as not tending toward either anchor. Therefore, despite tending toward the same anchor for most of the Effort-Shape qualities, there were significant differences between anger and joy related to the degree to which they tend toward the same anchor.

Table 24. Significant differences between target emotion Effort-Shape mean scores.

				Target Emotions				
Quality	**Chisq**	***df***	***p***	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Torso	500.45	4	< .001	Joy		Anger Content Joy Neutral	Joy	Anger** Joy
Limb	530.12	4	< .001			Anger Content Joy Neutral	Anger Joy	Anger Content* Joy
Space	813.03	4	< .001		Anger	Anger Content Joy Neutral	Anger Joy	Anger Content** Joy
Energy	574.93	4	< .001		Anger	Anger Content Joy Neutral	Anger Joy	Anger Joy
Time	1598.5	4	< .001			Anger Content Joy Neutral	Anger Joy	Anger Content** Joy
Flow	200.54	4	< .001		Anger	Anger Joy	Anger Joy**	Anger Joy

Note. Emotions listed in the table had means that were significantly greater than emotion in the column header. Unless otherwise noted, $p < .001$ for all significant pairwise comparisons.
* $p < .05$, ** $p < .01$

Interestingly, there were significant differences between judged styles for content and neutral for the limb, space, and time qualities. Walkers experiencing contentment had limb movements that tended to be more away from the body, they moved more directly through space, and were characterized as being faster than those experiencing neutral / no emotion.

The movement style characteristics for walkers experiencing sadness were significantly different than for the other target emotions with the exception of flow, which was only different from anger and joy. However, for all significant differences, the means for encoders experiencing sadness were less than the means for the other target emotions. Thus, the Effort-Shape means for sadness were significantly different regardless of arousal or pleasantness. Interestingly, sadness was only different from the high arousal emotions (joy and anger) for flow.

The positive emotions differed with respect to every Effort-Shape quality. Therefore, when walkers experienced joy, their torsos were more expanded, their limbs moved more away from their bodies, they moved more directly through space with a stronger energy and faster movements, and they were less free and relaxed than walkers experiencing contentment.

Judgements of the Effort-Shape qualities were affected by walker gender for some emotions. Therefore, we investigated this further to determine whether males and females displayed different characteristics for the six Effort-Shape qualities (i.e., tending towards different anchors on the Effort-Shape scale) or whether they tended to display the same characteristics yet had significantly different mean Effort-Shape scores. When experiencing anger, the mean scores for torso shape and space were .3 and .5 greater for females than males, respectively. Therefore, while the movement style associated with anger for both genders was characterized with an expanded torso shape and moving directly though space, females were judged as having a more expanded torso and moving more directly through the space than males. While joy was generally characterized as having strong energy and as neither free nor bound, further analysis showed that the energy and flow characteristics were .4 greater for females than males. When experiencing joy, males neither displayed a strong nor light energy (3.1). In addition, males were judged as relaxed (2.8). In contrast, females were judged as having a strong energy (3.5) and tended to be bound, tense, and controlled (3.2). When experiencing sadness, females were judged as moving their limbs close to the body or having a contracted limb shape (2.3). Although males also displayed this characteristic (2.5), it was more pronounced in females. When experiencing no emotion / neutral, females were judged as moving directly through space (3.2) while males neither moved directly nor indirectly through space (2.9). Additionally, for flow, females were judged as neither free nor bound (2.9) while males were judged as free and relaxed (2.6). Together, these results indicate that females tend more toward the anchor qualities than males.

Finally, observer gender, video sequence, and observer group did not affect movement quality judgments for any of the Effort-Shape qualities. However, for all Effort-Shape qualities the variances of the random walker and observer effects were significant ($p < .001$ for all qualities for both encoders and observers). Thus, walkers tended to have individual movement styles and observers differed in their assessment of the target emotions. Therefore, these effects were controlled for in the statistical models.

7.4.3 Effort-Shape characteristics associated with decoding accuracy

In the final analysis, we assessed whether characteristics of the Effort-Shape qualities were associated with decoding accuracy. Overall, movement style characteristics were moderately to highly correlated with recognition for most emotions **(Table 25).** Interestingly, the negative emotions had the greatest number of Effort-Shape qualities that were significantly correlated with decoding accuracy, and correlations were the strongest. The direction of the correlations for these two emotions were consistent with the expected relationships. For example, for sad, low mean Effort-Shape scores (i.e., the left anchor qualities) corresponded to high recognition rates. Conversely, for anger, high mean Effort-Shape scores (i.e., the right anchor qualities) corresponded to high recognition rates.

Table 25. Pearson correlation coefficients between Effort-Shape qualities and recognition rate for the target emotions.

	Emotions				
Quality	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Torso		.44	-.87		.33
Limb	.39	.41	-.52		
Space	.60	.31	-.91		.58
Energy	.74		-.78		.44
Time	.74	.35	-.82		.39
Flow	.66		-.51	-.31	.31

Note: N = 42 for all correlations.

The high-arousal positive emotion, joy, was consistent with the expected correlations: for all Effort-Shape qualities except limb and flow high mean scores (right anchor qualities) moderately corresponded to high recognition rates. In contrast to joy, mean Effort-Shape scores for the low-arousal positive emotion content correlated with only one Effort-Shape quality, flow. Further, the correlation was negative indicating low mean scores (left anchor quality) corresponded to high recognition rates.

For the negative emotions anger and sadness, the high and low recognition groups had means that tended toward opposite ends of the Effort-Shape scale. However, a general trend for the positive emotions did not emerge. For joy, the mean scores for the high and low recognition groups both tended toward the right anchor; thus, the movement characterizations for both groups were the same. Although the means for torso, limb, and time all tended toward the same anchor, there were significant differences between the means for the low and high recognition groups.

For the low-arousal positive emotion, content, the only significant difference between the two recognition groups was for flow. This would suggest that the only indicator of content is the Effort-Shape quality flow. However, descriptive statistics of the two groups for each Effort-Shape quality for content revealed an interesting effect:

for all Effort-Shape qualities, emotion portrayals associated with high decoding accuracy had less variability in the mean scores compared to the low recognition group (Table 26). Therefore, for content, a small range of means tended to be associated with high recognition while there was no apparent trend associated with the low recognition emotion portrayals.

Table 26. Interquartile ranges of the mean Effort-Shape scores for recognition groups for the target emotion content.

	IQR of Recognition group	
Quality	Low	High
Torso	1.1	.6
Limb	1.4	.5
Space	1.5	.5
Energy	1.4	.4
Time	2.5	.5
Flow	1.1	.5

With respect to neutral, five of the six Effort-Shape qualities were significantly correlated to recognition. Energy, time, and flow, however, were inconsistent with the hypothesized relationship between mean scores and high recognition. We expected correlations would be negative since the Effort-Shape qualities tended towards the left anchor qualities. However, the moderate yet positive significant correlations suggested that high mean scores correspond to high recognition rates. One possible explanation for the inconsistent relationships with our predicted relationships is that although the mean scores that correspond to high recognition are greater than the mean scores that correspond to low recognition, both mean scores tend toward the left anchor qualities on the Effort-Shape scale. This would indicate that exaggerating a specific tendency toward an anchor quality reduces recognition for neutral.

To investigate the relationship between decoding accuracy and movement style characteristics for neutral, we identified the emotion portrayals that were in the top and bottom quartiles for percent recognition for each emotion. A paired t-test was used to compare means between the high and low recognition groups for each Effort-Shape quality for each emotion (Table 27). This analysis indicates whether means for the two groups tend toward the same anchor, and assesses whether emotion portrayals with low decoding accuracy generally have qualities tending toward the opposite anchor compared to the group with high decoding accuracy. Indeed, for neutral, the Effort-Shape qualities energy, time, and flow tend toward the left anchor for both the high and low recognition groups. However, the low recognition group is significantly less than the high recognition group. This indicates that going too far toward an anchor reduces an observer's ability to accurately decode neutral / no emotion.

Table 27. Effort-Shape means for the top and bottom quartiles for the target emotions.

	Emotions									
	Anger		Joy		Sad		Content		Neutral	
	Low	High	Low	High	Low	High	Low	High	Low	High
Torso	3.0	3.1	3.1	3.7^{**}	3.3	2.0^{***}	3.0	3.4	2.8	3.2^{A}
Limb	3.0	3.6^{A}	3.2	3.9^{*}	3.1	2.3^{**}	3.0	3.2	2.6	3.2^{*}
Space	3.1	4.0^{***}	3.3	3.8	3.5	1.9^{***}	3.2	3.1	2.7	3.3^{***}
Energy	2.9	3.9^{***}	3.2	3.4	3.1	2.2^{***}	3.1	2.9	2.6	2.9^{*}
Time	2.7	4.0^{***}	3.1	3.8^{A}	3.0	1.5^{***}	3.0	2.5	2.3	2.8^{*}
Flow	2.8	3.7^{***}	3.0	3.0	3.0	2.4^{***}	3.1	2.6^{*}	2.7	2.9^{A}

^{A} $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

7.5 Discussion

The primary goal of this study was to characterize emotion-related movement styles for five target emotions. To accomplish this goal, we first evaluated the external validity of the emotion portrayals by assessing whether observers could accurately decode the target emotion in the portrayals that were used to characterize the movement styles. Second, we used an Effort-Shape analysis to characterize the movement style of each target emotion and third, we assessed whether characteristics differed between emotions. Finally, we investigated whether specific characteristics were associated with decoding accuracy. Together, the results of these analyses demonstrated that emotion affected movement style and that emotions may be more accurately described with a specific combination of Effort-Shape characteristics than any single quality.

Although the overall combination of movement characteristics for the six Effort-Shape qualities was unique for each target emotion, three general movement styles emerged. The first movement style was associated with the high arousal emotions anger and joy. These emotions were both judged by observers as having an expanded, stretched, and growing torso shape; limbs moved away from the body; movement through space was direct, focused, and channeled with strong, forceful, and powerful energy; and the timing of movements was sudden, hurried, and fast. The second movement style was shared by content and neutral and was judged as having an expanded, stretched, and growing torso shape; limbs moved neither close to nor away from the body and were neither contracted nor expanded; movement flow was free and relaxed; and movement timing was sustained and leisurely. The third movement style included only the low arousal emotion sadness. Sad movements were judged as having a contracted torso shape; limbs moved close to the body; movement through space was indirect, wandering, and diffuse with a light energy; the timing of movements was slow; and movements were considered free, relaxed, and uncontrolled.

The Effort-Shape characteristics for anger, joy, content, and sad that were found for the walking task were generally similar to the characteristics observed during a knocking task (Gross et al., Submitted). There were three exceptions. First, when experiencing sadness, walking was characterized as moving their limbs close to the body while the limb quality could be characterized as neither close to or away from the body during knocking. Second, when experiencing contentment, walking was characterized as having limbs that were neither contracted nor expanded and neither a strong nor light energy. However, during a knocking task the limbs were characterized as moving away from the body and as having a light, buoyant energy. Although the differences observed between tasks for the limb shape quality could be an artifact of the task (i.e. the necessary outward motion of the arm to produce the knocking movement), the general trend between the emotions was still consistent. For example, the high arousal emotions anger and joy displayed a greater amount of limb expansion compared to content and finally sadness, which was considered not tending toward either anchor during knocking and close to the body during walking. Additionally, the present study confirms the finding from the knocking analysis that emotions are associated with a unique set of Effort-Shape qualities. Together, despite the different movement tasks, the consistency of the results provides some of the first evidence that differences in movement style characteristics can be directly attributed to the experienced emotion rather than the movement task. Therefore, although previous studies suggest specific behaviors are associated with emotions, our findings additionally suggest that specific movement styles are associated with emotions.

In this study, Effort-Shape qualities were judged relatively consistently with respect to each of the emotions. For example, while some walkers had a more expanded torso shape than other walkers for joy, the amount of judged torso shape expansion tended to be in a small range on the Effort-Shape continuum. Additionally, similar characterizations yet significant differences in mean Effort-Shape scores were found between emotions. For example, although anger, joy, content, and neutral were all judged as having an expanded torso shape, there were significant differences in the amount of expansion between anger and content, joy and content, as well as neutral compared to anger and joy. Because of the large sample of encoders included in this analysis and measures taken to statistically account for encoder effects, significant differences in movement style characteristics could be attributed to emotion differences rather than encoder differences. Taken together, the similarity of judged characteristics with the differences in mean scores between emotions suggests that there may be a specific range on the continuum for each Effort-Shape quality that is associated with each target emotion.

Further support for the idea is provided by our data showing that moving out of a specific range on the continuum, or perhaps exaggerating a specific characteristic, reduces decoding accuracy. This is consistent with Wallbott and Scherer's (1986) finding that exaggerated movements tended to be associated with low recognition. Indeed, in our study, our expected relationships for neutral between the mean Effort-Shape scores and percent recognition were inconsistent with the actual relationships for energy, time, and flow. By comparing the mean scores of these Effort-Shape qualities for the emotion portrayals with high recognition compared to low recognition, we found that all of the mean scores tended toward the left anchor (i.e., all mean scores were less than 3). However, the low recognition group tended more toward the left anchor than the high recognition group. In our analysis, this effect was only observed for the target no emotion / neutral. Interestingly, compared to the other target emotions in this study, neutral had the highest percentage of trials that were considered not felt. For neutral, this indicates that they may have felt another emotion. Indeed, if an emotion were felt strongly enough or if an encoder was attempting to "act" neutral, movement patterns may change. The authors expect that for the other target emotions, if more trials were available that were feigned emotion or not felt, a similar effect to the one observed in neutral might have occured. Overall, this provides further evidence that there may be a specific range on the Effort-Shape continuum associated with emotion expression and also high decoding accuracy.

Evidence from the correlation analysis also suggests that decoding accuracy may be more associated with a combination of Effort-Shape characteristics than with any one Effort-Shape quality characteristic. The combination of Effort-Shape characteristics may be particularly important for recognizing positive emotions. Indeed, the negative emotions had the greatest number of individual Effort-Shape qualities correlated with decoding accuracy, and the correlations were generally stronger than those observed for the positive emotions or neutral. Thus, a specific range on the continuum for each Effort-

Shape quality together with a specific combination of Effort-Shape characteristics may be important for recognizing emotions, particularly for positive emotions.

Contentment was particularly revealing with respect to this observation. Although observers recognized contentment in the emotion portrayals and there were significant differences in the mean Effort-Shape qualities between content and other target emotions, only one Effort-Shape factor, flow, was correlated with decoding accuracy for this emotion, and the correlation was low. One possibility for the lack of significant correlations is that our Effort-Shape factors did not capture the qualities used by observers to identify contentment in walking. However, given that there were significant differences in Effort-Shape characteristics between content and the other target emotions, failure to capture observable qualities of contentment seems unlikely. Investigation of the range of scores for emotion portrayals associated with high recognition compared to the range of scores associated with low recognition revealed that there was a small range of scores associated with the high recognition group. In contrast, there was a large range of scores associated with the low recognition group. Therefore, the scores associated with high recognition were also associated with low recognition. This provides further support for the hypothesis that not only is there a small range of scores associated with high recognition, but that observers may also be responding to a specific combination of Effort-Shape characteristics.

Interestingly, there were gender differences related to how emotions were encoded by male and female walkers. This was surprising given that with respect to decoding accuracy, there was no difference between male and female observers, and additionally, there was no difference between how male and female observers judged the movement style qualities. Investigation of the gender effect suggested that, in general, female walkers were judged as tending toward the anchor quality more than the male walkers. The results also showed that emotion characterizations for each gender were the same as the overall characterization with the genders combined. The movement style difference between male and female encoders may be explained by one of two possibilities. First, these results may be interpreted as females being more expressive than males. However, there may have been a judging bias common across all observers. Thus, even if males and females are equally expressive, males may be judged as less expressive. Further investigation using objective and quantitative data, such as motion capture, are needed and may reveal whether the expressive movements of males and females are the same.

In addition to gender effects related to encoders, this study confirmed suggestions from previous studies that individuals differ in their encoding ability (Wallbott and Scherer 1986, Montepare et al. 1987, Gross et al, submitted). First, all target emotions had at least one walker for which not one observer accurately identified the target emotion. Second, all target emotions had one or more walkers communicate the emotion at a level greater than the average decoding accuracy for the specific target emotion. Finally, many individual walkers were able to communicate some but not all of the target emotions.

Although the emotion-related characteristics identified in this study are consistent with results from previous studies, the analysis should be repeated with different movement tasks. By repeating the analysis with different tasks, it might be possible to determine whether emotion-related movement qualities are task specific or if general features of movement styles are associated with specific emotions. Further, there may be more than one way to express the same emotion. Thus, more encoders are needed to identify these styles and to determine characteristics associated with different levels of recognition.

Overall, our results provide evidence for emotion-specific movement patterns that can be observed and characterized based on six Effort-Shape qualities. A principal contribution of this study was demonstrating emotion-related changes in movement style using a single movement task. Thus, differences in movement style characteristics could be attributed to the experienced emotion rather than the movement task. Additionally, specific movement style characteristics are associated with decoding accuracy.

Future analyses are needed to identify whether decoding accuracy is correlated with a specific combination of Effort-Shape qualities and to identify the range of scores for each Effort-Shape quality associated with decoding accuracy. Once the combined Effort-Shape characteristics and range of values for the specific characteristics have been identified, hypotheses about the movement style associated with each target emotion can be tested. For example, the small range of scores associated with decoding accuracy suggests that there may be specific emotion-related movement patterns. While the observed-based analysis could provide further information about emotion-related movement patterns, observer-based methods are not sufficient for developing quantitative models of expressive behavior. Thus, additional quantitative methods should be used to capture and assess motion data associated with specific emotion.

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Chapter 8

Kinematic Characteristics of Emotion-Related Body Movement

8.1 Abstract

The purpose of this study was to describe emotion-related posture and movement for the whole body using objective quantitative motion data. Joint angular kinematics commonly used in biomechanics were used to describe the position and range of motion of the limbs and torso during walking. Whole body motion data were collected from participants that experienced a range of emotions. Thus, this study used objective kinematic measures to quantify emotion-related body movement and to determine whether specific measures were associated with emotion recognition. This study demonstrated that quantifiable differences in joint kinematics exist between specific emotions, and these kinematic differences can be used to objectively characterize emotion-related body movements.

8.2 Introduction

Body posture and movement provide important nonverbal cues about a person's affective state. Further, research has established that emotion-related behavioral characteristics exist (Pollick, Paterson, Bruderlin, & Sanford, 2001; Wallbott, 1998), and these characteristics are effectively used by observers to decode what a person is feeling (Dahl, 2007; de Meijer, 1989; Sawada, Suda, & Ishii, 2003; Wallbott & Scherer, 1986). Despite significant findings demonstrating a relationship between body movement and emotion, these studies cannot give precise descriptions of how the quality is expressed.

Therefore, while qualitative methods have provided insight into behaviors and movement qualities associated with emotions, they are not sufficient for building comprehensive quantitative models of emotionally expressive behavior.

An alternative to qualitative characterizations of whole-body expressive movement would be using objective and quantitative kinematic methods. Such methods are used extensively in a variety of movement-based environments to describe temporal changes in body position within three-dimensional space (Cappozzo, Della Croce, Leardini, & Chiari, 2005; Davis, 'unpuu, Tyburski, & Gage, 1991; Holzreiter & Kohle, 1993; Toro, Nester, & Farren, 2007). Typically, these measures are obtained directly from the precise 3D marker coordinates of external skin markers recorded via state of the art motion capture methods (Capozzo et al., 2005). Data generated using these methods have contributed extensively to improved animation techniques of virtual humans and animated characters (Gaojin, Zhaoqi, Shihong, & Dengming, 2006) as well as clinical studies examining injury causing and/or pathological movement behaviors (Daly, Sng, Roenigk, Fredrickson, & Dohring, 2007; Kreulen, Smeulders, Veeger, & Hage, 2007; Toro et al., 2007). Using similar methods, the current study aims to accurately quantify and thus characterize and compare whole-body kinematics behaviors elicited during walking among a variety of emotions.

In the last decade, a handful of studies have moved towards an objective approach. Coulson (2004) and Kleinsmith, De Silva, & Bianchi-Berthouze (2006) both assessed the perception of static body postures using computer generated encoders. The advantage of using computerized encoders is that the position of individual joints in the body can be defined. Thus, the specific and objective quantitative description of the figure is available. Coulson (2004) generated computerized encoders to assess quantitative characteristics of body position by specifying the positions for head bend, chest bend, abdomen twist, shoulder swing, shoulder abduction and adduction, and elbow bend. Body postures were judged by observers and classified as one of six emotions, among them anger, sadness, and a general category for positive emotions referred to as happiness. Because the precise position of the angles investigated were known, emotions could be compared and described in terms of joint angular position. In a related study, Kleinsmith et al. (2006) also positioned the joints of a computerized encoder. Based on quantitative measurements of the postures, their analysis suggested that emotions can be discriminated into specific affective categories based on postural configuration measurements independent of subjective observer judgments. Together, these two studies suggest precise objective descriptions of emotion-related body movement are possible. Additionally, the use of quantitative measures offers that advantage that no subjective interpretation is needed to reproduce figures representing the specific emotions.

While these studies indeed highlight the potential for empirical assessment of emotion-related movement, the quantitative measures were generated using computer simulation rather than actual human encoders. Therefore, although observers and statistical discriminate procedures were able to categorize the body postures as specific emotions, it still is not known whether the joint positions of the figure accurately represent the effects of emotion on human generated body movement. Studies by Sawada (2003) and Pollick et al. (2001) were two of the first studies to overcome this limitation by using modern motion capture techniques to assess the effect of emotion on body movement qualities. These studies used kinematic methods to assess emotion-related movement characteristics. However, their studies were limited to assessing the kinematics of single joints or segments (e.g., the arm) and they did not provide any information on postural variables. Since it is has been observed that emotion affects body posture as well as limb movement (de Meijer, 1989; Sawada et al., 2003; Wallbott, 1998), it is important for studies to describe the effects of emotion on whole-body kinematics. Therefore, although these studies demonstrate the potential of using precise kinematic measures to quantitatively assess emotion-related movement, they are both limited because they are both limited to arm movement.

Besides the advantage of precise movement descriptions, quantitative methods remove subjectivity that is inherent in observer-based methods. Therefore, differences in specific movement responses can be more directly attributed to an explicit underlying factor rather than potentially confounding factors related to the observer (e.g., interpretation of context, observer mood, or interpretation of movement quality). For example, an observer-based qualitative analysis by Crane & Gross (In Preparation) suggests that females tend to be more expressive than males. While this may indeed be the case, the underlying observer-based method made it impossible to determine whether the effects were in fact sex-based or simply due to an overall bias in how we perceive expressive movement of males and females. Thus, quantitative methods offer the advantage of providing a consistent, objective, and study independent way to describe the behavior.

While previous studies on emotion-related body movement may not in isolation provide the necessary information to precisely and comprehensively characterize bodily expression, their outcomes can guide the design of more targeted quantitative studies. First, simultaneous torso and limb movements must be recorded and quantified for a comprehensive description of the whole body. Second, results of the previous studies indicate that assessing the general position of body (joint angular positions) (Coulson, 2004) as well as dynamic cues such as the range through which the joint moves (range of motion) (Gross, Crane, & Fredrickson, Submitted; Montepare, Goldstein, & Clausen, 1987) are a logical place to begin exploring whole body kinematics.

The primary purpose of this study was to describe emotion-related whole body movement using quantitative motion data. Additionally, we tested whether the quantitative measures differed among emotions. Joint angular kinematics commonly used in biomechanics will be used to describe the position and range of motion of the limbs and torso. Thus, this study used objective kinematic measures for quantifying emotion-related body movement and to determine whether specific measures were associated with emotion recognition.

8.3 Methods

The movement trials and emotion elicitation and recognition data used in this study were generated in a previous study (Crane et al., submitted). This section describes the methods used in that study 1) to capture motion data while participants experienced each of five target emotions, 2) to evaluate whether encoders experienced the target emotions while moving, and 3) to determine whether observers were able to accurately decode the target emotions in the emotion portrayals.

8.3.1 Data acquisition

8.3.1.1 Emotion elicitation and motion capture

Encoders (n = 42, 52% female) were recruited from the University of Michigan undergraduate student population. Ages ranged from 18-32 years (20.1 $\pm$ 2.7 yrs.). All participants were able-bodied and no special skills were required. Prior to data collection, participants reviewed a description of the study and signed a consent form approved by the Institutional Review Board (IRB).

Upon arrival, the participants were informed that the study was about the expression of emotion and that video and motion capture data would be recorded during walking. They were informed that their faces would be blurred in the whole-body videos and these videos would be shown to peers in another study.

An autobiographical memories paradigm (Labouvie-Vief, Lumley, Jain, & Heinze, 2003; Levenson, Carstensen, Friesen, & Ekman, 1991) was used to elicit emotions in participants. Participants were given as much time as needed to complete an autobiographical memories worksheet. They were informed that the worksheet was for their use only, to help feel emotions, and would remain confidential. On the worksheet, participants were asked to describe times in their own life when they felt two negative emotions (angry and sad), two positive emotions (content and joyful), and neutral emotion. The four negative/positive target emotions were chosen because they are balanced in terms of pleasantness and arousal (Russell, 1980). Neutral was included as a control and is referred to as a target emotion for the purpose of this study. Using only a few words, they were asked to indicate a) where they were, b) who they were with, and c) what caused the feeling/what was it about? For example, to elicit sadness, participants were asked to recall the following scenario.

Think of a time in your life when you felt in despair, for instance, when you felt low or depressed, or felt like you wanted to withdraw from the world.

After completing the worksheet, participants changed into a special motion capture suit, and forty-three passive retro-reflective markers (2 cm diameter) were placed on specific anatomical landmarks on the body in preparation for collection of motion capture data. A static (stationary) trial was recorded with the subject standing in the neutral position (Figure 7) using a 6-camera, high-speed (120 Hz) video system (Motion Analysis Corp.). To align the body with the laboratory coordinate system, the subject's position was visually monitored and adjusted (if necessary) prior to capturing the stationary shot so that the sagittal and frontal planes were parallel to the laboratory YZ and XZ planes, respectively. Additionally, the shoulder and elbow positions were adjusted (flexed slightly) if markers on the hip were occluded. Markers on the left and right iliac crest, left and right greater trochanter, medial and lateral humeral epicondyle, radial and ulnar styloid process, medial and lateral femoral epicondyle, and medial and lateral malleoli were subsequently removed prior to the recording of walking trials. A set of 31 tracking markers remained on the body, placed on the head, trunk, pelvis and left upper and lower limbs (Table 28).

Figure 7. Reference position.

Table 28. Placement of tracking markers.

Marker #	Marker Name	Anatomical Position
1	HT	Top of Head
2	HR	Right Side of Head
3	HL	Left Side of Head
4	C7	Spinous Process C7
5	IJ	Jugular Notch
6	T6	Spinous Process T6
7	ST	Sternum 3rd Rib
8	AR	Right Acromion
9	AL	Left Acromion
10	L3	3rd Lumbar Vertebrae
11	ASISR	Right Anterior Superior Iliac Spine
12	ASISL	Left Anterior Superior Iliac Spine
13	SA	Sacrum (Line up with PSIS)
14	UA1	Upper Arm Plate Superior
15	UA2	Upper Arm Plate Posterior
16	UA3	Upper Arm Plate Anterior
17	FA1	Forearm Plate Superior
18	FA2	Forearm Plate Posterior
19	FA3	Forearm Plate Anterior
20	MC3	3rd Metacarpal
21	MC2	2nd Metacarpal
22	MC5	5th Metacarpal
23	TH1	Thigh Plate Superior
24	TH2	Thigh Plate Posterior
25	TH3	Thigh Plate Anterior
26	SH1	Shank Plate Superior
27	SH2	Shank Plate Posterior
28	SH3	Shank Plate Anterior
29	HEEL	Heel
30	MT1	1st Metatarsal
31	MT5	5th Metatarsal

Once the set-up was complete, participants were asked to walk at a self-selected pace approximately 5 meters after recalling a memory from their worksheet. Before each walking trial, the participants read their notes to help recall the specific memory. Memories were referred to as numbers rather than emotions to help ensure that a bias was not introduced. Participants began walking when they felt the recalled emotion as strongly as possible; they did not wait for a cue from the experimenter to begin and they did not have to provide a cue to indicate they were ready to walk. As each participant walked, 2D (side-view) video and whole body 3-D motion capture data were recorded.

Participants performed three trials for each memory in a block to increase the probability that at least one trial would have usable video and motion capture data and that the target emotion would be felt. Subjective experience of emotion was assessed after each walking trial using a self-report questionnaire. The questionnaire included four target emotions and four non-target, distracter emotions. The non-target emotions were selected for inclusion based on their similarity, in terms of valance and arousal, to the target emotions. An item for neutral emotion was not included on the questionnaire. After each walking trial, participants rated the intensity with which they felt each of the eight emotions using a 5-item likert scale (0 = not at all; 1 = a little bit; 2 = moderately; 3 = a great deal; 4 = extremely). After each emotion block, the encoder was also asked to indicate the trial they felt was their best trial for that memory. The memory order was randomized for each participant.

One trial for each encoder for each emotion was selected for inclusion in the kinematic dataset (42 encoders x 5 emotions = 210 total observations). To be selected for inclusion in the dataset, a trial needed to have usable motion capture data and usable side-view video. Motion data were considered usable if data were available for all tracking markers for at least one gait cycle. If a marker was occluded for less than 10 frames, a cubic spline was used to interpolate the missing data in the motion capture software EvART (version 5.0). If more than one emotion trial met these criteria, the trial with the highest score for the target emotion item on the self-report questionnaire was selected. If two or more trials had the same score for the target self-report item, the self-selected best trial was used. If the self-selected best trial was not available, the trial with the lowest scores for all other questionnaire items was selected. Each trial included in the dataset was considered an *emotion portrayal*.

For each of the emotion portrayals, one gait cycle was selected. Gait cycles were defined from left heel strike to left heel strike. Heel strike events were defined via the localized minimum values of the vertical (Z) component of the heel marker coordinates. The 3D marker trajectories recorded during each trial were processed using Visual 3D software (C-Motion, Inc.), to solve for the 3D limb and torso joint rotations, and the 2D shoulder girdle and spine rotations at each time frame. Joint rotations were expressed relative to each subject's neutral position. These data were subsequently time normalized to 100% of the gait cycle, and were resampled at 1% increments (N=101). Motion data were filtered to reduce noise in the signal with a 6Hz low pass Butterworth filter (Pezzack, Norman, & Winter, 1977; Smith, 1989; Winter, Sidwall, & Hobson, 1974)

A kinematic model including the left arm, left leg, head, and torso, was constructed using Visual 3D software that consisted of eight skeletal segments (upper arm, forearm, hand, thigh, shank, foot, head-neck and thorax-abdomen) with 16 degrees of freedom (DOF). Specifically, the pelvis was assigned three rotational DOF relative to the global (laboratory) coordinate system defined with the cardan rotation sequence of X-Y-Z (i.e., about the medial/lateral, anterior/posterior, and vertical axes, respectively). The shoulder, elbow, wrist, hip, knee, and ankle joints were defined locally and each was assigned one DOF (flexion / extension) in accordance with the cardan rotation sequence of X-Y-Z. The standard Helen Hayes marker set and regression equations available in the software package were used for calculating the hip joint center (Davis et al., 1991). To calculate the shoulder joint center, a 10.4% offset was applied from the starting point of the left acromion to the elbow joint center. To calculate the elbow joint center, a 50% offset was applied from the starting point of the lateral humeral epicondyle to the medial humeral epicondyle. Additionally, the right and left acromion markers were adjusted by -0.019 and 0.019 meters in the Z (vertical) direction, respectively. The right and left greater trochanter markers were adjusted by -0.019 and 0.019 meters in the X (lateral) direction, respectively. These adjustments were made to correct for the marker pedestal height. The neck and trunk were defined locally and assigned three rotational DOF (flexion/extension, left/right tilt, left/right rotation) also in accordance with the cardan rotation sequence of X-Y-Z. Segments used to define each joint are listed in Table 29.

Table 29. Segments used to define joints.

Joint	Segment	Reference Segment
Shoulder	Left Upper Arm	Thorax / Abdomen
Elbow	Left Forearm	Left Upper Arm
Wrist	Left Hand	Left Forearm
Hip	Left Thigh	Pelvis
Knee	Left Shank	Left Thigh
Ankle	Left Shank	Left Foot
Neck	Head / Neck	Thorax / Abdomen
Trunk	Thorax / Abdomen	Pelvis

Four 2D angles were defined relative to the laboratory coordinate system using 3-point angle calculations in the Visual 2D software. Shoulder girdle retraction was defined in the XY (transverse) plane by the left acromion, jugular notch, and right acromion markers. Shoulder girdle depression was defined in the XZ (frontal) plane by the left acromion, jugular notch, and right acromion markers. The thoracolumbar angle was defined in the YZ (sagittal) plane by the 3rd lumbar, 6th thoracic, and 7th cervical markers. Finally, the lumbosacral angle was defined in the YZ (sagittal) plane by the 6th thoracic, 3rd lumbar, and sacrum markers. Marker selection for the 2D angles was based on previous work to model the shoulder girdle and spine during walking (Frigo, Carabalona, Dalla Mura, & Negrini, 2003). All rotational data were normalized to the encoders' neutral / reference position. That is, dynamic position data were quantified based on deviations from body and joint postures in this reference position (McLean et al., 2009).

8.3.1.2 External validity of emotion portrayals

A social consensus study was performed to determine if the target emotions were observable in the movement trials (Crane et al., submitted). Briefly, the encoders' faces were blurred in the side-view video clips that were associated with the 210 emotion portrayals (42 encoders x 5 target emotions). Observers selected among 10 emotion response items, and each emotion portrayal was viewed by 30 observers. Emotion portrayals were considered recognized if the observer recognition rate was greater than the chance (10%). Of the 210 emotion portrayals included in the study, 152 (72%) were considered recognized. Recognition was highest for neutral (83%) followed by sadness (76%), content (74%), joy (67%), and anger (62%) (Crane et. al, Submitted).

8.3.2 Data Analysis

8.3.2.1 Measures

Each joint DOF was characterized by an *angular position* and a *range of motion*. The angular position of each joint at the heel strike event was selected for analysis. Selecting the joint angular position at a specific event in the gait cycle provided a meaningful context for understanding, comparing, and discussing the whole-body configuration. Although other gait cycle events could have been selected, heel strike provides a consistent and reliably measured point in the gait cycle. Kinematic data comparisons at this time point are regularly made for other (pathology and injury) movement analyses (e.g., (Levinger, Webster, & Feller, 2008; McGorry, Chang, & DiDomenico, 2008; Monaghan, Delahunt, & Caulfield, 2006; Riley, Paolini, Della Croce, Paylo, & Kerrigan, 2007). Range of motion (RoM) was calculated as the difference between the maximum and minimum joint positions that occurred during the gait cycle.

To characterize the whole body configuration at heel strike, joint angles were defined with respect to the reference position, such that pure rotations (e.g., flexion or extension) were defined as a positive or negative deviation from the reference angle. For the shoulder, elbow, wrist hip, and ankle joints, flexion (plantarflexion) was defined as positive, while for the knee, neck, and trunk, extension was defined as positive. Neck and trunk left rotation and right tilt were defined as positive. Additionally, shoulder girdle retraction and depression as well as flexion of the lumbosacral and thoracolumbar angles were defined as positive. Because the shoulders and elbows were slightly flexed in the reference position, negative values did not necessarily indicate hyperextension of the elbow.

8.3.2.2 Effects of emotion on joint angular kinematics

To determine whether emotion affected joint angular kinematics, a linear mixed model with random encoder effects was used to model means on the response variables for each emotion (i.e., the joint positions at heel strike and the RoM for each joint). The full model included fixed effects of emotion, encoder gender, and the interaction between gender and emotion. First we checked for significant interaction effects using a likelihood ratio test (LRT). If there was a significant interaction, males and females were assessed separately to determine whether emotion affected the joint angular kinematics for each group. Next, we used a LRT to assess whether there was an overall gender effect in joints for which there was not an interaction effect (the interaction effect was removed from the model). If the main effect of gender was not significant ($p < .05$), it was removed from the model to assess the effects of emotion.

To determine whether there were significant correlations between kinematic measures and percent recognition, Pearson correlation coefficients were calculated between emotion recognition and each measure for each target emotion.

8.4 Results

8.4.1 Heel strike body configuration with neutral emotion

Gait kinematics with neutral emotion were consistent with those reported extensively in the literature for walking gait (Perry, 1992; Winter, 1987). With respect to the limb angle positions at heel strike, the shoulder (-16.3 deg), elbow (males: -10.3 deg, females: -14.5 deg)[1], and wrist (-14.2 deg) were all in an extended position. The hip and knee were flexed 22.2 and 2.5 degrees respectively while the ankles were plantarflexed 3.9 degrees (pointing the toes toward the ground). With respect to the torso, the neck was extended 7.7 degrees (i.e., chin up and away from chest), tilted to the left 1.5 degrees (i.e., the left ear was towards the left shoulder), and rotated to the right 2.3 degrees (i.e., the face was toward the right shoulder). The trunk was flexed 5.8 degrees (i.e. leaning forward), slightly tilted to the left 0.7 degrees, and rotated toward the left 7.6 degrees (i.e., twisting the upper body to the left). With respect to the spine, the lumbosacral segment was extended 5.2 degrees while the thoracolumbar segment was flexed 1.9 degrees. Additionally, the shoulder girdle was retracted 8.0 degrees (shoulders back) and slightly elevated -0.5 degrees. Finally evaluation of the joint angle minima and maxima showed that for 14 of the 16 DOF, the angle peaked (i.e. was either at the minimum or maximum angle) at heel strike.

8.4.2 Effects of emotion on gait kinematics

8.4.2.1 Whole body configuration at heel strike

Emotion had a quantifiable affect on body kinematics. Kinematic profiles of the mean position and the standard error of the means are reported in Table 33 and Table 35. Five of the six limb angles studied were affected by emotion: shoulder, elbow[1], wrist, hip, and ankle (Table 33). The shoulder was most extended during anger (-21.8 deg) and was significantly greater than when encoders experienced contentment (-18 deg), neutral / no emotion (-16.3 deg), or sadness (-13.1 deg). Shoulder flexion during sadness was significantly less than when encoders experienced anger (-21.8 deg), contentment (-18.0 deg), or joy (-18.9 deg). Although no significant differences occurred between the two high arousal emotions anger and joy, the shoulder was 4.9 degrees less flexed during the low arousal emotion sadness than contentment. Emotion only affected the elbow position

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[1] The elbow was only affected by emotion in females. See gender effects in results section 8.4.2.3 for further details.

at heel strike in females (see gender effects section 8.4.2.3 for details). For females, the elbow was most extended during anger (-17.2 deg) and joy (-17.7 deg) and least extended during sadness (-9.3 deg). Sadness was 5.2, 5.7, 7.9, and 8.4 degrees less extended compared to neutral, contentment, joy, and anger, respectively. The wrist was 2.2 degrees less extended in sadness than in joy.

The hip was most flexed for anger (24.9 deg) and joy (23.3 deg). Although anger was significantly 4.6, 2.8, and 2.7 degrees more extended than when encoders experienced sadness, contentment, or neutral, respectively, joy was 3.0 degrees significantly more extended than during sadness. The ankle was most plantarflexed when encoders experienced sadness (3.8 deg) and neutral (3.9 deg). Anger (2.4 deg) and Joy (2.4 deg) were both 1.4 degrees and 1.5 degrees less plantarflexed than when encoders experienced sadness or neutral, respectively.

Six of the ten torso angles evaluated were affected by emotion (Table 33). First, the neck angle (-2.0 deg) revealed that encoders held their heads down when experiencing sadness compared to the other emotions for which the encoders held their heads up. Overall, compared to sadness the neck was 11.6, 10.5, 9.7, and 7.1 degrees more extended in joy, contentment, neutral, and anger, respectively. In addition, the neck was 1.8 degrees tilted more to the left when experiencing joy compared to sadness.

With respect to the shoulder girdle, both shoulder retraction and shoulder depression were affected by emotion. However, shoulder girdle retraction was only affected by emotion in females. The shoulder girdle was most retracted when encoders experienced sadness (8.3 deg) and neutral (8.0 deg). Shoulder girdle retraction was 3.4 and 3.3 degrees more retracted during sadness than during anger or joy. The shoulder girdle was most elevated when encoders experienced anger (-4.2 deg). Overall, the shoulder girdle was 3.7, 3.2, 2.3, and 2.1 degrees more elevated during anger than neutral, contentment, sadness, and joy. Emotion also affected the thoracolumbar segment. When experiencing sadness, the thoracolumbar segment angle was 1.6 and 1.5 degrees more extended (chest was more upright) compared to joy and anger, respectively.

8.4.2.2 Range of Motion

Ranges of motion for 12 of the 16 joints were affected by emotion. Range of motion profiles for each emotion and the standard errors are reported in Table 34 and Table 36. All limb joints were affected with the exception of the ankle. When experiencing sadness the shoulder moved through the smallest range of motion (20.2 deg). Overall, shoulder range of motion during sadness moved through 5.1, 5.8, 8.1, and 9.0 degrees less range of motion than neutral, contentment, joy, and anger, respectively. Elbow range of motion was greatest during anger (37.2 deg) and joy (37.5 deg) and least during sadness (22.5 deg). When experiencing sadness elbow range of motion moved though 15.0, 14.7, and 9.4 degrees less range of motion compared to joy, anger, and contentment, respectively. The wrist moved through 3.7 degrees less range of motion when experiencing sadness compared to joy.

Hip range of motion was greatest during the high arousal emotions anger (43.6 deg) and joy (41.6 deg). Hip range of motion during anger and joy was significantly greater than the moderate and low arousal emotions contentment (39.3 deg), neutral (38.1 deg), and sadness (36.2 deg). While the hip range of motion differed between sadness and the high arousal emotions, it also moved through 3.1 degrees less range of motion compared to contentment. In addition, when experiencing contentment, the hip moved through 2.3 degrees less range of motion compared to joy. Knee range of motion was smallest during sadness (59.6 deg) and significantly 2.6 and 1.9 degrees less than during anger or neutral.

Emotion also affected ranges of motion for 7 of the 10 torso joints. Neck flexion / extension range of motion was greatest during joy (8.4 deg) and moved through 1.8, 2.2, and 2.3 degrees more range of motion than contentment, neutral, or sadness, respectively. The range of motion during rotation of the neck was smallest during sadness (4.6 deg) and moved through 2.4 degrees less range of motion compared to anger and neutral and 2.6 degrees less range of motion than joy. However, neck rotation was only affected by emotion in females (See section 8.4.2.3 for gender effect details). Trunk tilt range of motion was greatest during anger (11.8 deg) and joy (11.1 deg) and was significantly greater than when encoders experienced contentment (9.7 deg), neutral (9.6 deg), and sadness (8.6 deg). Trunk rotation range of motion was smallest during sadness (16.9 deg) and moved through 5.5, 5.2, and 3.2 degrees less range of motion than joy, anger, and contentment, respectively. In addition, during contentment the trunk rotated through 2.3 degrees less range of motion than during joy and 3.2 degrees more range of motion compared to sadness.

Shoulder girdle protraction / retraction range of motion was greatest during anger (4.3 deg) and moved through 0.9 degrees more range of motion compared to content and neutral, and 1.4 degrees more range of motion compared to sadness. In contrast, when encoders experienced sadness shoulder girdle protraction / retraction moved through 1.4 and 0.8 degrees less range of motion compared to anger and joy. Shoulder girdle depression / elevation moved through the smallest range of motion during sadness (3.8 deg) and moved through 0.8 degrees less range of motion compared to anger and contentment and 0.7 degrees less range of motion compared to joy. Thoracolumbar flexion / extension moved through the smallest range of motion during sadness (2.1 deg) and moved through 0.5 and 0.6 degrees less range of motion compared to anger and joy, respectively.

In general, arousal level seemed to be an important factor affecting range of motion. Therefore, a post-hoc analysis was done to investigate whether there were any significant correlations between arousal level (High – anger and joy, Moderate – neutral, and Low – contentment and sadness) and range of motion for each of the joint angles (Table 30). An increased range of motion was associated with arousal level for all limb joint angles except the ankle. With respect to the torso, neck flexion / extension, trunk tilt and rotation, shoulder girdle retraction and depression, and the thoracolumbar segement angle all increased in range of motion as arousal level increased.

Table 30. Correlations between arousal level and RoM[1].

Joint Angle	RoM
Limb	
Shoulder Flexion	.29 ***
Elbow Flexion	.40 ***
Wrist Flexion	.24 **
Hip Flexion	.38 ***
Knee Extension	.22 **
Torso	
Neck Extension	.22 *
Neck Left Rotation	.21 *
Trunk Right Tilt	.31 ***
Trunk Left Rotation	.39 ***
Shoulder Girdle Retraction	.32 ***
Thoracolumbar Lordosis	.19 *

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

[1] High (anger and joy), moderate (neutral), and low (sadness and contentment) arousal emotions were coded as 3, 2, and 1 respectively.

Overall, range of motion seemed to be moderately correlated with arousal level and tended to increase as arousal level increased. With this finding in the post-hoc analysis, for completeness we calculated the height normalized gait velocity for each emotion and assessed whether the gait velocity was affected by emotion. The gait velocity was greatest when encoders experienced anger (.84 BH/s)[2] and joy (.83 BH/s), followed by content (.72 BH/s) and neutral (.70 BH/s), and finally sadness (.61 BH/s). Significant differences in normalized gait velocity were observed between sadness and both of the high arousal emotions anger and joy ($p < .05$).

[2] Gait velocity was normalized to body height. Thus, gait velocity (meters/second) / body height (meters) = BH / s

8.4.2.3 Gender effects

A main effect of gender was not observed in position nor in the range of motion for any of the joints assessed. However, significant interactions were found between gender and emotion for elbow flexion / extension (Chisq = 11.992, df = 4, p = .017) and for shoulder girdle retraction / protraction (Chisq = 10.195, df = 4, p = .037), as well as neck rotation range of motion (Chisq = 9.975, df = 4, p = .041). Because of the significant interaction effect for these joints, males and females were assessed separately to identify whether there were significant differences between emotions for each gender. For all measures that had a significant gender by emotion interaction, only females were affected by emotion when the data were separated into two datasets (male and female) and the statistical analysis was rerun. Therefore, for the set of measures that did have a significant interaction effect, post-hoc analyses indicated that males did not change their behavior in response to experiencing an emotion. Females, however, did have measurable behavioral changes in response to experiencing the target emotions, for that specific set of variables. Overall, more measures were affected by emotion in females than in males. Results for each emotion are reported for each gender in tables (Table 33 and Table 34). The behavioral changes observed in the females were consistent with the general trends reported for whole body position and range of motion.

8.4.2 Kinematics associated with decoding accuracy

Only eight of the 16 limb and torso joint positions at heel strike were significantly correlated with decoding accuracy for one or more emotions (Table 31). However, range of motion for 12 of the 16 joints angles was significantly correlated with decoding accuracy for one or more emotions (Table 32). For anger, decoding accuracy was negatively correlated with shoulder flexion position and shoulder girdle depression position at heel strike and positively correlated with range of motion for shoulder, elbow, and hip flexion, neck extension and left rotation, trunk right tilt and left rotation, and shoulder girdle retraction. Thus, as decoding accuracy increased, the shoulder tended to become more extended and more elevated at heel strike while the range of motion of both limb and torso joints angles tended to increase.

For joy, decoding accuracy was negatively correlated with elbow flexion position and neck right tilt position at heel strike and positively correlated with elbow and wrist flexion, and neck and trunk right tilt. Therefore, decoding accuracy for joy improved in emotion portrayals that were associated with more elbow extension and less neck right tilt at heel strike compared to joy portrayals that were not accurately decoded.

For sadness, decoding accuracy was positively associated with elbow flexion position and negatively associated with neck extension and trunk left rotation positions. Range of motion was negatively correlated with decoding accuracy for movement at the elbow, hip, and trunk rotation.

For contentment, only one joint position was associated with decoding accuracy and there were no significant correlations for range of motion. Thus, the only kinematic cue that seemed to be associated with an observer ability to accurately decode an emotion portrayal as contentment was increased shoulder girdle depression.

For neutral, decoding accuracy was associated with increased neck extension, trunk right tilt, and increased lumbar lordosis compared to trials that were not recognized. In addition these portrayals were associated with an increased range of motion at the elbow and ankle.

Table 31. Heel strike position associated with decoding accuracy.

	Emotions				
Joint Angle	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Limb					
Shoulder Flexion	-.37*				
Elbow Flexion		-.49***	.49***		
Torso					
Neck Extension			-.64***		.34*
Neck Right Tilt		-.40**			
Trunk Right Tilt					.32*
Trunk Left Rotation			-.47**		
Lumbosacral Lordosis					.35*
Shoulder Girdle Depression	-.45**			.31*	

* p < .05, ** p < .01, *** p < .001

Table 32. Range of motion associated with decoding accuracy.

	Emotions				
Joint Angle	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Limb					
Shoulder Flexion	.32 *				
Elbow Flexion	.41 **	.33 *	-.41 **		.47 **
Wrist Flexion		.39 *			
Hip Flexion	.49 ***		-.54 ***		
Ankle Plantarflexion					.34 *
Torso					
Neck Extension	.37 *				
Neck Right Tilt		.39 *			
Neck Left Rotation	.48 ***				
Trunk Flexion					
Trunk Right Tilt	.50 ***	.35 *			
Trunk Left Rotation	.40 **		-.55 ***		
Shoulder Girdle Retraction	.51 ***				

* p < .05, ** p < .01, *** p < .001

8.5 Discussion

This is the first study to provide a full whole body kinematic profile for five target emotions. Further, this study demonstrated that kinematic measures changed in response to experiencing an emotion. Finally, specific kinematic measures were associated with emotion recognition. Unique aspects of this work include emotion induction with a manipulation check to assess the emotion experience and emotion recognition of a single movement task (walking) of a large sample of encoders (n = 42). Whole body motion capture data were also captured. The results reported in this analysis provide a critical framework for advancing our understanding of how emotion affects movement and the characteristics that are important for observer recognition of emotion. Thus, the results demonstrate the exciting potential for the use of precise kinematic measures to detect and synthesize emotion-related behavior.

Unique to this study was the use of a set of emotions that were balanced with respect to arousal and pleasantness based on the circumplex model of emotion (Russell, 1980). Therefore, comparisons can be made to evaluate whether observed effects were related to specific aspects of emotion such as arousal level or pleasantness. Although it is argued that these are not the only characteristics that define an emotion (Scherer & Ellgring, 2007), comparing emotions based on these qualities provides a necessary first step. Differences were observed between emotions with similar arousal level (anger / joy, sad / content) and between emotions with similar pleasantness (anger / sad, joy / content). Anger and sadness seemed to represent the two extremes associated with movement style. Because these are both negative emotions that are opposite in pleasantness, differences may be due to arousal level.

In contrast to the large number of differences observed between the negative emotions, fewer differences were observed between the positive emotions. Although no differences were identified between joy and content for joints at the heel strike position, range of motion was different in four joints: hip, neck extension, and trunk tilt and rotation. For each joint, the range of motion was greater when encoders experienced joy compared to contentment. Thus, consistent with the negative emotion pair, motion tended to be larger for high arousal emotions than low arousal emotions. Because arousal level seemed to be associated with range of motion, we explored whether this may have resulted from an increased walking speed associated with high arousal emotions. Indeed, walking speed was greater for the high arousal emotions. Therefore, further investigation is necessary to determine whether walking speed confounded the effects associated with the high arousal emotions.

Although it is not known whether walking speed contributed to the observed effects, differences were observed between emotions with similar arousal levels and speeds, which indicated that differences were associated with emotion effects. More differences were observed between the low-arousal emotions (sadness and contentment) than the high-arousal emotions (anger and joy). Overall, five joint positions at heel strike (shoulder, elbow, neck extension, trunk left rotation, and thoracolumbar flexion) differed between sad and content. The joint positions were closer to the standing references position during sadness than content. For the high arousal emotions, the shoulder girdle was more depressed when encoders experienced anger compared to joy. Although no range of motion differences were observed between anger and joy, differences were observed between sad and content for five joints (shoulder, elbow, hip, trunk left rotation, and shoulder girdle depression). For each joint, the range of motion was greater in for the positive emotion contentment compared to the negative emotion sadness. Because these comparisons were made between emotions of similar arousal level, the results suggest that the pleasantness dimension also affects movement kinematics.

The use of objective kinematic measure that do not rely on subjective observer judgments about emotion-related behavior allows us to begin assessing whether there are gender differences in how an emotion is expressed. In an observer-based study, Crane et al. (In Preparation) reported that females tended to be more expressive than males. However, because these results could have been confounded by a possible observer bias, it was not clear whether females were more expressive or if the movement style were the same but observers perceived the females as more expressive. In the current study, gender interacted with emotion for elbow flexion position, shoulder girdle retraction position, and neck rotation range of motion. In each case, only females were affected. Although assessing gender differences was not a primary goal of this study, our results suggest gender interacts with emotion expression. Therefore, further studies are needed to investigate gender-related differences in the bodily expression of emotion.

The current study also examined whether specific kinematic characteristics were associated with emotion recognition. Overall, range of motion seemed to be more associated with emotion recognition than joint position at heel strike. For example, for anger, only two joint positions (shoulder extension and shoulder girdle elevation) were associated with emotion recognition while eight ranges of motion were associated with emotion recognition. In contrast, the positive emotions joy and contentment together had a total of seven kinematic measures associated with emotion recognition. This result is consistent with Gross et al.'s (Submitted) conclusion that positive emotions may result in more variability in motor expression. Consequently, individual kinematic characteristics may not be as strongly associated with emotion recognition. However, the fact that observers can recognize positive emotions at levels greater than chance suggests that there are specific characteristics associated with these emotions. Indeed, previous studies suggest that the relationship between joint motions may be associated with emotion recognition (Pollick et al., 2001). One study has suggested that these emotions may be more associated with patterns of coordinated joint movement (Gross et al., Submitted) than with individual kinematic measures. In their study, Gross et al. (Submitted) explored the relationship between joint coordination and emotion recognition by examining angle-angle graphs of individuals that experienced different target emotions; that study showed, for example, that specific joint motions were broadened when experiencing contentment compared to the other emotions (Gross et al., Submitted). Although the current study did not find many differences between the high arousal emotions anger and joy, it did not explore whether coordinated behavior was affected by emotion. Given the number of variables and combinations of angle-angle plots that could be generated, the current study provides an important foundation for focusing investigations of the relationship between joint motions.

A potential limitation of this study was the use of joint position at heel strike rather than at a different event in the gait cycle. Because joint positions tend to peak at heel strike and range of motion is a function of the difference between peaks, the information assessed may have been redundant. Evidence against this supposition is that peak positions were not always associated with the greatest ranges of motion. For example, we reported that the shoulder girdle was more elevated during anger than all other emotions, but the range of motion was not greater during anger than all other emotions. If the information were purely redundant, we would expect that the extreme values would also be associated with the largest range of motion. However, further work is needed to assess whether the relationships identified in this study are consistent throughout the gait cycle.

The current study provides significant steps forward in evaluating emotion-related movements by assessing quantitative and precise kinematic measures whole body movement in response to a variety of expressed emotions. For example, our results were consistent with previous findings that emotions tend to be communicated using specific characteristics (i.e., head down in sadness). However, we also found that the degree to which the characteristic is displayed varies widely among encoders. While previous studies reported mean scores from observer based rating scales, we did not know the true magnitude of the difference between emotions with respect to the actual quantitative movement parameters. Our results suggest that, at the individual joint level, the differences in position or range of motion between emotions are relatively small for a given task. Because we controlled for encoder effects by including random effects of encoder in our statistical model, we believe our observed kinematic differences between emotions are significant and meaningful. However, observer sensitivity to these small changes between emotions needs to be further explored in future studies.

Table 33. Effect of emotion on whole body configuration at heel strike.

Joint Angle	Chisq	*df*	*p*	Emotion				
				Anger	Joy	Sad	Content	Neutral
Limb								
Shoulder Flexion	49.77	4	<.001	-21.8^{CNS}	-18.9^{S}	-13.1^{ACJ}	-18.0^{AS}	-16.3^{A}
Elbow Flexion (M)[2]	7.11	4	.130	-9.0	-10.4	-7.3	-7.3	-10.3
Elbow Flexion (F)[2]	33.14	4	<.001	-17.2^{S}	-17.7^{S}	-9.3^{ACJN}	-15.0^{S}	-14.5^{S}
Wrist Flexion	9.80	4	.044	-14.4	-15.9^{S}	-13.7^{J}	-14.3	-14.2
Hip Flexion	39.11	4	<.001	24.9^{CNS}	23.3^{S}	20.3^{AJ}	22.1^{A}	22.2^{A}
Knee Extension	9.39	4	.052	-2.9	-2.5	-0.9	-1.5	-2.5
Ankle Plantarflexion	18.89	4	.001	2.4^{NS}	2.4^{NS}	3.8^{AJ}	3.4	3.9^{AJ}
Torso								
Neck Extension	52.26	4	<.001	5.1^{S}	9.6	-2.0^{ACJN}	8.5^{S}	7.7^{S}
Neck Right Tilt	11.78	4	.019	-2.5	-2.6^{S}	-0.8^{J}	-2.4	-1.5
Neck Left Rotation	1.14	4	.889	-2.0	-2.4	-1.9	-2.5	-2.3
Trunk Extension	4.65	4	.325	-6.4	-5.6	-6.5	-5.7	-5.8
Trunk Right Tilt	2.70	4	.609	-0.9	-0.6	-0.4	-0.5	-0.7
Trunk Left Rotation	40.27	4	<.001	9.6^{NS}	9.5^{NS}	6.9^{ACJ}	8.5^{S}	7.6^{AJ}
Shoulder Girdle Retraction (M)[2]	5.75	4	.218	5.5	7.2	7.0	6.2	6.6
Shoulder Girdle Retraction (F)[2]	17.88	4	.001	4.9^{S}	5.0^{NS}	8.3^{AJ}	6.9	8.0^{J}
Shoulder Girdle Depression	29.19	4	<.001	-4.2^{CJNS}	-2.1^{A}	-1.9^{A}	-1.0^{A}	-0.5^{A}
Lumbrosacral Lordosis	2.65	4	.618	5.8	4.6	5.6	5.3	5.2
Thoracolumbar Lodosis	13.14	4	.011	-2.2	-1.3^{S}	-2.9^{CJ}	-1.4^{S}	-1.9

[1] Significant pairwise comparisons are indicated by superscripts. A = anger, C = Content, J = Joy, N = Neutral, S = Sad

[2] Indicates a significant interaction between emotion and gender. Therefore emotion effects were assessed separately for each gender (M= male, F= female)

Table 34. Effect of emotion on range of motion.

				Emotion				
Joint Angle	**Chisq**	***df***	***p***	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Limb								
Shoulder Flexion	44.16	4	<.001	29.2^{S}	28.3^{S}	20.2^{ACJN}	26.1^{S}	25.3^{S}
Elbow Flexion	48.11	4	<.001	37.2^{NS}	37.5^{NS}	22.5^{ACJ}	31.9^{S}	29.3^{AJ}
Wrist Flexion	14.77	4	.005	8.1	10.4^{S}	6.7^{J}	7.6	8.2
Hip Flexion	73.90	4	<.001	43.6^{CNS}	41.6^{CNS}	36.2^{ACJ}	39.3^{AJS}	38.1^{AJ}
Knee Extension	18.38	4	.001	62.2^{S}	61.2	59.6^{AN}	60.6	61.5^{S}
Ankle Plantarflexion	9.16	4	.057	30.0	30.7	28.3	29.7	29.6
Torso								
Neck Extension	16.01	4	.003	6.8	8.4^{CNS}	6.1^{J}	6.6^{J}	6.2^{J}
Neck Right Tilt	8.68	4	.070	5.5	6.2	5.1	5.8	5.0
Neck Left Rotation (M)[2]	7.26	4	.123	5.8	7.7	6.2	6.4	6.2
Neck Left Rotation (F)[2]	16.14	4	.003	7.0^{S}	7.2^{S}	4.6^{AJN}	6.6	7.0^{S}
Trunk Extension	4.01	4	.405	4.6	5.2	4.9	4.6	4.6
Trunk Right Tilt	50.58	4	<.001	11.8^{CNS}	11.1^{CNS}	8.9^{AJ}	9.7^{AJ}	9.6^{AJ}
Trunk Left Rotation	51.69	4	<.001	22.1^{NS}	22.4^{CNS}	16.9^{ACJ}	20.1^{JS}	19.1^{AJ}
Shoulder Girdle Retraction	26.25	4	<.001	4.3^{CNS}	3.7^{S}	2.9^{AJ}	3.4^{A}	3.4^{A}
Shoulder Girdle Depression	15.27	4	.004	4.6^{S}	4.5^{S}	3.8^{ACJ}	4.6^{S}	4.1
Lumbrosacral Lordosis	8.55	4	.074	6.4	6.6	5.7	6.5	6.3
Thoracolumbar Lordosis	15.01	4	.005	2.6^{S}	2.7^{S}	2.1^{AJ}	2.5	2.3

[1] Significant pairwise comparisons are indicated by superscripts. A = anger, C = Content, J = Joy, N = Neutral, S = Sad

[2] Indicates a significant interaction between emotion and gender. Therefore emotion effects were assessed separately for each gender (M= male, F= female)

Table 35. Standard Error of the Mean for each emotion at heel strike position.

	Emotion				
Joint Angle	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Limb					
Shoulder Flexion	1.4	1.4	1.4	1.4	1.5
Elbow Flexion (M)	2.2	2.3	2.2	2.2	2.3
Elbow Flexion (F)	2.2	2.0	2.1	2.1	2.2
Wrist Flexion	1.4	1.4	1.4	1.4	1.4
Hip Flexion	0.8	0.8	0.8	0.8	0.8
Knee Extension	0.9	0.9	0.9	0.9	0.9
Ankle Plantarflexion	0.6	0.6	0.6	0.6	0.6
Torso					
Neck Extension	1.6	1.5	1.4	1.5	1.6
Neck Right Tilt	0.6	0.6	0.6	0.6	0.6
Neck Left Rotation	0.8	0.8	0.8	0.8	0.8
Trunk Extension	0.8	0.8	0.8	0.8	0.8
Trunk Right Tilt	0.4	0.4	0.4	0.4	0.4
Trunk Left Rotation	0.6	0.6	0.5	0.6	0.6
Shoulder Girdle Retraction (M)	1.1	1.1	1.1	1.1	1.1
Shoulder Girdle Retraction (F)	1.1	1.0	1.0	1.1	1.1
Shoulder Girdle Depression	0.8	0.8	0.8	0.8	0.9
Lumbrosacral Lordosis	0.9	0.9	0.9	0.9	1.0
Thoracolumbar Lordosis	0.6	0.5	0.5	0.5	0.6

Table 36. Standard Error of the Mean for range of motion.

	Emotion				
Joint Angle	**Anger**	**Joy**	**Sad**	**Content**	**Neutral**
Limb					
Shoulder Flexion	2.7	2.6	2.6	2.6	2.7
Elbow Flexion	2.8	2.7	2.7	2.8	2.9
Wrist Flexion	1.1	1.1	1.0	1.1	1.1
Hip Flexion	1.2	1.2	1.2	1.2	1.2
Knee Extension	1.0	1.0	1.0	1.0	1.0
Ankle Plantarflexion	1.1	1.1	1.1	1.1	1.1
Torso					
Neck Extension	0.7	0.7	0.6	0.7	0.7
Neck Right Tilt	0.7	0.6	0.6	0.6	0.7
Neck Left Rotation (M)[2]	0.6	0.7	0.6	0.6	0.7
Neck Left Rotation (F)[2]	0.7	0.6	0.6	0.6	0.7
Trunk Extension	0.4	0.3	0.3	0.3	0.4
Trunk Right Tilt	0.7	0.7	0.7	0.7	0.7
Trunk Left Rotation	1.2	1.2	1.2	1.2	1.2
Shoulder Girdle Retraction	0.3	0.3	0.2	0.3	0.3
Shoulder Girdle Depression	0.3	0.3	0.3	0.3	0.3
Lumbrosacral Lordosis	0.5	0.5	0.5	0.5	0.6
Thoracolumbar Lordosis	0.2	0.2	0.2	0.2	0.2

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Chapter 9

Multimodal Analysis of Face and Body Expression Data

9.1 Abstract

Although previous studies suggest an interaction between expressive modalities, the specific behaviors associated with emotion recognition and how they interact across modalities is not known. Characteristics of these multimodal patterns have important implications in a variety of fields ranging from emotion research to virtual environments. Therefore, the purpose of this study was to combine objective measures from the face and body to evaluate whether these measures capture complex emotion-related interactions between modalities. To do this, we performed a cluster analysis on a multimodal dataset that included data from the face and the body. Emotion-related patterns were found to be most consistent in the FACS dataset, followed by the multimodal dataset, and lastly the body dataset. Therefore, this analysis did not find strong support for specific multimodal patterns related to emotionally expressive behavior.

9.2 Introduction

The face and body play an important role in the recognition of emotionally expressive behavior (Atkinson, Dittrich, Gemmell, & Young, 2004; Cohn, Ambadar, & Ekman, 2007; Coulson, 2004; Dahl, 2007; de Gelder, 2006; P. Ekman, 1993; Scherer & Ellgring, 2007a; Wallbott, 1998). A range of studies, including observer-based judgment studies and fMRI studies, also suggests that complex interactions occur between expressive modalities (Cohn et al., 2004; Paul Ekman & O'Sullivan, 1991; Meeren, van Heijnsbergen, & de Gelder, 2005; Scherer & Ellgring, 2007b; Van den Stock, Righart, & de Gelder, 2007; Wallbott & Scherer, 1986). Indeed, Ekman (1964) provided some of the first systematic evidence for observer sensitivity to interactions between modalities during interview behavior. In addition, Meeren et al. (2005) found that observer judgments of emotion were more accurate and made faster with combined and congruent modalities compared to judgments based on a single modality. Van den Stock et al. (2007) replicated this finding with a different set of emotions and additionally found that if a facial expression was ambiguous, the body expression influenced the perception of the facial expression. Although previous studies suggest an interaction between expressive modalities, many questions about the interactions remain. Characteristics of these multimodal patterns have important implications in a variety of fields ranging from emotion research to virtual environments. Therefore, the purpose of this study was to combine objective measures from the face and body to evaluate whether these measures capture complex emotion-related interactions between modalities.

Previous studies have used statistical classification methods to assess the relative value of multimodal information compared to information from individual modalities (Castellano, Kessous, & Caridakis, 2008; Scherer & Ellgring, 2007b). For example, in a 2008 study by Castellano et al., statistical methods were used to classify multimodal input as representative of a specific emotion, including measures from the face, body, and voice. Multimodal classification accuracy was compared to classification rates for each individual modality. Overall, Castellano et al. (2008) found that classification rates were highest when data from multiple modalities were combined. Results from statistical classification methods are consistent with findings from observer studies, both suggesting that combining modalities generally improves emotion recognition.

The most extensive examination of multimodal behavioral patterns was completed by Scherer and Ellgring (2007b). Their study assessed the co-occurrences of facial, vocal, and bodily behaviors. FACS was used to code facial behavior, Wallbott and Scherer's (1986) coding scheme was used to code bodily behavior, and acoustic analyses were used to characterize vocal behavior. A stepwise discriminant analysis was used to determine how variables combine to discriminate between emotions. With a set of only 10 multimodal variables used as input into the model, the cross-validated prediction accuracy was 50.4%, which was quite a bit higher than the unimodal prediction accuracies (Scherer & Ellgring, 2007b).

To date, all multimodal studies have investigated gesticulatory behavior and have not assessed whether the emotion was felt by the encoder. Given the potential for exaggerated movement to occur when emotions are displayed, thereby possibly affecting movement qualities (Crane & Gross, In Preparation-a; Wallbott & Scherer, 1986), it is important to assess emotion portrayals for which the emotion was felt. Further, expressive behaviors are not limited to gestures (Crane & Gross, In Preparation-b; Gross, Crane, & Fredrickson, Submitted; Montepare, Goldstein, & Clausen, 1987). Thus, a whole category of expressive movement remains unexplored. Therefore, beyond establishing evidence for a relationship between modalities that affects observer recognition and statistical classification of emotion, comprehensive description of multimodal patterns has not been identified or characterized.

To assess multimodal behavioral patterns, data from each affective modality included in the analysis must be collected simultaneously. Therefore, previous studies on multimodal behavior have been limited to tasks for which the encoder faces the video camera to capture a clear and consistent view of the face while simultaneously capturing video of the body. Thus, gestures have typically been studied because they can be performed while a person is stationary and looking at the camera. Because emotion affects movements that are not stationary (Crane & Gross, In Preparation-b; Gross et al., Submitted; Montepare et al., 1987), results from previous multimodal analysis may be limited by the behaviors studied (Scherer & Ellgring, 2007b). Since the introduction of a head-mounted camera (Crane, Gross, & Fredrickson, Submitted), this technical constraint of capturing video of the face during a movement task in which a subject changes location has been overcome.

The purpose of this study was to explore whether there is evidence for the presence of multimodal patterns when an emotion is experienced during a whole body movement task. To do this, we performed a cluster analysis on a multimodal dataset that included data from the face and the body. Results from the multimodal cluster analysis were compared to cluster analyses performed on each individual modality to determine if more emotion-portrayals clustered together with the multimodal data compared to either of the individual modalities.

9.3 Methods

This paper is the final paper in a series that first assessed the feasibility of capturing facial expression video during a dynamic movement task (Crane et al., Submitted), second, described emotion-related movement style characteristics (Crane & Gross, In Preparation-a) and third, evaluated emotion-related movement kinematics (Crane & Gross, In Preparation-b). For these studies, motion capture data were collected while participants experienced each of five target emotions while walking. A self-report questionnaire was used to determine whether the target emotion was felt and a social consensus paradigm was used to determine whether observers were able to accurately recognize the emotion portrayals. Face video and motion capture data were collected in Crane et al. (Submitted).

Although details of the data collection methods are described Elsewhere (Crane et al., Submitted), details relevant to this study are reviewed here. Walkers (n = 21, 48% female) were recruited from the University of Michigan undergraduate student population. Ages ranged from 18 to 32 years (20.2 $\pm$ 3.0 yrs.). All participants were able-bodied and no special skills were required. Prior to data collection, participants reviewed a description of the study and signed a consent form approved by the Institutional Review Board (IRB).

To capture a consistent image of the face during movement, a head mount was custom designed in our laboratory to support a small video camera (Adventure Cam II, Viosport). Since wearing a head-mounted camera could potentially interfere with emotional expression, we assessed the effect of the head-mount on emotion elicitation, emotion recognition, qualitative aspects of body movement, and quantitative aspects of body movement. The results of these studies indicated that while the head-mount may slightly constrain arm movement, wearing the head-mounted camera during motion capture is a valid method for collecting facial and bodily data (Crane et al., Submitted).

To capture kinematic data, participants wore a form-fitting clothing (similar to a unitard), and thirty-one passive retro-reflective markers (2 cm diameter) were placed on specific anatomical landmarks on the body in preparation for collection of motion capture data. The placement of the markers allowed the body to be demarcated into eight linked segments, each segment representing a bony segment of the musculo-skeletal system (See Crane & Gross (In Preparation-b) for details about the model and data processing). Participants were asked to walk approximately 5 meters at a self-selected pace while experiencing one of five target emotions (anger, joy, content, neutral, or sad). Emotions were elicted using an autobiographical memories paradigm and felt emotion was assessed after each trial with a self-report questionnaire. Participants began walking when they felt the recalled emotion as strongly as possible; they did not wait for a cue from the experimenter to begin and they did not have to provide a cue to indicate they were ready to walk. As each participant walked, side-view video, face video, and whole body 3-D motion capture data were recorded.

One portrayal for each walker for each emotion was selected for inclusion in the final kinematic dataset (21 walkers x 5 emotions = 105 total emotion portrayals). To be selected for inclusion in the dataset, a portrayal needed to have usable kinematic data, usable side-view video, and usable face video. For each emotion portrayal the neck, trunk, shoulder, elbow, wrist, hip, knee, and ankle joint 3D kinematics were calculated, in addition to four 2D postural angles. All calculations were completed using C-Motion Visual 3D software package. Overall, eight limb angles and ten torso angles were included in this analysis (Table 37).

Table 37. Limb and torso angles included in the kinematic analysis.

Limb angles	Torso angles
Shoulder Flexion	Neck Extension
Elbow Flexion	Neck Right Tilt
Wrist Flexion	Neck Left Rotation
Hip Flexion	Trunk Flexion
Knee Extension	Trunk Right Tilt
Ankle Plantarflexion	Trunk Left Rotation
	Lumbar Lordosis
	Shoulder Retraction
	Shoulder Depression
	Thoracic Lordosis

The Facial Action Coding System (FACS) was used to code facial behavior. Facial expression is recognized as a valid indicator of emotion and can be described using (FACS) (Cohn et al., 2007; Cohn & Ekman, 2005; Paul Ekman & Rosenberg, 2005). As characterized by Cohn et al. (2007), FACS has emerged as the most widely used, comprehensive, and psychometrically rigorous coding system for describing facial expression (Cohn et al., 2007; Cohn & Ekman, 2005; Paul Ekman & Rosenberg, 2005). A complete list of FACS action units can be found in Ekman, Friesen, & Hager (1978). Only the frames corresponding to the gait cycle selected for analysis were coded. All action units for every frame were coded as on or off.

9.3.1 Data Analysis

Three separate datasets were constructed for this study: FACS, body, and multimodal. All three datasets included the same set of 105 emotion portrayals. Additionally, all three datasets included a variable to represent whether the emotion portrayal was felt or not.

The FACS dataset included a variable for each of the action units. Although each action unit was coded as on or off for each frame of video for each emotion portrayal, facial expressions tended to remain constant throughout the gait cycle. Therefore, the final FACS dataset included only one observation for an emotion portrayal for each action unit. In this dataset, action units were coded as *activated*, if they were activated for more than 50% of the gait cycle. Seventeen action units were not activated for any emotion portrayal and were therefore excluded from the final dataset. Thus, the final FACS dataset included 14 action units (Table 38).

Table 38. FACS action units that were activated in at least one emotion portrayal.

AU	Name
AU 6	Cheek raiser
AU 7	Lid tightener
AU 43	Eyes Closed
AU 10	Upper lip raiser
AU 12	Lip corner puller
AU 14	Dimpler
AU 15	Lip corner depressor
AU 22	Lip funneler
AU 24	Lip Pressor
AU 28	Lip Suck
AU 25	Lips apart
AU 26	Jaw drops
AU 31	Jaw Clencher
AU 38	Nostril Dilator

The body dataset included the joint angle position at heel strike and the range of motion of each of the joint parameters described earlier (Table 37). Thus, the full kinematic dataset included 16 joint position variables and 16 joint range of motion variables. Finally, the multimodal dataset was an aggregation of the facial and body datasets.

A cluster analysis was performed individually on the FACS dataset and the body dataset before performing the analysis on the multimodal dataset. The two-step cluster algorithm in SPSS version 16 was used for all analyses. The distance measure was computed using the log-likelihood method. In addition, the number of clusters was fixed to five, since five target emotions were investigated in this analysis. Because the aim was to explore whether there was evidence for emotion-related multimodal patterns, the cluster for which each trial became a member was saved and cross-tabulated with the experienced emotion. It was hypothesized that evidence for multimodal patterns would be supported if the multimodal dataset resulted in more portrayals clustering for a given emotion than for either of the unimodal datasets.

9.4 Results

Overall, emotion-related patterns were found to be most consistent in the FACS dataset, followed by the multimodal dataset, and lastly the body dataset (Table 39). Therefore, this analysis did not find strong support for specific multimodal patterns related to emotionally expressive behavior.

Table 39. The percent of emotion portrayals that grouped together into one cluster[1].

Dataset	# of Variables	Anger	Joy	*Sad*	*Content*	*Neutral*
Face	14	40	65	45	65	81.2
Body	32	35	40	35	35	31**
Multimodal	46	40	45	40	45	50

[1] The percent of emotion portrayals presented in the table represents the highest percentage of trials that grouped together for the individual emotion.
** A total of 62% of the trials divided equally into two clusters (i.e. 31% in each cluster).

The combination of FACS action units that activated when encoders felt one of the target emotions was most consistent across encoders for neutral / no-emotion (81%), followed by the positive emotions joy and contentment (65%). Although the fewest portrayals clustered together when anger or sadness was experienced, 40% of the anger portrayals and 45% of the sad portrayals clustered together. All portrayals classified as joy and contentment displayed AU12 (lip corner puller). However, the additional action units AU25 (lips apart), AU26 (jaw drops), and AU6 (cheek raiser) were displayed when experiencing joy. In contrast to the positive emotions, the negative emotions anger and sadness, had very little overlap in the action units activated when experiencing these emotions. Sadness tended to be expressed with AU 43 (eyes closed), AU 25 (lip parted), and AU 26 (jaw drops). Interestingly, all trials classified as sadness displayed AU 26 (jaw drops). A pattern was less clear for anger. AU 15 (lip corner depressor) was the action unit most common to this group. However, it is notable that all action units that characterize the anger cluster are absent from all other clusters, with the exception of AU 43 (eyes closed). Finally, neutral was characterized by an absence of any activated action units.

Compared to the FACS dataset, fewer portrayals in the body dataset clustered together for each of the emotions. The greatest number of portrayals clustered together when encoders experienced joy (40%). Following joy, when anger, sadness, or contentment were felt, 35% of the portrayals clustered together for each individual emotion. Interestingly, when neutral / no-emotion was experienced, 62% of the portrayals grouped into two separate clusters with 31% of the portrayals falling into each of the two clusters. Table 40 provides the mean values for each body variables for each cluster. Anger, joy, and content tended to be characterized by cluster 3, neutral portrayals were characterized by clusters 2 and 3, and sad tended to be characterized by cluster 2.

Combining data from the face and body datasets did not result in the largest number of portrayals that clustered together for an individual emotion. Although combining data from the face and the body increased the number of portrayals considered as sharing similar patterns for all emotions, the number of portrayals that clustered together for each emotion was still less than when only considering facial behavior. The number of emotion portrayals that clustered together was greatest for neutral (50%), followed by the positive emotions joy and contentment (45%), and lastly the negative emotions anger and sadness (40%).

Table 40. Mean values of body variables for each cluster.

	Cluster 1	2	3	4	5	Combined
ShoulderFlexionROM	17.575	17.985	29.094	21.489	41.367	24.118
ElbowFlexionROM	21.675	25.152	33.309	23.781	39.383	28.230
WristFlexionROM	3.425	4.852	8.147	7.800	11.667	7.146
HipFlexionROM	35.475	33.141	39.975	44.611	41.433	39.260
KneeExtensionROM	66.275	61.878	58.853	60.152	67.017	60.889
AnklePlantarflexionROM	30.250	26.641	30.206	26.311	28.917	28.029
NeckExtensionROM	6.925	4.756	5.981	6.137	12.800	6.146
NeckRightTiltROM	5.525	4.241	4.547	4.681	13.200	5.080
NeckLeftRotationROM	8.000	5.344	6.888	5.944	9.817	6.418
TrunkExtensionROM	2.950	3.393	4.847	4.441	4.967	4.252
TrunkRightTiltROM	7.900	8.337	11.953	9.711	21.667	10.744
TrunkLeftRotationROM	19.825	14.115	18.669	20.122	22.367	18.076
LumbarLordosisNormalizedROM	3.925	3.656	6.619	7.215	8.800	5.977
ShoulderRetractionNormalizedROM	2.000	2.400	3.616	3.115	5.133	3.160
ShoulderDepressionNormalizedROM	3.400	3.167	3.669	4.941	5.267	3.974
ThoracicLordosisNormalizedROM	2.500	1.930	1.806	2.474	3.367	2.155
ShoulderFlexionHS	-22.6003	-11.8313	-22.1277	-19.0828	-27.7149	-18.7444
ElbowFlexionHS	3.8954	-4.0733	-14.9340	-17.3123	-14.3593	-11.7278
WristFlexionHS	-7.6899	-13.3113	-14.7649	-19.5174	-16.1141	-15.4823
HipFlexionHS	24.1960	20.4134	21.5878	26.4080	25.8186	22.9863
KneeExtensionHS	-10.6225	1.4984	-2.2574	-5.3180	1.4956	-2.1759

AnklePlantarflexionHS	-1.4488	5.6191	3.1817	2.0259	4.8866	3.4558
NeckExtensionHS	-.0219	2.5321	10.2091	2.8133	5.1666	5.2284
NeckRightTiltHS	-9.0329	-.8795	-1.6060	-1.1559	-7.4932	-1.9525
NeckLeftRotationHS	2.9491	-3.5871	-3.1720	-3.7691	7.8186	-2.5147
TrunkExtensionHS	-11.9031	-5.9113	-7.3828	-5.1554	-.8117	-6.1201
TrunkRightTiltHS	.2415	.7871	-1.2025	.4978	-3.4828	-.2470
TrunkLeftRotationHS	11.9810	5.7608	7.8165	8.6676	7.3625	7.6229
LumbarLordosisNormalizedHS	-25.1089	5.0498	6.7852	2.7097	.8067	3.4483
ShoulderRetractionNormalizedHS	6.3673	6.4239	6.8384	10.7583	1.5083	7.4715
ShoulderDepressionNormalizedHS	-4.0363	-.4054	-.3753	3.4217	-2.4098	.4044
ThoracicLordosisNormalizedHS	-103.5234	-1.5899	-1.5484	-2.2154	.4768	-5.8701

9.5 Discussion

The methodology used in the current study demonstrated multimodal data resulted in more consistent behavioral patterns than data generated from the body alone. However, facial expressions were more consistent then either bodily or multimodal expressions. Although it was expected that multimodal patterns would be more consistent than patterns in either of the individual modalities, this finding could have resulted from methodological issues related to the type of movement. Therefore, while this study did not provide strong evidence for the existence of multimodal patterns, the results suggest that subsets of measures from the body may combine with facial measures to form consistent emotion-related multimodal patterns.

Our assumption that multimodal patterns would be more consistent than patterns in either of the individual modalities was based on evidence from observer-based studies and statistical classification studies that have assessed recognition of emotions. First, these studies have demonstrated that observers can accurately recognize target emotions from a single modality (i.e. body or face)(Bachorowski, 1999; Dahl, 2007; Dittrich, Troscianko, Lea, & Morgan, 1996; Matsumoto, 1989; Pollick, Paterson, Bruderlin, & Sanford, 2001; Sawada, Suda, & Ishii, 2003; Scherer & Ellgring, 2007a). If observers can detect an emotion, then the assumption that follows is that observers detect a behavioral pattern and associate the pattern with the target emotion. Indeed, production studies that have assessed behavioral characteristics of a single modality confirm that behavior is affected by emotion and specific behavioral characteristics are associated with emotion decoding accuracy (Crane & Gross, In Preparation-a, In Preparation-b; Gross et al., Submitted; Montepare et al., 1987; Pollick et al., 2001; Wallbott, 1998). If there are emotion-related behavioral patterns, then statistical methods should also be able to discriminate target emotions based on behavioral data from a single modality. This assumption was tested in previous studies by comparing discrimination results based on individual modalities to results from a dataset that combined the data into a multimodal dataset. Results demonstrated that statistical classification methods can discriminate data as a target emotion with respectable accuracy (Castellano et al., 2008; Scherer & Ellgring, 2007b).

Because observers often have access to multiple modalities, a few studies have gone on to assess the effect of combining expressive modalities on emotion recognition. These studies demonstrate that combining modalities increases emotion decoding accuracy when the modalities individually communicate the same target emotion. Additionally, evidence from fMRI studies suggests that the processing time of observers decreases with multiple congruent modalities compared to the processing time required to decode a single modality (Van den Stock et al., 2007). One possible explanation for the decrease in processing time is that observers detect an interaction between the modalities associated with emotion-related behavior that observers are detecting. If individual behavioral characteristics are affected by emotion in individual modalities, it is logical to assume that when modalities combine these interactions could be captured in the patterning of behaviors between the modalities. This assumption is supported by statistical discriminant methods that combine multiple modalities, resulting in an increase in accurate emotion recognition compared to individual modalities. For statistical discriminant methods to work, there has to be a consistent emotion-related pattern among the variables included in the analysis. For example, when experiencing joy, AUs 12 and 6 are typically activated. However, when experiencing anger a contrasting set of AUs are activated, typically AUs 4 and 7. Therefore, in a FACS dataset, trials that are characterized by AUs 12 and 6 should be classified as joy while trials characterized by AUs 4 and 7 should be classified as anger.

One challenge for multimodal studies related to identifying cross-modal patterns is that variables from individual modalities are often different – FACS action units are categorical variables that are coded as on or off while the kinematic variables are continuous. Scherer and Ellgring (2007) recognized that combining different types of variables could challenge current statistical methods used to find clusters of similar patterns in datasets. Therefore, they made a respectable effort to overcome this challenge in a multimodal analysis that combined categorical variables characterizing the face and the body with continuous acoustic variables for characterizing the voice. Acoustical variables were transformed into categorical variables by categorizing the continuous values as either high or low. As a result of the transformation, all the variables included in their multimodal analysis were categorical binary variables.

Although a similar transformation could be used to categorize the continuous joint kinematics variables, the body variables would lose a meaningful interpretation if this categorical transformation occurred. For example, if the position of the shoulder joint in the sagittal plane (i.e. shoulder flexion / extension) were categorized as high, we would lose the context of whether high referred to a flexed or extended position. In addition, the selection of two categories for a continuous variable (high and low) is arbitrary and may therefore lead to overstating the results or potentially missing significant interactions between variables. Finally, transforming continuous variables into categorical variables loses the precision afforded by using motion data. Therefore, we did not transform the continuous body variables into categorical variables.

A consequence of leaving the body variables as continuous variables was that a range of values occurred across encoders for each body variable for each emotion. Consequently, it is harder to find two encoders that share the same, or very close to the same, values for each parameter. That is, the values across the variables for each emotion portrayal need to be similar across encoders because current statistical methods require all variables to be similar to form a cluster. As a result, if the shoulder, hip and knee joint positions at heel strike were similar across encoders for a target emotion but the remaining variables had a lot of variability between encoders, that variability could overwhelm the reliable pattern observed in the shoulder, hip and knee. Given this statistical challenge, the cluster of emotion portrayals in the body and multimodal datasets was impressive because in a large dataset with continuous variables, finding stable patterns among all variables across encoders would be difficult to achieve. Further exploration is needed to investigate whether subsets of variables combine in reliable patterns across encoders for each of the target emotions. For example, the full body dataset could be subdivided into a torso dataset and a limb dataset. Investigating smaller sets of variables, both in the body dataset and in the multimodal dataset, may provide evidence for more local patterns of emotion-related expressive behaviors.

An alternative explanation for the lack of strong evidence for the existence of multimodal patterns could be that we selected the wrong combination variables. A potential limitation of this analysis was that configuration variables (i.e. static joint positions and face positions) were combined with RoM variables that captured a dynamic movement quality in the body – that is, the combination of static and dynamic variables included in our analysis may be not capturing the same type of expressive information. Given that empirical evidence exists demonstrating that static and dynamic qualities in both the face and body are affected by emotion (Ambadar, Schooler, & Cohn, 2005; Atkinson et al., 2004), the authors do not believe combining static and dynamic variables contributed to the lack of support for multimodal patterns. However, as technology for measuring facial dynamics becomes available (e.g. AFA from CMU-Pitt) it will be possible to combine continuous variables that characterize dynamic qualities of emotion-related facial expressions with continuous variables that characterize the expressive dynamic qualities in the body.

The results of the body cluster analysis also suggests that there were two general types of movements with sad tending to look different from the other target emotions. In general, the sad cluster was characterized by less range of motion at the joints and limbs that were closer to the body than the cluster characterizing the other target emotions. A possible alternative that may improve discrimination is to normalize person's movements by their neutral / no emotion walking kinematics. This could potentially control for confounding encoder effects by including only information associated with how the movement changes due to an experienced emotion.

A potential limitation of this analysis is the lack of social interaction. Although expressions occurred in each modality, it is possible that congruency is more pronounced and expressive signals are stronger during social interaction when there is a clear advantage to using nonverbal signals to help communicate expressive meaning. However, this is the first study to provide empirical evidence that expressions do occur in multiple modalities even in the absence of social interaction. Additionally, combining modalities did improve clustering compared to the body. Thus, continuing to investigate how modalities interact, even in the absence of social interaction, is a valuable component to this area of research.

As a next logical step, the multimodal dataset used in this analysis should be used to test the prediction that subsets of body variables may cluster together. These smaller body clusters can then be combined with face data to determine whether there are more local patterns representing multimodal expression. Because clear and consistent videos of the face are available, when technology is available, these videos could also be used in automatic coding systems that could provide a data type more closely related to the body variables.

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Chapter 10

Conclusions

The goal of this dissertation was to investigate emotion-related multimodal behavioral patterns of the body and face. To do this, methodological limitations were addressed to allow comprehensive qualitative and quantitative characterizations of emotion-related movement. First, specialized equipment was designed and constructed for capturing facial expression during an unconstrained whole body movement task. The feasibility of using the equipment for studies on emotion-related behavior was then validated. Second, qualitative movement characteristics associated with emotions that were both felt by encoders and recognized by observers were assessed. Third, methods from biomechanics were used to quantitatively characterize the bodily expression of five target emotions during a walking task. Facial expressions that occurred during the walking task were also characterized, providing the data necessary for a multimodal analysis. Finally, the multimodal analysis combined objective measures from the face and body to evaluate whether these measures capture complex emotion-related interactions between modalities.

To address the specific aims of this dissertation, five datasets were necessary. Each dataset was derived from either encoder or observer participants. Overall, a total of 42 encoders and 120 observers contributed to the datasets in this dissertation. The encoders were non-actors and performed a constrained whole body movement task (walking). A balanced set of positive and negative emotions were assessed while a head-mounted camera simultaneously captured facial expressions during the walking task.

Specific Aim 1: Feasibility of using a head-mounted camera to capture facial expressions during body movement.

One challenge to studying multimodal signals has been the ability to simultaneously capture signals from different affective modalities. Therefore, the purpose of Specific Aim 1 was to develop and validate methodology for collecting face video during body movement. In this study, we tested the feasibility of assessing concurrent facial and bodily expressions while subjects experienced a range of target emotions. To collect facial expression data, we used a custom-designed head-mounted video camera that would provide adequate images for facial expression microanalysis but would not limit freedom of movement. Since wearing a head-mounted camera could potentially interfere with emotional expression, we assessed the effect of the head-mount on emotion elicitation, emotion recognition, qualitative aspects of body movement, and quantitative aspects of body movement. The results of these studies suggest that, while the head-mount may slightly constrain arm movement, wearing the head-mounted camera during motion capture is a valid method for collecting facial video during body movement.

Specific Aim 2: Effort-Shape Characteristics of Emotion-Related Body Movement.

The purpose Specific Aim 2 was to provide a comprehensive qualitative characterization of movement style for five target emotions and to assess whether specific movement style characteristics were associated with an observer's ability to accurately decode the emotion felt by the encoder. Although previous studies have demonstrated that expressive cues in body movement communicate emotion-related meaning, the comparison, replication, and further exploration of results from individual studies have been limited by the system chosen to characterize the expressive behaviors. Thus, an Effort-Shape analysis, a comprehensive and standard system for describing body movement, was used to characterize felt and recognized emotions during a walking task.

Overall, the combination of movement characteristics for the six Effort-Shape qualities was unique for each target emotion. Movement styles for the high arousal emotions anger and joy were judged by observers as having an expanded, stretched, and growing torso shape; limbs moved away from the body; movement through space was direct, focused, and channeled with strong, forceful, and powerful energy; and the timing of movements was sudden, hurried, and fast. Movement styles for the moderate arousal emotions content and neutral were judged as having an expanded, stretched, and growing torso shape; limbs moved neither close to nor away from the body and were neither contracted nor expanded; movement flow was free and relaxed; and movement timing was sustained and leisurely. The low arousal emotion sadness was judged differently from all other target emotions. Sad movements were judged as having a contracted torso shape; limbs moved close to the body; movement through space was indirect, wandering, and diffuse with a light energy; the timing of movements was slow; and movements were considered free, relaxed, and uncontrolled.

The consistency of judged emotion characteristics and the differences between emotions suggested that there may be a specific range on the continuum for each Effort-Shape quality that is associated with each target emotion. Evidence from the correlation analysis suggested that decoding accuracy may be more associated with a combination of Effort-Shape characteristics than with any one Effort-Shape quality characteristic. The combination of Effort-Shape characteristics may be particularly important for recognizing positive emotions. Thus, a specific range on the continuum for each Effort-Shape quality together with a specific combination of Effort-Shape characteristics may be important for recognizing emotions, particularly for positive emotions. This provides further support for the hypothesis that not only is there a small range of scores associated with high recognition, but that observers may also be responding to a specific combination of Effort-Shape characteristics.

Although this study did not aim to assess gender-related differences in expressive movement characteristics, the effect of gender on emotion expression isn't yet known. Therefore, gender was accounted for in this study, and interesting effects emerged that warrant further exploration in future analyses. Interestingly, female walkers were judged as tending toward the anchor more than the male walkers. The movement style difference between male and female encoders may be explained by one of two possibilities. First, these results may be interpreted as females being more expressive than males. However, there may have been a judging bias common across all observers. Thus, even if males and females are equally expressive, males may be judged as less expressive. Further investigation using quantitative data may reveal whether the movements of males and females are the same.

Specific Aim 3: Kinematics of Emotion-Related Body Movement

The purpose of Specific Aim 3 was to quantify and compare emotion-related whole-body kinematics. An alternative to observer-based coding of whole-body expressive movement is to use objective and quantitative kinematic methods. These methods describe body position and how it changes over time from 3-dimensional coordinate data generated with a motion capture system.

This study was the first to report whole body joint angular kinematics for five target emotions that were both felt by encoders and recognized by observers. The effects of emotion on position and range of motion characteristics were assessed for the limbs and torso. Because the movement task was held constant across encoders and emotions, significant differences in the joint angular kinematics could be attributed to the experienced emotion. Overall, our results suggest that while arousal level significantly affected both position and range of motion of the limbs and torso, there is also evidence for differences between emotions of the same pleasantness. Thus, joint angular kinematics including joint position and range of motion can be used to objectively characterize emotion-related body movement and to quantify differences between emotions.

While previous studies reported mean scores from observer based rating scales we did not know the true magnitude of the difference between emotions with respect to the actual quantitative movement parameters. Our results suggest that, at the individual joint level, the differences in position or range of motion between emotions are relatively small. Because we controlled for walker effects by including random effects of walker in our statistical model, we believe the validity of the significant difference between emotions. However, observer sensitivity to these small changes between emotions needs to be further explored in future studies.

Similar to the Specific Aim 2, gender was not a primary factor of interest. However, because little is known about the effect of gender on emotion expression, gender was accounted for in the kinematic analysis. Although a main effect of gender was not observed for any of the kinematic variables, significant interactions were found between gender and emotion for the elbow angle and for shoulder retraction / protraction, as well as neck rotation range of motion. In each case, emotion only affected females. This is consistent with findings in the qualitative analysis that suggested females are more expressive than males. Although the findings in this dissertation to do not rule out the possibility of observer bias, evidence is suggests that there may indeed be some gender differences in emotion expressivity. However, further work is needed to explicitly assess this hypothesis.

Specific Aim 4: Multimodal Analysis

The purpose of Specific Aim 4 was to combine objective measures from the face and body to evaluate whether these measures capture complex emotion-related interactions between modalities. Although previous studies suggest an interaction between expressive modalities, many questions about the nature of the interactions remain. Characteristics of these multimodal patterns have important implications in a variety of fields ranging from emotion research to virtual environments.

To explore whether there was evidence for the presence of multimodal patterns when an emotion is experienced, we performed a cluster analysis on a multimodal dataset that included data from the face and the body. It was hypothesized that evidence for multimodal patterns would be supported if the multimodal dataset resulted in more portrayals clustering for a given emotion than either of the unimodal datasets. Therefore, results from the multimodal cluster analysis were compared to cluster analyses performed on each individual modality to determine if more emotion-portrayals clustered together with the multimodal data compared to either of the individual modalities.

The methodology used in the current study demonstrated multimodal data resulted in more consistent behavioral patterns than data generated from the body alone. However, facial expressions were more consistent then either bodily or multimodal expressions. Although it was expected that multimodal patterns would be more consistent than patterns in either of the individual modalities, this finding could have resulted from methodological issues related to the type of movement. Therefore, while this study did not provide strong evidence for the existence of multimodal patterns, the results suggest that subsets of measures from the body may combine with facial measures to form consistent emotion-related multimodal patterns.

As a next logical step, the multimodal dataset used in this analysis should be used to test the prediction that subsets of body variables may cluster together. These smaller body clusters can then be combined with face data to determine whether there are more local patterns representing multimodal expression. Because clear and consistent videos of the face are available, when technology has been validated and is available, these videos should be used in automatic coding systems that could provide a data type more closely related to the body variables.

Summary

Overall, this dissertation established the validity of important methodology opening the possibility to characterize expressive multimodal behavior. Previous methodological limitations were related to simultaneously capturing behavior from multiple modalities (specifically the face and body) and methods for characterizing expressive bodily behavior. Thus, methodological limitations had to be addressed to allow comprehensive qualitative and quantitative characterizations of emotion-related body movement.

This dissertation developed and validated a specialized head-mounted camera for capturing facial expression during a movement task. Previous limitations related to the emotion portrayals were overcome by using a set of stimuli generated with non-actor subjects, a constrained whole body movement task, emotion elicitation procedures to induce target emotions in the subjects, and a balanced set of positive and negative emotions. Before assessing the qualitative and quantitative behavioral characteristics in the emotion portrayals, an emotion recognition study was conducted to determine whether the emotion signal was present in each emotion portrayal. A forced-choice questionnaire that included the target emotions and a distractor item for each target ensured that the emotion selected by the observers was not due to chance. These methodological advances ensured the quality of the emotion portrayals and.

In addition to the methodological needs related to generating the emotion stimuli, several important advancements were also made related to assessing the behavioral characteristics. A systematic methods for qualitatively assessing whole body movement style characteristics was used. Additionally, this was the first study to quantitatively assess whole body movement characteristics associated with emotions during walking. Finally, the face and body were assessed simultaneously during walking and methods were used that allowed multimodal features of emotionally expressive behavior to be explored.

Because of these methodological advances, this dissertation provided a validated method for simultaneously capturing face video during body movement that has not been available, yet is necessary for studying multimodal behavior. Second, this dissertation provided a comprehensive characterization of expressive body movement using a study-independent methodology. Use of these biomechanical methods provided a comprehensive and systematic assessment of emotion-related movement kinematics.

These methods provided a novel assessment tool for investigating questions about the psychology of emotion that could not be addressed with the tools previously available.

Overall, these studies demonstrate that emotion affects movement style characteristics and these characteristics can be measured both qualitatively and quantitatively. In addition to these findings, several methodological advances were made. This dissertation showed that emotions can be elicited and recognized in non actors during walking. A method for capturing video of facial expression during a whole body movement task was developed and validated, thereby demonstrating that face and body data can be captured simultaneously. Analysis of the face video revealed that facial expression occurred during walking without social interaction. With respect to the body, a unique Effort-Shape profile was generated for each of the target emotions and kinematic characteristics were associated with the target emotions. Finally, results of the multimodal analysis suggest that subsets of kinematic variables may be more useful in multimodal classification. Key results can be categorized into one of three groups: bodily expression, multimodal expression, emotion recognition.

Bodily expression

1. **The use of Effort-Shape qualities to describe body movement provided a comprehensive and study-independent system for characterizing emotion-related body movement.** Thus, the results of this study can be compared to future analyses on expressive body movement, an important methodological necessity for moving this research forward.

2. **Emotion arousal level may be an important factor related to measures of expressive behavior.** During high arousal emotions, the shape of the limbs and torso can be characterized as expanded. Likewise, joints tended to move through a large range of motion during high arousal emotions. Because walking speed was not controlled in these studies, further investigation is necessary to explicitly assess whether results are only due to changes in speed.

3. **Emotion-related movement tends to be associated with specific characteristics.** For example, the neck tended to be flexed (head down) when experiencing sadness despite the amount of flexion varying by individual.

4. **The magnitude of differences between emotions for an individual characteristic could be quite small.** This suggests that changes due to emotion may be subtle. Further studies are needed to systematically test the clinical and practical significance of these small differences.

Emotion recognition

5. **A small range of Effort-Shape scores may be associated with decoding accuracy.** This result indicates that observers are sensitive to subtle changes in movement style and that exaggerated movement may affect emotion recognition.

6. **A combination of Effort-Shape characteristics may be more important for observer recognition of emotion than any single characteristic, particularly for positive emotions.** Thus, a single characteristic may not provide adequate discrimination between emotions.

7. **A combination of kinematic parameters may be more important for observer recognition of emotion than any single characteristic, particularly for positive emotions.** Similar to the corresponding finding in the qualitative analysis, this finding implies that a single characteristic may not provide adequate discrimination between emotions.

Multimodal expression

8. **Wearing a head-mounted camera is a valid methodology for capturing facial expression during movement tasks.** This validated equipment opens new

opportunities for studying expressive behavior that previously limited multimodal studies.

9. **Combined data from the face and body improved clustering compared to the body data alone.** Therefore, further investigation is necessary to assess whether subsets of body variables improve clustering in the body.

Applications

Although many basic science questions resulted from this dissertation, the potential exists to begin developing and exploring real world applications. Applications range from military, clinical / therapeutic, to entertainment. The common theme to all of these applications is understanding what the cues are that communicate expressive meaning, how are they measured, and how are they interpreted.

Clinical / Rehabilitation -- Imagine a virtual application that could help children with autism or adults with Asperger's syndrome learn to read and possibly even teach them to produce nonverbal social cues. This type of system could provide training in a controlled setting to guide the person as they develop knowledge about nonverbal communication. These skills could improve their everyday functioning and overall quality of life.

Since the introduction of the Wii in 2006, development of applications that use the whole body for interaction has exploded. A promising direction for this technology is to use whole body interaction for physical rehabilitation. Thus, patients could supplement physical therapy at home with interactive exercises that could both provide immediate feedback to the patient and track specific clinical measures for the therapist.

Entertainment – An ongoing challenge in the entertainment and gaming community is generating realistic human movement. Two methods are currently used to help guide the generation of the animated movements: Effort-Shape qualities and motion capture. Past use of Effort-Shape qualities has been limited because an interpretation between the qualities and the characteristics associated with specific expressions have not been available. The outcome of my dissertation begins providing practical information about the Effort-Shape qualities that animators can start applying to games and films. A remaining question is how these qualities translate to the actual movements (i.e., the kinematics).

Military – Virtual training systems are currently under development for military applications. These systems require realistic movement from the virtual human. Additionally, these systems need to both detect and generate expressive behaviors that allow natural interaction between the virtual and real humans.

Law enforcement -- If we understand how multiple modalities combine during expressive behavior, improved methods for detecting lies behavior may be developed. Thus, subtle inconsistencies between modalities may prove to be an important indicator of deceptive behavior.

The common thread that ties all of these applications together is that subtle movement qualities can be measured and can have important social meaning. Although small changes in behavior may not always be mechanically significant, those same changes may be socially significant. That is, small changes in behavior can result from changes in an individual's internal state. Whole body movement and multimodal interactions can provide measurable cues that correspond to the internal state.

Next Steps

To continue progressing towards the development of applications such as the ones described above, further research is necessary to explore bodily expression, emotion recognition, and multilmodal expression. Overall, the methods used in this dissertation provide valuable tools for exploring these areas of expressive behavior. Based on the outcomes of this dissertation many questions are ready to be addressed. The list below includes some ideas but is not exclusive.

1. Assess the effect of speed related kinematic changes in gait. Are they different from what we observed between arousal level, or are there changes that are due to just emotion and not arousal level (i.e. speed).

2. Begin development of a large scale motion capture database using the methods in this dissertation. Ideally, additional data would include a full body (i.e., both limbs) kinematic model, multiple tasks and multiple trials for each affective state.

3. Develop and validate training procedures for the used of Effort-Shape analysis. A possible outcome of this 6 item questionnaire is to begin using it in clinical settings as an assessment tool.

4. Use statistical methods that do not require parameterization of the joint kinematic variables to assess the effects of emotion on movement.

5. Begin assessment of effect of emotion on joint coordination.

6. Assess the practical meaning of small emotion-related differences in joint kinematics.

Appendices

Appendix 1. Elicitation Feelings Questionnaire

Feelings Questionnaire

Instructions: In any given circumstance, people often have a number of different feelings. Please think back to how you felt while you were walking. Please indicate how much of each emotion you felt during that time. Use the following 0 to 4 scale to make your ratings.

0 = not at all
1 = a little bit
2 = moderately
3 = quite a bit
4 = extremely

____ 1. I felt angry, irritated, annoyed.
____ 2. I felt content, serene, peaceful.
____ 3. I felt glad, happy, joyful.
____ 4. I felt awe, wonder, amazement.
____ 5. I felt sad, downhearted, unhappy.
____ 6. I felt scared, fearful, afraid.
____ 7. I felt surprised, amazed, astonished.
____ 8. I felt disgusted, repulsed, revolted.

Appendix 2. Walker Recruitment Flyer

Subjects Needed

The goal of this research project is to determine how human movement patterns are changed when different emotions are expressed. You will be asked to walk while experiencing different emotions. Whole body motion data will be collected using video cameras. The study requires about 60 minutes and you will receive $25 for your participation. To be eligible you must be 18-35 years old.

For more information, contact Beth Crane in the Dept. of Movement Science at bcrane@umich.edu (preferred) or by phone at 763-0013.

Appendix 3. Autobiographical Memories Worksheet

Autobiographical Memories Task

Later in this study, we will ask you to visualize and try to relive specific memories from your own life experience. To facilitate this process, we'd like you to locate these specific memories right now, by answering a few questions about each. Take a moment to consider each of the following five autobiographical memories.

NOTE: Identify people with initials and relationship descriptors only (e.g., my mom, my boyfriend, T.S.).

MEMORY #1

Think of a time in your life when you felt very offended, for instance, when you felt furious or enraged, or felt like you wanted to explode.

Using only a few words, please indicate:

a) ….where you were:

b) …who you were with:

c) ….what caused the feeling/what was it about?

MEMORY #2

Think of a time in your life when you felt in despair, for instance, when you felt low or depressed, or felt like you wanted to withdraw from the world.

Using only a few words, please indicate:

a) ….where you were:

b) …who you were with:

c) ….what caused the feeling/what was it about?

MEMORY #3

Think of a time in your life when you did not feel any emotion, for instance, when you put gas in your car or did your laundry.

Using only a few words, please indicate:

a) ….where you were:

b) …who you were with:

c) ….what caused the feeling/what was it about?

MEMORY #4

Think of a time in your life when you felt fulfilled, for instance, when you felt satisfied or comfortable, or felt like you wanted to relax and savor life.

Using only a few words, please indicate:

a) ….where you were:

b) …who you were with:

c) ….what caused the feeling/what was it about?

MEMORY #5

Think of a time in your life when you felt exhilarated, for instance, when you felt euphoric or very playful, or felt like you wanted to jump up and down.

Using only a few words, please indicate:

a) ….where you were:

b) …who you were with:

c) ….what caused the feeling/what was it about?

Appendix 4. Walker Consent Form

CONSENT FOR RESEARCH STUDY

Title of research project: Kinematics of Bodily Expression of Emotion

Names of researchers: Melissa Gross, Ph.D.
Elizabeth Crane, M.S.

Purpose of study: The purpose of the study is to understand how emotion affects body movements. Subjects will perform ordinary body movements while experiencing different emotions. Subjects' body motions will be recorded using video cameras and the data will be analyzed to determine how emotions change the body motions in characteristic ways. Other subjects will view the videos and assess the emotions in the body movements. The study is unique because it uses an interdisciplinary approach that integrates contemporary psychological, kinesiological, and engineering methods to yield important new insights into the relationship between emotion and body movement that may be useful in both basic science and clinical settings.

The outcome of the study will be new information regarding bodily expression of emotion. It is expected that results of the study will be published in peer-reviewed scientific journals, will be presented at scientific meetings, and will serve as preliminary analyses for grant proposals to external funding agencies.

Description of the research project: Once the Consent form is signed, you will be asked to change into close-fitting exercise clothing. You can either supply your own clothing or wear laboratory-provided clothes. The laboratory clothing consists of a black sleeveless tank top and "bike" shorts. You will change clothes in a restroom located near the laboratory. After you have changed, the investigator will attach approximately 35 markers on specific locations on your body. The location of these markers will be tracked by the video cameras. The markers are light-weight, spherical balls covered with reflective tape that will be attached to your clothing or skin with adhesive stickers or velcro.

After being videotaped while standing, you will be asked to do an autobiographical memories task. In this task, you will be asked to recall memories related to five different emotional states and write them down. Later you will be asked to recall these specific emotional memories.

Now, videos will be made while you walk across the laboratory (approximately 20 feet) with the different emotions. Emotions will be induced by asking you to review the memories that you previously recalled and wrote down. You will be asked to perform three trials of each of the emotions. The order of emotions will be randomly selected. Immediately after each you will be asked to complete a Feelings Questionnaire that will allow you to identify the feelings you had during the movement trial.

Finally, the investigator will remove markers from your clothing and skin, and you can change back into your clothes. When you return to the lab after changing, the investigator will answer any remaining questions that you have, will give you a copy of your signed Consent form, and will discuss details of compensation with you.

Duration of participation of the subject in the study: It will take approximately 60 minutes to complete the experimental session.
Risks and discomforts of the research: The markers placed on your skin may cause slight discomfort when they are removed. The floor of the laboratory is flat and obstacle-free but a slight chance exists that you might trip when doing the walking trials. You may feel some discomfort when wearing close-fitting clothes in front of the investigators or when performing movement tasks in front of video cameras. You may be uncomfortable when you recall experiences associated with negative emotions in the autobiographical memories task.

Measures taken to minimize risks and discomforts: To minimize skin discomfort when removing markers, the investigators will give you the option of removing the markers yourself. The investigators will keep the floor free of obstacles to minimize your risk of tripping. The investigators can help minimize discomfort of performing movements in front of others or cameras by maintaining a professional atmosphere in the laboratory. You can minimize your discomfort in recalling unpleasant experiences by choosing to recall different, less uncomfortable experiences.

Expected benefits to subjects and to others: We do not expect that there will be direct benefits to you from participating in this study. The results of the study will provide new information and insights into how emotions are expressed in body movements which may be beneficial in the future in clinical settings and basic understanding of emotional content in movement.

Costs to subject resulting from participation in the study: No costs to you resulting from your participation in the study are expected.

Payments to subject for participating in the study: You will receive $25 for your participation in this study. You will receive full payment even if you choose not to complete the study.

Confidentiality of information collected: You will not be identified in any reports on this study. The records will be kept confidential to the extent provided by federal, state and local law.

Electronic copies of your digital videos, as well as the videotapes themselves, will be kept in a locked cabinet or on a password-protected computer. Electronic data and videotapes that might have identifiable information will be destroyed five years after the data from this study are published.

If you are a student affiliated with one of the investigator's school or college, you should know that no person who is or may be involved in your instruction and no person who is a student in your school or college will have access to information associated with your name or a code linked to your name.

Management of physical injury: In the unlikely event of physical injury resulting from research procedures, the University will provide first-aid medical treatment. Additional medical treatment will be provided in accordance with the determination by the University of its responsibility to provide such treatment. However, the University does not provide compensation to a person who is injured while participating as a subject in research.

Availability of further information: If significant new knowledge is obtained during the course of this research which may relate to your willingness to continue participation, you will be informed of this knowledge. Also, you may contact the following person for answers to further questions about the research, your rights, or any injury you may feel is related to the study.

Name of person: Melissa Gross, Ph.D.
Telephone #: 734-668-0240

Voluntary nature of participation: Your participation in this project is voluntary. Subsequent to your consent, you may refuse to participate in or withdraw from the study at any time without penalty or loss of benefits to which you may otherwise be entitled.

Documentation of consent: One copy of this document will be kept together with our research records on this study. If you are in the Dental School as a dental student, a second copy may be placed in your dental school record. If you are a student in the School of Music, a second copy may be placed in your music school record. In other schools, a copy may be placed in the school's record. A third copy will be given to you to keep.

Audio/visual recording: Videotapes will be taken of you from the side and back during the study. Your videos will be shown to other participants in the study to validate the emotions you expressed, but your face will be obscured electronically and your identity will not be revealed. The videotapes may also be used in scientific presentations, but your identity will be protected by electronically blurring your face. Other videos will be taken of your face while you walk. These face videos will be viewed only by Dr. Gross or her Ph.D. student, Elizabeth Crane. Please sign below if you are willing to participate in the study, and to have videotapes taken of you during the study. You may still participate in the study if you are not willing to be videotaped.

Questions about participation: Should you have questions regarding your rights as a participant in research, please contact: Institutional Review Board Kate Keever 540 East Liberty Street, Suite 202 Ann Arbor, MI 48104-2210 734-936-0933 email: irbhsbs@umich.edu

Consent of the subject: I have read the information given above. I understand the meaning of this information. Dr. Gross has offered to answer any questions I may have concerning the study. I hereby consent to participate in the study.

I consent to participate in the study.

Signed: ______________________________ Date: ____________________

I consent to be videotaped during the study.

Signed: ______________________________ Date: ____________________

____

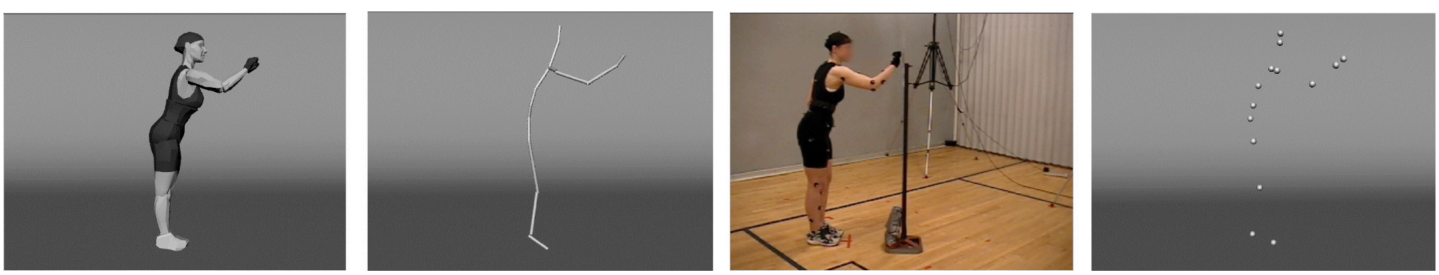
Printed Name Consenting Signature

Appendix 5. Observer Recruitment Flyer

Subjects Needed

The goal of this research project is to determine how emotions affect body movements. You will be asked to watch videos of people walking with different emotions. The study requires about 60 minutes and you will receive $15 for your participation. To be eligible you must be 18-35 years old.

For more information, contact Erica Lewis, Movement Dynamics Lab, Dept. of Movement Science at erlewis@umich.edu (preferred) or by phone at 734-763-0013.



Appendix 6. Observer Consent Form - Recognition Study

CONSENT FOR RESEARCH STUDY

Title of research project: Kinematics of Bodily Expression of Emotion

Names of researchers: Melissa Gross, Ph.D.
Elizabeth Crane, M.S.

Purpose of study: The purpose of the study is to understand how emotion affects body movements. Subjects will perform ordinary body movements while experiencing different emotions. Subjects' body motions will be recorded using video cameras and the data will be analyzed to determine how emotions change the body motions in characteristic ways. Other subjects will view the videos and assess the emotions in the body movements. The study is unique because it uses an interdisciplinary approach that integrates contemporary psychological, kinesiological, and engineering methods to yield important new insights into the relationship between emotion and body movement that may be useful in both basic science and clinical settings.

The outcome of the study will be new information regarding bodily expression of emotion. It is expected that results of the study will be published in peer-reviewed scientific journals and will serve as preliminary analyses for grant proposals to external funding agencies.

Description of the research project: Once the Consent form is signed, you will be asked to view a series of video sequences. The sequences consist of videos of people walking. You will be seated in front of a computer, and the videos will be displayed on a computer screen. The same video will be repeated three times; after each sequence, you will be asked to complete the Feelings Questionnaire. The Feelings Questionnaire will allow you to identify the feelings that you think the person experienced while they walked. You will have as much time as needed to complete the Feelings Questionnaire before proceeding to the next set of video images.

Duration of participation of the subject in the study: It will take approximately 60 minutes to complete the experimental session.

Risks and discomforts of the research: No risks or discomforts are anticipated from your participation in the experimental session.

Expected benefits to subjects and to others: We do not expect that there will be direct benefits to you from participating in this study. The results of the study will provide new information and insights into how emotions are expressed in body movements which may be beneficial in the future in clinical settings and basic understanding of emotional content in movement.

Costs to subject resulting from participation in the study: No costs to you resulting from your participation in the study are expected.

Payments to subject for participating in the study: You will receive $15 for your participation in this study. You will receive full payment even if you choose not to complete the study.

Confidentiality of information collected: You will not be identified in any reports on this study. The records will be kept confidential to the extent provided by federal, state and local law.

Any data that might have identifiable information will be stored in a locked cabinet or on a password-protected server and will be destroyed five years after the data from this study are published.

If you are a student affiliated with one of the investigator's school or college, you should know that no person who is or may be involved in your instruction and no person who is a student in your school or college will have access to information associated with your name or a code linked to your name.

Management of physical injury: In the unlikely event of physical injury resulting from research procedures, the University will provide first-aid medical treatment. Additional medical treatment will be provided in accordance with the determination by the University of its responsibility to provide such treatment. However, the University does not provide compensation to a person who is injured while participating as a subject in research.

Availability of further information: If significant new knowledge is obtained during the course of this research which may relate to your willingness to continue participation, you will be informed of this knowledge. Also, you may contact the following person for answers to further questions about the research, your rights, or any injury you may feel is related to the study.

Name of person: Melissa Gross, Ph.D.
Telephone #: 734-668-0240

Voluntary nature of participation: Your participation in this project is voluntary. Subsequent to your consent, you may refuse to participate in or withdraw from the study at any time without penalty or loss of benefits to which you may otherwise be entitled.

Documentation of consent: One copy of this document will be kept together with our research records on this study. If you are in the Dental School as a dental student, a second copy may be placed in your dental school record. If you are a student in the School of Music, a second copy may be placed in your music school record. In other schools, a copy may be placed in the school's record. A third copy will be given to you to keep.

Questions about participation: Should you have questions regarding your rights as a participant in research, please contact: Institutional Review Board Kate Keever 540 East Liberty Street, Suite 202 Ann Arbor, MI 48104-2210 734-936-0933 email: irbhsbs@umich.edu

Consent of the subject: I have read the information given above. I understand the meaning of this information. Dr. Gross has offered to answer any questions I may have concerning the study. I hereby consent to participate in the study.

I consent to participate in the study.

Signed: ____________________________ Date: ___________________

Printed Name Consenting
Signature

Appendix 7. Feelings Questionnaire - Recognition Study

Feelings Questionnaire

Instructions: In any given circumstance, people often have a number of different feelings. Please think back to how they felt while they were walking. Choose one of the following.

____ 1. They felt angry, irritated, annoyed.
____ 2. They felt content, serene, peaceful.
____ 3. They felt glad, happy, joyful.
____ 4. They felt proud, confident, self-assured.
____ 5. They felt sad, downhearted, unhappy.
____ 6. They felt scared, fearful, afraid.
____ 7. They felt surprised, amazed, astonished.
____ 8. They felt disgusted, repulsed, revolted.
____ 9. They felt neutral.
____ 10. None of the above.

Appendix 8. Recognition Study Testing Instructions

Head mount Phase II Study
Testing Instructions

Step 1 - Study Preparation:

1. Determine the subjects ID number and survey version from the subject sheet.

2. **Computer set-up**

   a. On the computer, open Survey Monkey via Netscape at (www.surveymonkey.com) and log in.

   b. Select and open the appropriate survey version in Survey Monkey that corresponds to the video version:

   c. Enter the subject number on the first page.

3. **Paper Work Preparation**
   Collect the necessary paper work materials.
   - Consent Form for the subject to sign
   - Subject ID sheet to record subject number, name, test date

Step 2 – Running the Study

1. Welcome the subject, introduce yourself, and thank them for coming

2. Sit down with the subject in the testing area.

3. Review the Consent Form with them:
   - We are studying how emotion affects body movement
   - When testing is over, I will have you fill out the paper work to get paid
     - → Are you a UM employee or UM non-employee?
   - All information that you provide including your name will be kept confidential and will not be mentioned in any reports.
   - If you have any questions after the study you can contact Dr. Gross, Beth Crane, or the IRB. Their contact information is listed in this Consent Form, which you will receive a copy of at the end of the study.
   - Your participation is voluntary
   - I want to remind you that we are not testing you; we want to know what people think of these clips. There is no wrong answer.

4. Tell the subject that you will now give them a chance to review the Consent Form and to notify you when they are finished going over the form. *Go do something else away from the testing room until they notify you that they are finished.*

5. Ask if they have any questions. After questions have been answered take the signed Consent Form and tell them that you will make them a copy of the Consent Form to keep for their records. *You will give a copy to them at the end of the study*.

6. Explicate/review the testing procedures with the subject and run through the practice videos with them:

Testing procedures:

1- Before we start the testing, I need you to fill in Background Information page. Answering these questions is voluntary.

2- You will be watching 110 clips of people walking.

3- After each clip you will be asked to take a survey to assess the body movements of the person in the clip.

4- You will watch the clip on this page *(click next from the demographics page get to the page)*

5- The clip will automatically play when the page opens.

6- When you are finished watching the clip select the response from this drop down menu that best fits what you think the person in the clip is feeling. Remember, there are no wrong answers.

7- Once you have made your selecting for the clip you can click the NEXT button to view the next clip.

8- Now, Here is a clip that you can practice with.

Appendix 9. Effort-Shape Study Testing Instructions

Step 1 - Study Preparation:

4. Determine the subjects ID number and survey version from the subject sheet.

5. **Computer set-up**

    a. Open link placed in grosslab/validation/hmount/documentation/surveymonkeylinks.

    b. Select and open the appropriate survey version in Survey Monkey that corresponds to the video version:

    c. Enter the subject number on the first page.

6. **Paper Work Preparation**
    Collect the necessary paper work materials.
    - Consent Form for the subject to sign
    - Subject ID sheet to record subject number, name, test date

Step 2 – Running the Study

7. Welcome the subject, introduce yourself, and thank them for coming

8. Sit down with the subject in the testing area.

9. Review the Consent Form with them:
    - We are studying how emotion affects body movement
    - When testing is over, I will have you fill out the paper work to get paid
        → Are you a UM employee or UM non-employee?
    - All information that you provide including your name will be kept confidential and will not be mentioned in any reports.
    - If you have any questions after the study you can contact Dr. Gross, Beth Crane, or the IRB. Their contact information is listed in this Consent Form, which you will receive a copy of at the end of the study.
    - Your participation is voluntary
    - I want to remind you that we are not testing you; we want to know what people think of these clips. There is no wrong answer.

10. Tell the subject that you will now give them a chance to review the Consent Form and to notify you when they are finished going over the form. *Go do something else away from the testing room until they notify you that they are finished.*

11. Ask if they have any questions. After questions have been answered take the signed Consent Form and tell them that you will make them a copy of the

Consent Form to keep for their records. *You will give a copy to them at the end of the study*.

12. Explicate/review the testing procedures with the subject and run through the practice videos with them:

Testing procedures:

9- Before we start the testing, I need you to fill in Background Information page. Answering these questions is voluntary.

10- You will be watching 120 clips of people walking. One survey will have 110 clips and a second survey will have 10 more clips.

11- After each clip you will be asked to take a survey to qualitatively assess the body movements of the person in the clip.

12- You will watch the clip on this page *(click next from the demographics page get to the page)*

13- The clip will automatically play when the page opens.

14- When you are finished watching the clip click on next to answer 6 questions about what you think about the movement. Remember, there are no wrong answers.

15- What you see now is the survey you will take after you watch each clip.

- This survey will not change through out the study
- There are 6 body movements that you will be assessing
- Each bar is a different scale that is unique to each of the body movements you will be evaluating
- For each body movement, you will be qualitatively rating the characteristics of the movement based on the three word descriptions on each ends of the scale.
- The circles correspond to how much you think the body movement corresponds to the word descriptions given on each side of the scale. The closer the circles are to the left side of the scale, the more the body movement depicts the three characteristics labeled on the left side. The closer the circles are to the right side, the more the body movement depicts the three characteristics labeled on the right side and the less the movement depicts the characteristics labeled on the opposite (left) side of the scale.
- *For example*, the first body movement you will need to rate is the torso shape.
    - If you think that the torso of the person in the clip is extremely contracted, bowed, and shrinking, then you will select the very left circle of the scale *(point to it)*.
    - If you think that the torso of the person in the clip is extremely expanded, stretched, and growing, then you will select the circle on the very right side of the scale *(point to it)*.

- If you think that the torso shape is between being contracted, bowed, shrinking and being expanded, stretched, growing, then you will select the circle in the middle.
- If you think that the torso shape is not extremely contracted, bowed, and shrinking, but a little less so, then you would select the second circle from the left *(point to it)*.
- If you think that the torso shape is not extremely expanded, stretched, and growing, but a little less so, then you will select the second circle from the right *(point to it)*.

16- Once you have completed the survey page by rating all 6 body movements, click NEXT at the end of the page to view the next clip.

17- Now, practice clips.

18- After you have completed the first survey, please notify me and I will bring up the next survey.

Step 3 – Finishing Up

- Have the subject fill out the necessary information on the payment form

- Make any necessary copies of the payment form:
  - → **Employee Payment Form:**
    - Subject = nothing
    - Lab = copy (file form in binder in Effort Shape Study drawer)
    - Nancy = original (put form in "*Payment Form" bin*)
  - → **Non-employee payment form (mailed)**
    - Subject = copy
    - Lab = copy (file form in binder in Effort Shape Study drawer)
    - Nancy = original (put form in "Payment Form" bin)
  - → **Non-employee payment form (subject pick-up)**
    - Subject = original
    - Lab = copy (file form in binder in Effort Shape Study drawer)
    - Nancy = copy with note that says "For your records" on the form (put form in "Payment Form" bin)
- Remind the subject that if they have any questions or concerns regarding payment, they can e-mail Beth Crane

The paper trail:

<u>Consent Form:</u>
- Subject = copy
- Lab = original

<u>Employee Payment Form:</u>
- Subject = nothing
- Lab = copy (file form in binder in Effort Shape Study drawer)
- Nancy = original (put form in "*Payment Form" bin*)

<u>Non-employee Payment Form (mailed):</u>

- Subject = copy
- Lab = copy (file form in binder in Effort Shape Study drawer)
- Nancy = original (put form in "Payment Form" bin)

Non-employee Payment Form (subject pick-up):

- Subject = original
- Lab = copy (file form in binder in Effort Shape Study drawer)
- Nancy = copy with note that says "For your records" on the form (put form in "Payment Form" bin)

Appendix 10. Effort-Shape Study Recruitment Flyer

Subjects Needed

The goal of this research project is to determine how emotions affect body movements. You will be asked to watch videos of people walking with different emotions. The study requires about 60 minutes and you will receive $15 for your participation. To be eligible you must be 18-35 years old.

For more information, contact Alissa Harakal, Movement Dynamics Lab, Dept. of Movement Science at haraam@umich.edu.