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The effect of emotion on movement smoothness during gait in healthy young adults

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ABSTRACT

This study aimed to investigate the effect of emotion on movement smoothness during gait. We followed an autobiographical memories paradigm to induce four target emotions, neutral emotion, sadness, anger and joy, in eighteen healthy young adults. Participants performed gait trials while feeling the target emotions. We collected gait data using an eight-camera optoelectronic motion capture system. We measured spatiotemporal gait parameters, smoothness of linear movements for the whole body center-of-mass (COM), head, thorax and pelvis in the anterior–posterior (AP), vertical (VT) and mediolateral (ML) directions, and smoothness of angular movements in the sagittal plane for the shoulder, elbow, wrist, hip, knee and ankle. Movement smoothness was measured as jerk, the first time derivative to acceleration, normalized to movement distance and stride time. Compared to sadness, gait speed increased with anger and joy, and spatiotemporal parameters associated with increased gait speed changed accordingly. In the VT direction, movement smoothness in the whole body COM, head, thorax and pelvis increased for anger and joy compared to sadness. In the AP direction, movement smoothness increased only for the head for neutral emotion, anger and joy compared to sadness. In the ML direction, emotion did not affect movement smoothness. In angular movements, smoothness in the hip and ankle increased for anger compared to sadness. Smoothness in the shoulder increased for anger and joy compared to sadness. The present findings suggest that emotion affects movement smoothness during gait, and that anger and joy are associated with increased movement smoothness.

1. Introduction

Feeling emotions influences gait patterns. Montepare et al. (1987) characterized gait performed with sadness, anger, happiness and pride based on observations. They reported that emotional gait can be qualitatively described like “heavyfootedness” for angry gait. Crane and Gross (2013) applied a systematic analysis based on observations of movement qualities to gait performed with neutral emotion, anger, contentment, joy and sadness. They reported the movement qualities were distinct for gait performed with different emotions. These studies suggest that emotion affects body movements in ways that can be detected by observers, but the qualitative descriptors limit biomechanical quantification of the effects.

Researchers have quantified body movements during emotional gait. Michalak et al. (2009) investigated gait characteristics associated with sadness and happiness. They found, compared to happiness, decreased gait speed, arm swing and vertical movement, and increased body sway and slumped posture for sadness. Roether et al. (2009) examined important features for perceiving anger, happiness, sadness, fear and neutral emotion from gait. They identified that speed and posture are critical for emotion perception during gait. Gross et al. (2012) investigated how gait changes while feeling neutral emotion, anger, contentment, joy and sadness. They reported the fastest gait speeds for anger and joy, the slowest gait speeds for sadness, and corresponding changes in limb movements to changes in gait speeds. They reported, however, that postural changes in the upper body are independent of gait speed. These studies document attributes of body movement during emotional gait, but it is difficult to relate biomechanical findings to the observational descriptors provided in the existing literature. The effect of emotion may be to coordinate body movement, as suggested by Frijda (1987), defining emotion as a “tendency to act”. Thus, biomechanical variables that assess movement coordination may be useful in documenting the effect of emotion on body movement.

Smoothness is considered as a measure of coordinated movement (Hogan and Sternad, 2009) but it has been investigated in only a few movement studies of emotion. Montepare et al. (1999)

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documented qualitative smoothness during expressive gestures for neutral emotion, happiness, anger and sadness. They reported "jerky movement" for happiness and anger, and "smooth movement" for neutral emotion and sadness. Pollick et al. (2001) measured jerk, the first time derivative to acceleration, of the wrist during drinking and knocking performed with strong, happy, excited, angry, neutral, relaxed, afraid, sad, tired and weak affects. They reported jerkier movement for angry, excited, happy, strong and neutral affects compared to sad, tired, relaxed, weak and afraid affects. In contrast, Kang and Gross (2015) measured normalized jerk of the whole body center-of-mass (COM) during sit-to-walk performed with neutral emotion, sadness, anger and joy. They found the opposite result, that is, jerkier movement for sadness than for anger and joy.

One possible reason for these conflicting findings may be how smoothness was assessed. If movement time and amplitude are not normalized, jerk increases with faster and larger movements (Hogan and Sternad, 2009). Findings from Montepare et al. (1999) were based on observers' qualitative judgements, and it is unclear which particular aspects of body movement were assessed or what the influence of movement time and amplitude might have been on the observers' judgements. Jerk reported by Pollick et al. (2001) was not normalized thus could be confounded by movement time and amplitude (Hogan and Sternad, 2009). To control for the potential confounding effects of movement speed, it may be necessary to quantify movement smoothness using normalized jerk measures.

Another possible reason for these conflicting findings may be related to the notion of emotion acting to coordinate body movements (Frijda, 1987). It is possible that the expressive demands on the body might be different for individual body segments and the whole body COM. If this is the case, it may be that emotion coordinates motions of all segments of the body to achieve an expressive goal, regardless of the consequences on motion of the whole body COM. By investigating normalized jerk in body segments and the COM, we may understand better how emotion coordinates body movements.

An emotion can be described using a combination of emotional arousal and valence, based on the circumplex model (Russell, 1980). The emotional arousal and valence indicate the degrees of activation-deactivation and pleasantness-unpleasantness, respectively. For example, sadness is an emotion with low arousal and unpleasant valence (Posner et al., 2005). Emotions with different arousals and valences can be elicited in the laboratory by recalling past episodes of one's own life, referred to as "autobiographical memory". Retrieval of an autobiographical memory includes several neural processes associated with brain activities in the prefrontal cortex (Svoboda et al., 2006; Cabeza and Jacques, 2007). Briefly, an autobiographical memory requires efforts that search one's memory about an event, infer the event and detect errors about the event, and finally one constructs the autobiographical memory. These neural processes entail an emotion (Svoboda et al., 2006; Cabeza and Jacques, 2007), which are manifested in emotionally expressive movements.

We aim to investigate the effect of autobiographically recalled emotions on movement smoothness during gait in healthy young adults. We quantified jerk normalized to movement time and amplitude for measuring smoothness. Comparing anger and sadness enabled us to examine how emotional arousal independent of valence affects smoothness. We were also able to examine how emotional valence independent of arousal affects smoothness by comparing joy and anger. Finally, we explored associations between movement coordination during gait and emotions based on these comparisons.

2. Methods

2.1. Participants

Eighteen adults with no musculoskeletal or neurological illnesses participated in this study (11 women; age = 20.2 ± 1.8 years; height = 1.67 ± 0.07 m). Informed consent approved by the University of Michigan Institutional Review Board was obtained from all participants.

2.2. Procedures

We used an eight-camera motion capture system (Motion Analysis, Santa Rosa, CA, USA) to collect motion data from 41 reflective markers attached on participants' anatomical landmarks: bilaterally on the anterior superior iliac spine, posterior superior iliac spine, greater trochanter, lateral epicondyle of the femur, shank, lateral malleolus, heel, the first metatarsal head, acromion, upper arm, lateral epicondyle of the humerus, forearm, ulnar styloid process, radial styloid process, the second metacarpal head, forehead and posterior head, and unilaterally on the suprasternal notch, xiphoid process, C7, T10 and right scapula. We sampled motion data at 60 Hz, and filtered the data at 6 Hz using a 4th-order Butterworth low-pass filter.

Participants performed sit-to-walk and gait along a 10-m walkway while feeling four target emotions, neutral emotion, anger, sadness and joy. Sit-to-walk results have been reported elsewhere (Kang and Gross, 2015). Three gait trials with each target emotion were performed in a block, and the target emotion blocks were in randomized order across participants. For eliciting the target emotions, we followed an autobiographical memories paradigm that has been used in previous work (Roether et al., 2009; Gross et al., 2010, 2012; Barliya et al., 2013; Fawver et al., 2014). Participants wrote a note about their own life events that met criteria for the four target emotions. The criteria were "you felt very offended, when you felt furious or enraged, or felt like you wanted to explode" for anger, "you felt in despair when you felt low or depressed, or felt like you wanted to withdraw from the world" for sadness, "you felt exhilarated when you felt euphoric or very playful, or felt like you wanted to jump up and down" for joy, and "you did not feel any emotion, for instance, when you put gas in your car or did your laundry" for neutral emotion. Just before each target emotion block, participants read the notes that they had written down. For each trial in a target emotion block, participants spent as much time as needed to recall the life event for the target emotion. Between each target emotion block, participants spent approximately 5 min on card sorting task for washing out the previous target emotion.

After each trial, the intensity with which the target emotion was felt was assessed using a 5-item Likert scale (0 = not at all; 1 = a little bit; 2 = moderately; 3 = quite a bit; 4 = extremely) (Table 1). For angry, sad and joyful trials, we included trials if the intensity of the target emotion was greater than 1 ("a little bit"). For neutral trials, we included trials if the intensity of neutral emotion was greater than 1 ("a little bit"), and the intensity of the other target emotions was less than 2 ("moderately").

2.3. Data analysis

We used Visual 3D (C-Motion, Germantown, MD, USA) for biomechanical analysis. We created a 15-segment biomechanical human model: head, thorax, upper arms, forearms, hands, pelvis, thighs, shanks, and feet. Data analysis was performed for one gait cycle from each gait trial. We followed a kinematic method to identify gait cycles (Zeni et al., 2008).

We calculated spatiotemporal gait parameters (Table 2). For assessing movement smoothness in the whole body COM, head COM, thorax COM and pelvis COM, we calculated linear jerk (J, m/s^3) in the anterior–posterior (AP), vertical (VT) and mediolateral (ML) directions (Fig. 1). For assessing movement smoothness in the upper and lower limbs, we calculated angular jerk (J, deg/s^3) in the sagittal plane for the hip, knee, ankle, shoulder, elbow and wrist (Fig. 2). Then, we calculated normalized jerk scores (NJS) as suggested by Hogan and

Table 1
Mean values for mood intensities in gait trials with each target emotion across participants.

Target emotions	Mood intensity			
	Neutral	Sad	Angry	Joyful
Neutral	3.5	0.2	0.2	0.2
Sad	0.2	3.3	1.2	0.0
Angry	0.2	0.7	3.2	0.0
Joyful	0.2	0.0	0.0	3.6

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