Expression of Emotional States during Locomotion based on Canonical Parameters

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Abstract— **Humans have the ability to use a complex code of non-verbal behavior to communicate their internal states to others. Conversely, the understanding of intentions and emotions of others is a fundamental aspect of human social interaction. In the study presented here we investigate how people perceive the expression of emotional states based on the observation of different styles of locomotion. Our goal is to find a small set of canonical parameters that allow to control a wide range of emotional expressions. We generated different classes of walking behavior by varying the head/torso inclination, the walking speed, and the viewing angle of an animation of a virtual character. 18 subjects rated the observed walking person using the two-dimensional circumplex model of arousal and valence. The results show that, independent of the viewing angle, participants perceived distinct states of arousal and valence. Moreover, we could show that parametrized body posture codes emotional states, irrespective of the contextual influence or facial expressions. These findings suggest that human locomotion transmits basic emotional cues that can be directly related to canonical parameters of different dimensions of the expressive behavior. These findings are important as they allow us to build virtual characters whose emotional expression is recognizable at large distance and during extended periods of time.**

INTRODUCTION

The ability to understand others emotional intention, communicated solely by non-verbal cues, has a clear evolutionary advantage which is reflected in the social capability of an individual [1], [2]. Emotional states are the result of a complex multidimensional mechanism that integrates the perception of external stimuli with subjective internal needs [3], [4], [5]. The result is an active or passive response often accompanied by expressive components, such as facial expressions, vocalizations, body movements or physiological reactions. It has been shown that expressive behavior, especially facial expressions, can directly be related to internal emotional states, that are coded by universal, culturally unaffected schemata [6], [7], [8], [9]. Recent studies have shown similar results for verbal and non-verbal emotional vocalizations [10], [11]. Yet, emotional behavior does not only express emotional states; different studies have questioned this view, claiming that non-verbal emotional expressions are mainly a social construct, rather than expressing purely internal emotional states [12], [13]. These studies show that humans use non-verbal emotional body language mainly to establish social relations and interactions. Hence, emotional expressive behavior can have two main functions: Firstly, the communication of internal emotional states, and secondly, to foster social relationships and hierarchical structures.

One major challenge for the understanding of the meaning of expressive behavior is to find a schematic classification. This is not a trivial task, that motivates researchers from sociology, behavioral psychology, theater, and dance studies since decades. While a great deal of attention was focused on the understanding and classification of emotional facial expressions [14], [6], [7], [8], [9], relationally little systematic research has been carried out in the field of emotional body language. One approach to describe body movements is the Laban Movement Analysis (LMA), that divides expressive biological motion into four different dimensions: Body, Effort, Shape and Space [15], [16]. Using its own symbolic notation, this analysis method is capable of specifically describing body movements. The LMA is a powerful tool that can be used for the production and especially the reproduction of human behavior in acting and dance. Despite these capabilities, the LMA lacks a clear linkage between behavior and emotions. Another theoretical concept is Bridwhistell's theory of kinesics that understands the language of the human body as a "structured dynamic process of communication" [17], [18]. Unfortunately, the results of his extensive studies are not systematical ordered and thereby difficult to quantify [19]. A simpler classification system was proposed by Mehrabian, focusing on the orientation of the head in relation to the body and the angles of bodies interacting with each other [20].

What all classification systems have in common is a difficulty to find a direct relationship between the affective state and concrete corporal configuration and body movement. In contrast to facial expressions, where we can observe coherent relationships between basic emotions and expressive behavior [6], the inter-

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pretation of expressive body behavior is more sensitive to contextual and social influences [21]. Nevertheless, there is some empirical evidence that the movement and the form of the human body communicates emotions [22], [23], [24], also at a distance where facial expression is not detectable [25]. A promising approach is to analyze the emotion attributing of predefined body postures or movements, and correlate them with the parameters defining the body configuration. Studies following this idea differ methodological by either exposing viewers to real actors playing [23], video scene of actors playing [2], computer animations of virtual humans [26], [27], point-light animations that conceptualize human body movements [28], [29], [30], [31], [22], or drawn figures [32]. The results of these and similar studies show that affective states can be identified by observing static postures [33], [26], [34], [35] or moving behavior [36], [37], [23], [2].

The exact contribution of form and movement for the perception of emotional states is the topic of an extended discussion in the field. A recent study by Roehter et al. states that the understanding of affective body language is an integrative process of the perception of both dimensions, form and movement [38]. They identify the limb flexion velocity as an important feature for the perception of fear and anger, while the upper body posture, especially the head inclination communicates a sadness. These results are in line with a study from Thurman et al that investigates the perception of different critical features for biological motion [39]. Exaggerated body movement facilitates the recognition of affective states, especially the intensity of them [40]. On the other side the contribution of the form dimension for the identification of emotional states was made visible by a study using inverted and reversely played sequences of a moving person [41]. The result of these studies can be interpreted that the form plays a crucial role in affect identification, while kinetics help to solve conflicts and the identification of the intensity of the emotion. A finding that is in line with perceptual studies investigating the neurobiological mechanism of motion perception [42].

The emotional classifications used to describe affective behavior differ in complexity. The basic emotion approach is claiming that there exist a finite set of distinguishable emotions that can be attributed to expressive behavior [43], [44], [45], [46]. The numbers of proposed basic emotions vary between 4 -10, including happiness, fear, sadness, surprise, disgust, anger, joy, interest, elation, subjection, tender-emotion, wonder, contempt, guilt, and shame. The dimensional approach to emotions describes affective states using a two-dimensional classification system known as the circumplex model [47], [48]. This theory provides a circular classification space of basic emotions using valence and arousal to describe the quality and intensity of different emotional states. Both systems are used to describe expressive body movements [26], [2].

The purpose of the study presented here is to find a set of canonical parameters that control the expression of emotions in locomotion animations that are not dependent on facial expressions. The motivation is that we want to construct believable interactive characters for immersive virtual environments and mixed reality spaces, we need to investigate the emotional meaning of active behavior that is also perceivable at distance; virtual humans that interact with physical humans in a closed loop scenario only become realistic if we understand the emotional meaning of animated behavior, not only looking at fixed postures. Here we present the results of how people perceive the emotional state of a person walking. Based on the results of previous studies [26], [2], [32], we constructed different animations of expressive locomotion by varying three parameters of the movement: The head/torso inclination, including the erection of the shoulder, the speed of the movement, and the viewing angle.

Methods

A. Participants

We selected 18 participants from the University Pompeu Fabra for our study. All the participants were either master students, PhD students or professionals working in academic and were permanent living in Spain. The mean age of the participants was 28.4 years (SD = 4.3; M = 70 %; W = 30 %).

B. Materials

The animations were modeled using Autodesk 3ds Max [49] and transferred to the Torque Game Engine [50]. As stimuli we exported from Torque 10 sequences of a length of 10 seconds each. For the stimuli exposure, and the rating of the sequences we used a 15 inch IBM Think Pad Laptop running the E-prime1 experiment exposure software [51]. The self-assessment manikin rating scale [52] was used for the evaluation of the sequences.

C. Stimuli Design

We constructed 12 different animations of a person walking by varying the parameter of the head-torso inclination, the speed of the movement, and the viewing angel (Figure 1). We defined the head-torso inclination of the neutral body posture as inclination angle zero, and used this as a reference for the other animations. The deviation of the head-torso varied between -55 and +15 degrees. The convention applied was that minus inclination indicates a ventral direction, positive declination a dorsal one. Half of the animations were showing the walking body in profile view (90 degree

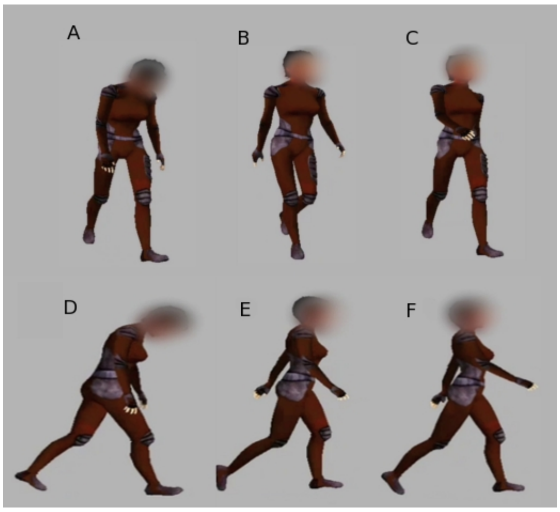

Fig. 1. Still images of stimuli in frontal view (A-C), and side view (D-F). Head/Torso inclination varied between 55 degree down (A, D), zero degrees (B, E), and 15 degrees up (C, F).

viewing angle), the other half in 45 degree rotated frontal view (Table I). The animated avatar was a women wearing a dark, red-blackish suit, and dark shoes. To avoid any contextual influence we used a neutral gray color as background [53], [21]. The face of the character was blurred to avoid any influence of the facial expression [54], [55].

TABLE I
SPECIFICATION OF THE STIMULI PARAMETERS

Viewing Angel	Inclination [Degree]	Speed [steps/sec]
45	Neutral [0]	Medium [0.75]
90	Neutral [0]	Medium [0.75]
45	Up [+ 15]	Medium [0.75]
90	Up [+ 15]	Medium [0.75]
45	Down [- 55]	Medium [0.75]
90	Down [- 55]	Medium [0.75]
45	Neutral [0]	Slow [0.5]
90	Neutral [0]	Slow [0.5]
45	Neutral [0]	Fast [1.4]
90	Neutral [0]	Fast [1.4]

D. *Procedure*

Participants were sitting alone at a table in front of a computer laptop used for the stimuli presentation, and asked to rate the valence and arousal state of a walking person. Each sequence was played for 10 seconds, followed by a black screen. After 2 seconds the valence and arousal rating scale appeared until a rating was given. The pause before the next stimulus sequence was played was 4 second. The order of the sequences was randomized. After the experiment, participants were asked by the experimenter if they had any problems to follow the experiment. Participants were not informed about the specific objective of the study.

RESULTS

The data was analyzed using the SPSS software package. The valence and arousal ratings were submitted to two multivariate analysis of variance (MANOVAs) where Wilks Lambda was used as the multivariate criterion. The first MANOVA factors were 2 (viewing angle) x 3 (head inclination), and the second MANOVA factors were 2 (viewing angle) x 3 (movement speed). All data satisfied the normality criterion as verified using the Kolmogorov-Smirnov test.

E. *Effects of head/torso inclination*

The analysis showed that the head/torso inclination factor had a significant effect on the ratings ($F(4, 13) = 23.5, p < 0.001, \Lambda = 0.1$). This effect was pronounced both for arousal, $F(2, 29) = 49.9, p < 0.001$, and for valence, $F(1, 24) = 45.2, p < 0.001$. The post-hoc Bonferroni comparisons for the arousal ratings showed that the difference between head/torso down (M = 2.5, SD = 0.3) condition was significantly lower ($p < 0.001$) than normal the head/torso condition (M = 5.4, SD = 0.3), and the head/torso up condition (M = 6, SD = 0.3). The same comparisons for the valence ratings showed significant differences for all three conditions. The head/torso up condition was perceived as most pleasant followed by the normal head/torso position, and head/torso down. The means were M = 6.7, SD = 0.2; M = 5.9, SD = 0.3; and M = 2.8, SD = 0.5, respectively. No effect of the viewing angle, or interaction between the angle and the head/torso position reached significance.

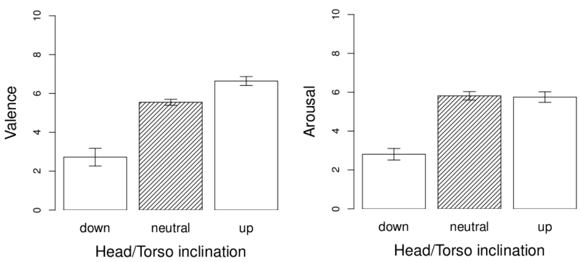

Fig. 2. Valence and arousal rating for Head/Torso inclination. Error bars indicate standard error. Valence rating 0 indicates a very sad emotional state, rating 10 a very happy state. Arousal rating 0 indicates a low arousal state, arousal rating 10 indicates a high arousal state.

F. *Effects of walking speed*

The movement speed factor reached significance at $F(4, 13) = 41.1, p < 0.001, \Lambda = 0.07$. This effect was caused only by the arousal ratings, $F(2, 27) = 58.6, p < 0.001$. The post-hoc Bonferroni comparisons for the arousal ratings showed that fast speed motion (M = 8.1 SD = 0.2) was significantly different from the normal speed (M = 5.4 SD = 0.3), and from the slow speed conditions (M = 4.2 SD = 0.3). No effect of viewing angle, or interaction between the angle and the movement speed reached significance.

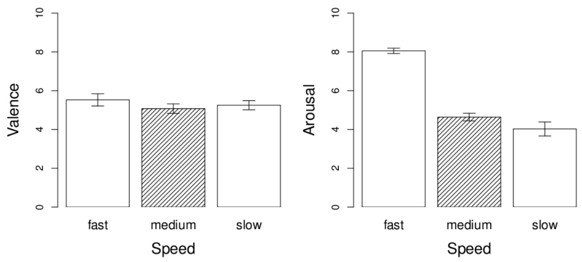

Fig. 3. Valence and arousal rating for Head/Torso inclination. Error bars indicate standard error. Valence rating 0 indicates a very sad emotional state, rating 10 a very happy state. Arousal rating 0 indicates a low arousal state, arousal rating 10 indicates a high arousal state.

When locating the animations in the circumplex model of valence and arousal (Figure 4), we see that a wide area is covered, indicating the power of the head/torso inclination and speed parameters to express a range of emotional states. The coordinates that are not sufficiently covered yet, are the combinations of high valence/low arousal, and low valence/high arousal.

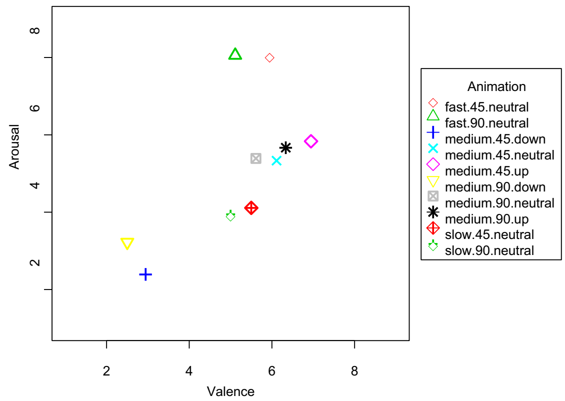

Fig. 4. Distribution of the animations in the circumplex. The legend indicates the stimuli parameter space of the different animations: <speed>.<viewing angle>.<head/torso inclination>. The speed parameter is defined as Fast = 1.4 m/sec, Medium = 0.75 m/sec and Slow = 0.5 m/sec. The viewing angle varies between profile view = 90 degrees, and rotated frontal view = 45 degrees. The parameter for the head/torso inclination varies between Neutral = 0 degrees, Up = + 15 degrees and Down = -55 degrees.

Discussion

Our results show that participants assigned distinct emotional states to animations of a walking person that only differed in the erection of the posture, and walking speed. An upright head/torso position was significantly related with a positive emotional state or high valence, a lower position with a more unpleasant emotional state. Even small changes in head/torso position of 15 degrees induced a significantly different perception of the emotional quality. This is indicative of the high sensitivity of humans in relating subtle differences in body language to internal states. Next to the valence, also the arousal rating was significantly affected by the body posture: Animations with negative head/torso inclinations were perceived as less aroused compared to body postures with more upright head/torso positions. These results are in line with studies showing that especially the static configuration of the upper body part code important features responsible for the perception of emotional states [38], [41]. While the valence rating differed in all three head/torso conditions, in the arousal rating we only observed significant difference for the most extreme negative head/torso inclination . This finding suggest that only extreme down positions of the head clearly code low values of arousal, which is in line with other studies that found that depressive states were characterized by non-erected postures [56], [38]. The different walking speeds had a clear effect on the perception of arousal: Higher speed yielded higher arousal ratings compared to slower movements. This means that the velocity of the body movements does provide information about the magnitude of an emotional state of a person. This finding is in line with recent studies showing that the velocity of body movements codes the intensity of a perceived emotional state [40], [38]. Contrary to this observation, the speed had no effect on the valence rating of the perceived emotion. If we are searching for canonical parameters that control the expression of emotions in animations, we aim at finding parameters that are independent of the angle from which their are seen. Indeed, our results show that the emotional quality of the animations generated based on the chosen set of parameters are independent of the viewing angle.

Conclusion

The identification and empirical evaluation of canonical parameters that control the expression of emotions in locomotive behavior is the main contribution of this study. Our results are coherent with previous work, showing that upright upper body postures are perceived as emotionally more positive and forward leaning postures more negative [32], [26], [38], and studies that found associations between "dropped head" positions and sadness [2], [57]. The perception of the arousal state can be related to a variation of the velocity of the movement, which is in line with findings from [56], [58]. The results of our study confirm previous results stating that the intensity of a perceived emotion is directly linked to the velocity of the identified body gesture [40]. Our study therefor supports the hypothesis proposed by others that the static configuration of the body parts, especially the upped back, shoulders and head inclination valence value [38], [41], while the kinematic dimension codes the intensity of the emotion [40].

Even though context [2], [53], [21] and facial expressions [54], [55] play an important role in giving meaning to bodily expression, our results show that people recognize distinguishable emotional states of a moving person independent of those two factors. Hence, we show that the characteristic of locomotion by itself can convey emotional states.

These findings are important as they allow us to build virtual characters whose emotional expression is recognizable at distances larger than those at which facial expression can be decoded. Additionally, the moving characters can keep their emotional state during an extended period of time. This is important since observing an isolated emotive face over a long time can be perceived as a non-natural behavior. The understanding of both of the mentioned aspects is of relevance for the construction of avatars that interact with users in virtual worlds or in environments such as CAVEs [59] and mixed-reality spaces such as the eXperience Induction Machine [60]. Future work will include the investigation of additional parameters that allow to cover the entire circumplex space. Additionally, we plan to apply our finding to the control of the emotional expression of a real-world robotic platforms such as the humanoid robot iCub [61].

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