Expressing emotion through posture and gesture

Introduction

Emotion and its physical expression are an integral part of social interaction, informing others about how we are feeling and affecting social outcomes (Vosk, Forehand, and Figueroa 1983). Studies on the physical expression of emotion can be traced back to the 19th century with Darwin's seminal book[1] "The Expression of the Emotions in Man and Animals" that reveals the key role of facial expressions and body movement in communicating status and emotion (Darwin 1872).

While emotions can be expressed through different modalities, facial expressions have been the most extensively studied. A smile can convey pleasure and agreement, a raise of eyebrow skepticism and clenched teeth cold anger. More than 95 per cent of the literature on emotion in humans has used faces as stimuli, at the expense of other modalities (Gelder 2009).

Less studied are the ways our body also conveys emotional information, such as adopting a collapsed posture when depressed or leaning forward to show interest. Indeed, our interest here is this less extensively studied field of *bodily expression of emotion* that models how people communicate emotion through body posture and gesture, and how people make inferences about someone else's emotional state based on perceived posture and gesture.

In addition to furthering basic understanding of human behavior, work on the bodily expression of emotion has played a key role in research on Embodied Conversational Agents (ECAs; Cassell 2000), also known as Virtual Humans (Rickel et al., 2001). ECAs are animated characters capable of social interaction with people through dialogue and nonverbal behaviors, using the same modalities such as voice, facial expression, postural shifts and gestures that people use in face-to-face interaction.

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[1] Darwin was strongly influenced by the work of a French anatomist, Pierre Gratiolet who explored "body language" shared by men and animals. Unfortunately, Gratiolet's work remains largely unknown since his book has never been translated into English (Gratiolet 1865).

Given emotion's role in human social interaction, it is not surprising that research in ECAs has sought to endow them with the ability to employ emotion and emotional expression. A computational model of the relation between emotion and its bodily expression can serve several roles in the design of ECAs. For one, it can guide the recognition of the emotional state of the user (see Chapter 15). This chapter focuses on another role, the generation of appropriate bodily expression for ECAs.

One of the fundamental questions in studying bodily expression has been what aspects of emotion are expressed through the various physical behaviors and additionally what do observers reliably infer from such behaviors. Specifically, there has been considerable debate as to whether posture and movement reliably convey emotion categories or rather, consistent with a dimensional view, convey the intensity of emotion (see Paul Ekman 1965; Paul Ekman and Friesen 1967 for a discussion of this point). A related question arises as to which features of the bodily movement are relevant to inferences of emotion. These features might concern the form of the movement or posture, the quantity of movement or the dynamics of the motion.

In this chapter, we discuss the methodological issues that arise in studying the bodily expression of emotion and the solutions that have been proposed. Then, we present a review of which features seem to be specific to certain emotions or to certain properties of emotion (such as intensity) according to several psychological studies. The last section describes the computational models of bodily expression that have been designed for virtual humans, most particularly Embodied Conversational Agents, to perform postures and gestures that reflect their emotional state.

Issues in the study of emotion expression in posture, movement and gesture

The study of the bodily expression of emotions faces several theoretical and methodological challenges, ranging across fundamental theoretical questions about how emotions are defined and how emotional expressions are represented, experimental issues concerning how emotional expressions are invoked in subjects and design issues concerning the goals of the ECA designer in using emotional expressions.

Encoding and decoding

One of the central issues impacting the study of emotional expression concerns the distinction between a person's encoding of emotion in physical behavior versus an observer's decoding of emotion from observations of the person's behavior. How emotion is encoded in nonverbal behavior can differ from how it is decoded (See Gifford, 1994 for a related work on personality and nonverbal behavior). This discrepancy leads to several theoretical and methodological issues. As we discuss below, studies of human expression of emotion have often used actors to create stimuli for experiments. However, actors, depending on how their training and approach to acting, may be more concerned with how an audience decodes a behavior as opposed to a naturalistic encoding. Regardless, intentionally realizing a natural performance is difficult at best and impossible in some cases, leading to differences in dynamics of the motion, timing and symmetry. Further, there is also the related question of whether expressive behavior reflects an underlying emotional state (Paul Ekman and Friesen 1967) as opposed to the view that expressive behaviors only serve to as intentional signals aimed at influencing other's behaviors (Fridlund 1991; Fridlund 1997). These issues touch upon the intentions of the designer of the ECA, who must address both whether naturalistic encoding versus ease of decoding is the design goal as well as whether emotion is conveying underlying emotion of the ECA and/or is being used as explicit social signal.

Representation of posture, movement and gesture

Foremost is the absence of a standard that codifies which are the features under study, including what are the components of the movement and how their dynamics are specified. In contrast, the work on facial expressions has relied on an agreed upon standard, the Facial Action Coding System (FACS;(Paul Ekman, Friesen, and Hager 1978; Paul Ekman, Friesen, and Hager 2002)). Such a system facilitates the coding of observed behaviors as well as the design of stimuli for experiments. In the absence of an agreed upon standard, researchers must answer the question of how to represent the parts of the body that are involved, the dynamics of the movement and the form of the movement.

We describe in the following some of the coding systems that have been used to study the bodily expression of emotion. Representing posture and body-parts position

Posture usually refers to the quasi-static configuration of the whole body.

Seating, standing and lying can be considered as three postures (Argyle 1975), but this description is too restrictive to study the effect of emotion.

Posture is usually defined by the position and orientation of specific body parts. Orientation can be relative. For example, (Mehrabian 1972) uses a few global descriptors such as relative orientation to the partner, closeness or openness and symmetry of body limb. (Harrigan 2005) reports that posture coding systems use the following common descriptors: trunk lean (upright, forward or backward), trunk orientation (facing, turned), arms and leg positions and configurations (e.g. hands in pockets, legs crossed). Absolute orientation values are described regarding the sagittal, frontal and transverse axis of the body (e.g. (Gross, Crane, and Fredrickson 2012)).

Representing movement

Early studies on body movement manually detailed the position of each body part over time (Birdwhistell 1970; Frey and Pool 1976). Such an approach is tedious and time-consuming, so researchers looked for ideas from other disciplines.

Choreographers describe the body movement preserve and transmit a dance score to dancers. In particular, Rudolf Laban, his students and colleagues have developed several frameworks to represent movement. The Laban Movement Analysis described the actions of the body parts over time by using a notation system composed of symbols that represent the quantitative and qualitative features of movements. Symbols are organized into five categories: Body (parts of the body involved), Space (locale, directions and path of a movement), Effort (how the body performs movements) and Shape (forms that the body makes in space). The Effort-Shape analysis (Dell 1977) derives from Laban and only focuses on the effort and shape dimensions.

Representing gesture

All gestures are movements, but not all movements are gestures. A gesture is a movement that communicates information, intentionally or not (David McNeill 2008). Most of the literature has focused on hand and arms gestures used in verbal communication[2]. They are usually separated into the following categories: emblems, illustrators and adaptors (P. Ekman and Friesen 1969; Kendon 1983).

Emblems are gestures that convey meaning by themselves and are assumed to be deliberately performed by the speaker. They are conventionalized symbols and strongly culture-dependent (Efron 1941; Efron 1972; Kendon 1983).

Illustrators (or conversational gestures) are gestures that accompany the speech. One particular category of illustrators is the *beats*, i.e. simple, repetitive, rhythmic movements that bear no obvious relation to the semantic content of the accompanying speech. Other categories of conversational gestures have a communicative intent and are semantically linked to the meaning of the speech. They can further be distinguished into deictic, iconic and metaphoric gestures (David McNeill 1985; David McNeill 1987). Deictics consist in pointing towards a concrete object or an abstract concept that has been materialized in front of the speaker. Iconics and metaphorics are gestures that represent derived features of an object or

[2] Head nods and gaze also are nonverbal behaviors that convey meaning, but they are out of the scope of this paper.

an action, such as drawing a square to represent a frame or mimicking writing. Iconics describe concrete objects and actions while metaphorics represent abstract concepts.

Gesture may also convey additional information, although such information is not, strictly speaking, part of the speaker's intended meaning. Adaptors are not communicatively intended or perceived to be meaningfully related to the speech. Self-adaptors (later renamed self-manipulators then body-manipulators) involve one part of the body doing something to another part of the body such as scratching one's head, stoking the chin, hand-to-hand movement, lip licking and hair. Object-manipulators involve handling or using an object for some type of body contact like playing with a pencil or scratching the ear with a paper clip (Paul Ekman and Friesen 1977, 47).

A segmentation-and-classification approach has been proposed to integrate dynamics into gesture description (D. McNeill 1992; David McNeill 2008).). Segmentation is done using the concept of three sequential movement phases: preparation, stroke and retraction. The stroke is the meaningful part of the gesture. Before the stroke, the arm moves from the rest position to the position to get ready for the stroke (preparation phase). After the stroke, the arm gets back to a rest position (retraction phase). Classification consists in describing gestures with objective features like handedness, hand shape, palm orientation or motion direction. (Calbris and Doyle 1990) propose a classification system that was designed to describe gestures used by French speakers.

Combining body and body-parts position, movement and gesture

Recently, an effort has been made to propose a system that would guide the coding of body and body-parts positions, movement and communicative intent of gestures. The Body Action and Posture Coding System (BAP) integrates several coding approaches to study emotion expression by using a multilevel (anatomical, form and functional) coding system (Dael, Mortillaro, and Scherer 2012).

The anatomical level is used to specify which body parts are concerned by a movement or a communicative intent. Available articulators are the neck, the trunk (including spine and chest), the upper and lower-arms (including shoulders, elbow, wrist and fingers) and the legs.

The form level describes the form of the movement of a set of articulators. Movement is characterized with respect to the sagittal, vertical and transverse axis of the body.

The functional level proposes to distinguish between emblems, illustrators and manipulators gestures (Paul Ekman and Friesen 1972). The classification of (Calbris and Doyle 1990) is used to describe the gesture.

Overall, BAP includes 141 objective behaviors that can be combined to describe the position and movement of body and body-parts as well as, when applicable, the communicative intent of a gesture. Additionally, this system can be used to conduct multimodal behavior analyses by integrating facial and speech features.

BAP has been used to code the performance of professional actors encoding emotional states in the GEMEP corpus (Dael, Mortillaro, and Scherer 2011).

Representation of emotions

In addition, researchers must determine what emotions will be studied and how they will be represented. However there is not a theoretical consensus on what an emotion is (see Section 1). Discrete emotion theories claim that there is a limited number of emotions. Fear, happy, anger, sadness, surprise and disgust (P. Ekman and Friesen 1969) are often considered, as well as interest, shame and guilt (Izard 1977). Dimensional theories define dimensional spaces that account for the similarities and differences in emotional experience. For example, the PAD model describes an emotional state with values of pleasure, arousal, dominance (Russell and Mehrabian 1977). Appraisal theories emphasize the link between emotion and cognition, and according to these theories, an emotion arises from the appraisal of the situation, regarding our beliefs, desires and intentions (Lazarus 1991). Patterns of appraisal are associated to specific cognitive physiological and behavioral reactions, in particular action tendencies that are "states of readiness to execute a certain kind of action", for example "impulses to approach or avoid, desires to shout and sing or move" (Nico H. Frijda 2007, 273).

How emotions are represented has a great influence on the study. An approach grounded in a categorical model of emotion would look for the relation between emotion categories like anger or happiness and their behavioral expression while an approach using a dimensional model would focus on intensity and valence and therefore look for those dimensions in the bodily expression.

Choosing one type of model or the other is not clear, since we tend to use discrete emotions to describe our emotional state (e.g. "I feel happy") and dimensions to describe the emotion inferred from body and gesture movement (e.g. "more energetic", "less emphatic"). That is why some studies have looked at this problem from the opposite side, seeking to address whether a categorical or dimensional model would best explain the observed data.

Obtaining realistic expressions of emotions

One of the major obstacles researchers have encountered is obtaining realistic nonverbal expressions that are valid indicators of various emotional states (Bänziger and Scherer 2007). The natural observation of emotions raises the issue of inducing the emotional state while acted portraya**ls are often judged exaggerated** or stereotypical.**Natural observation of emotional expression**

This technique consists in observing other people's emotional expressions in naturally occurring situations, i.e. outside the laboratory. The resulting emotional expressions are considered to be spontaneous.

However, researchers must rely only on post-hoc reports (Nisbett and Wilson 1977; Bänziger and Scherer 2007). Asking observers to focus on emotions may change the way they describe emotions, leading them to notice more subtle feelings than they normally would, or at the contrary, only report very obvious emotional expressions. Another bias is the interpretation about someone else's (and sometimes our own) emotional state, which may be completely different from the real one.

Acted portrayals of emotions

Professional actors are supposed to convincingly portray emotional characters by invoking emotional feelings. In emotion studies, they are usually given a short script that contains a description of the situation as well as a few dialogue lines. Gestures are usually improvised during the course of the scene (Wallbott and Scherer 1986; Wallbott 1998).

Filmed performances, especially theater plays, have also been used as a source of emotional portrayals (Kipp and Martin 2009). Their advantage is that a same actor shows a wide range of emotional displays and the expressive behavior are rehearsed and validated by the director. Additionally, using long stories provides some context regarding interpersonal relationships and the character's personality that can help decode emotional state.

However, portrayed performances can sometimes be judged exaggerated, stereotyped or unnatural. This can happen if the actors are given specific directions such as "act angry" or "use this gesture"[3] or when they cannot invoke emotional feelings. Exaggerated expressions enhance emotion recognition but produce higher emotional-intensity ratings (Atkinson et al. 2004), leading the observer to judge the performance as inappropriately portraying the emotion (Wallbott 1998).

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[3] Rather, to create an emotionally realistic performance, the actor needs situational or interpersonal context such as "your spouse has stayed out all night and comes home drunk".

Inducing emotional states

Different strategies can be used to invoke an emotional state. The simplest, showing the subject pictures and videos, has been used since the first emotion studies (James 1932). Another strategy is the autobiographical memory paradigm, in which subjects are asked to recall a memory during which they experienced a specific emotion. In a study conducted by (Gross, Crane, and Fredrickson 2010), 92% of the participants reported actually feeling the target emotion during their performance by using the autobiographical memory paradigm inducing strategy. Interestingly, the participants also reported feeling other emotions, close to the target one, at the same time.

Individual differences in encoding

Individuals differ in their capacity at encoding an emotional state (Gross, Crane, and Fredrickson 2010). They also have different styles, preferring to use certain gestures instead of others (Kipp and Martin 2009), as well as preferences regarding the modalities to use (facial expressions, voice, body). Using a small number of subjects restricts the range of encoded gestures and styles associated to a particular emotion. Some authors suggest using a relatively large number of individuals to capture the whole range of expression (Wallbott 1998; Atkinson et al. 2004; Gross, Crane, and Fredrickson 2010).

Avoiding interference from other modalities

Since the goal is to study posture and gesture, other modalities have to be masked so not to interfere in emotion recognition.

Avoiding interferences from facial expression is quite easy. The encoder can be masked while performing, or the facial expression can be blurred afterwards (e.g. (Gross, Crane, and Fredrickson 2010; Sprengelmeyer et al. 1999)).

Avoiding interferences from the voice is more challenging. Researchers have used nonsense sentences (i.e. that do not convey semantic meaning) and flattened the pitch and prosody of the voice (e.g. (Banse and Scherer 1996; Wallbott 1998)). However, using a verbal utterance without meaning may constrain the variety of emotional expressions that are used, leading to performances that lack spontaneity and naturalness.

Other elements responsible for bodily expression

By using an encoding-decoding approach, researchers suggest that the emotional state can be inferred from the bodily expression. But posture and gestures may also be caused by mental states different than emotions, such as intentions or requests (Dittmann 1987). For example, we may yawn because we’re bored, but sometimes it’s only because we’re tired or because we’re mirroring another’s yawn. Having folded arms across the chest do not necessarily indicate pride or social distance, but may be used to increase the temperature when cold or because not having pockets to put the hands on (Harrigan 2005). The distinction is theoretically important but difficult to demonstrate empirically (Coulson 2004).

Studies of the expressive elements of posture and gesture

Despite the issues presented above, there have been attempts to study the bodily expression of emotions. We broadly characterize those studies in term of their focus. Specifically, we give an overview of the work on posture, movement, hand gestures, and conclude with multimodal approaches that investigate the combination of bodily movement with facial expressions and vocal qualities.

Expressing emotion through static Posture

Dance choreographers have known for a long time that body posture can signal an affect-related meaning. For example, ballet dancers have been shown to use an angular posture to suggest a threatening character and a round posture to represent a warm character (Aronoff, Woike, and Hyman 1992).

The early studies conducted by Ekman suggested that, while the face is the most effective channel for expressing specific emotion, the posture provides more information about the *Gross Affect*, i.e. general information about the emotional state such as the degree of arousal or tenseness, but does not allow to determine the specific emotional state (Paul Ekman 1965; Paul Ekman and Friesen 1967). Some studies confirmed that the gross affect can be derived from static posture. For example, (Schouwstra and Hoogstraten 1995) generated 21 figures by varying three head positions and seven spinal positions and reported that a straight posture is judged more positively whereas the figure with pelvis backward, shoulder and head forward (leaning posture) was judged the most negatively.

However, contrary to Ekman’s statement, some emotions can be accurately decoded from a static posture. Table 1 presents the features of postures that frequently occur depending on the emotional states. It compiles data from various studies (Walters and Walk, reported in Coulson 2004; Atkinson et al. 2004; Wallbott 1998).

Emotion	Frequent posture features
Anger	Head backward, no chest backward, no abdominal twist, arms raised forwards and upwards, shoulders lifted
Joy	Head backward, no chest forward, arms raised above shoulder and straight at the elbow, shoulders lifted
Sadness	Head forward, chest forward, no abdominal twist, arms at the side of the trunk, collapsed posture

Surprise	Head backward, chest backward, abdominal twist, arms raised with straight forearms
Pride	Head backward or lightly tilt, expanded posture, hands on the hips or raised above the head
Fear	Head backward, no abdominal twist, arms are raised forwards, shoulders forwards
Disgust	Shoulders forwards, head downwards,
Boredom	Collapsed posture, head backwards not facing the interlocutor

Table 1 – Expressive elements of posture

Emotions such as anger, sadness and joy obtain the same recognition rate when expressed with a static body posture as through facial expression (Walters and Walk, reported in Coulson 2004). Still, some emotions are not recognized (disgust), and others are confused (surprise and joy) (Coulson 2004).

Expressing emotion through movement

Kinesics, the study of nonverbal movements, argues that the dynamics of a movement can be sufficient to infer an underlying emotional state. Both objective (using motion-capture data) and subjective studies showed that velocity, acceleration and jerk are movements variable that are particularly affected by an emotional state.

Most studies on kinesics have taken a holistic approach, i.e. focused on the dynamics of the whole body. Human walk has received most of the attention (Montepare, Goldstein, and Clausen 1987; Rossberg-Gempton and Poole 1993; Roether et al. 2009; Hicheur et al. 2013). General level of movement activity and spatial extent seem to be important features for the recognition of emotion from movement. Angry movements tend to be large, fast and relatively jerky, while fearful and sad movements are less energetic, smaller and slower.

Studies on specific body parts, generally involving the arms and the hands, confirm and detail these results, whether by using coding-decoding methodology only (Pollick et al. 2001; Patterson, Pollick, and Sanford 2001; Hietanen, Leppänen, and Lehtonen 2004), or combining it to objective data obtained with motion capture (Gross, Crane, and Fredrickson 2012). The amplitude and speed of body parts involved in the movement, as well as the time spent in the different gesture phases (preparation, stroke, relax) seem to be impacted too. Table 2 reports the observations made by (Wallbott 1998; Gross, Crane, and Fredrickson 2010) on which features of arm movement are characteristic of certain emotional states.

Emotion	Frequent features of arm movement
Anger	Lateralized hand/arm movement, arms stretched out to the front, largest amplitude of elbow motion, largest elbow extensor velocity, highest rising arm,
Joy	High peak flexor and extensor elbow velocities, arms stretched out to the front

Sadness	Longest movement time, smallest amplitude of elbow motion, least elbow extensor velocity.
Anxiety	Short movement times, constrained torso range of motion.
Interest	Lateralized hand/arm movement, arms stretched out to the front
Fear	Arms stretched sideways

Table 2 – Expressive features of arm movement

The body seems to present a dissymmetry in its emotional expressivity. More particularly, the left side uses higher energy and higher amplitude when realizing emotional movements than the right side (Rossberg-Gempton and Poole 1993; Roether, Omlor, and Giese 2010). A correlation between the handedness and emotion is also mentioned: for two hand-righted actors, the right hand was more used when experiencing anger and the left hand when experiencing relaxed and positive feelings (Kipp and Martin 2009).

Expressing emotion through specific gestures

A class of emblems, *Affect Emblems*, specifically groups emblems that convey emotional meaning. For example, the "Hand Purse" gesture, in which the fingers and thumb are pressed together at the tips and held upright, represents "fear". However, emblems are symbols whose meaning is culture-dependent. This specific emblem means "fear" in France and Belgium, represents a "query" in Italy, and is not used in North America (D. McNeill 1992). Moreover, affect emblems are only used to convey an emotional meaning and not to imply that the sender is actually experiencing it.

Adaptors may reveal unconscious thoughts or feelings (Mahl 1956; Mahl 1968) or thoughts and feelings that the speaker is trying to conceal (Paul Ekman and Friesen 1969; Paul Ekman and Friesen 1974). Even if little systematic research has been done on this topic, it is clear that adaptors and particularly self-adaptors (like scratching or touching one-self) seem to be more frequent when experiencing negative valence emotions (e.g. anxiety, inhibition, depression and shame). Table 3 presents the adaptors observed when experiencing certain emotional states (from (Wolff 1972 as cited in ; Argyle 1975; Dittmann 1972; Wallbott 1998)).

Emotion	Frequent adaptors
Anxiety	Touching or pulling the hair, plucking eyebrows, wriggling or interlocking the hands, opening and closing the fist, aimless fidgeting, hiding the face
Inhibition	Touching or pulling the hair, stereotyped and unnecessary movements, withdrawal movements, general motor unrest
Depression	Hiding and withdrawal gestures

Pride	Arms crossed in front of chest
Shame	Touching or pulling the hair, plucking eyebrows, wriggling or interlocking the hands

Table 3 – Frequent adaptors involved in specific emotional states

Expressing emotion through multimodal combinations

There are rare studies about the conjoint expressive patterns of the face, the voice, and the body (Bänziger and Scherer 2007).

(Scherer and Ellgring 2007a) combine the results from previous studies to identify intra and inter-modality clusters in gestures, voice and face (Wallbott 1998; Banse and Scherer 1996; Scherer and Ellgring 2007b). They aim at identifying multimodal clusters that would be characteristics of two emotion dimensions, arousal and valence. One highly expressive gesturing cluster (arms stretched out in frontal direction, use of illustrator gestures, hands opening and closing, shoulders moving up) is particularly used when experiencing high arousal. This cluster is combined to face and voice clusters into multimodal clusters that are representative of agitation (high arousal situations) and joyful surprise (positive valence).

Computational models for generating emotionally expressive bodily movements

Mirroring the psychological work, the computational modeling the expression of emotion in virtual characters has been more concerned with facial expressions (see Chapter 22) as opposed to bodily movements

However there has nevertheless been significant work in this area, particularly in the field of Embodied Conversational Agents (ECA). Most of the systems have built on the psychological studies discussed earlier to generate bodily expressions that are congruent with an emotional state. But given the absence of a comprehensive psychological theory of the relation between emotion and expressive bodily movements, the results are only partial.

Following the psychological work that distinguished the impact of emotion on the quality of movement and impact the types of movement, computational work can similarly be broadly characterized in terms of expressive animation of a motion versus the selection between expressive behaviors.

Expressive realization of nonverbal behaviors

Expressive animation systems

Expressive animation systems change the dynamics of the movement regarding a set of expressivity parameters. Expressive animations are procedurally generated by applying a set of transformations on “neutral” gestures.

Most of the animation systems are designed to apply any kind of transformations, not necessarily emotional ones. For example, the system proposed by (Neff and Fiume 2006) ensures that body constraints (overall body position and balance) are respected when applying transforms on a skeleton.

Some systems propose to learn the emotional transforms. The Emotion from Motion system compares motion-capture data of a movement performed with a specific emotion to the same movement performed with a neutral emotion (Amaya, Bruderlin, and Calvert 1996). This process generates emotional transforms that represent the difference of speed and spatial amplitude of the movement over time. The emotional transform can then be applied to the same body part or to a different one. For example, sad and angry transforms were created using motion capture data of drinking (focusing on the arm) and used to successfully generate sad and angry knocking and kicking movements.

Direct mapping from emotional state to expressivity parameters

(Ball and Breese 2000) develop a domain-dependent Bayesian network that can be used both to recognize the emotional state of the user and to generate appropriate behavior in response to the user's action. This system uses a two dimensions model of emotion composed of valence and arousal. The arousal of the emotional state affects the size and speed of gestures as well as aspects of facial expressions and speed speech, while the valence impacts the facial expression and voice pitch.

MARC is an ECA that models the influence of emotion on posture through the use of action tendencies (Tan et al. 2010). A corpus-based approach is applied to generate a library of expressive postures. A direct mapping is then used at runtime to select an appropriate posture depending on the agent's action tendencies.

Emotional state and expressivity parameters

In certain architectures, the transformations are dynamically generated depending on the mental state of the virtual human, and particularly, the emotional state of the virtual human.

PARSYS (Parameterized Action Representation SYStem) is a component that allows an agent to act, plan and reason about its actions or actions of others (Badler et al. 2002). It takes into account the mental state of the virtual human, composed of a personality (OCEAN model (Wiggins 1996)) and an emotional state (OCC model (Ortony, Clore, and Collins 1988)). This mental state influences the action selection as well as its realization, by using a mapping between the mental state's elements and expressivity transforms.

The expressivity transforms are transmitted to EMOTE (Expressive Motion Engine) that realizes them. EMOTE is a 3D graphic engine that proposes a computational realization of the Shape-Effort Analysis (Dell 1977) and focuses on torso and arm movements (Chi et al. 2000; Badler et al. 2000; Zhao and

Badler 2001). By applying a set of shape and effort transformations neutral animations, the original performance is altered to represent the mental state of the virtual human. A mapping from the personality to the shape and effort transforms has been implemented (Allbeck and Badler 2002), and a mapping from the emotional state to expressivity transforms could be integrated.

Emotional state, communicative intent and expressivity

Modifying the expressivity of a gesture can alter it globally, regardless of its meaningful elements. Adding noise to a deictic gesture (e.g. pointing hand) can obscure the form of the pointing finger or change the pointed direction. This is particularly problematic for ECAs since it can override the meaning conveyed by a gesture.

GRETA is an ECA architecture that addresses this issue. It uses a gesture specification language that describes, for each gesture phase (preparation, stroke, retraction) which elements carry semantic meaning and which ones can be modulated to change the expressivity (Björn Hartmann, Mancini, and Pelachaud 2006).

These expressivity parameters are based on the psychology literature (Hanke 2004): the s*patial extent* represents how large the gesture is in space, the *temporal extent* how fast the gesture is executed, the *fluidity* how two consecutive gestures are co-articulated, the *repetition* how often the gesture is repeated, the *power* how strong a gesture is and the *overall activation* the overall quantity movement on a given modality channel.

Each ECA modeled with GRETA is given a baseline that contains its default expressivity parameters for each modality (gesture and facial expression) (e.g. the ECA prefers using gestures with high power, low fluidity, etc.). This baseline is dynamically modified depending on the communicative intentions that represent the information the ECA wants to communicate, for example an emotional state or information about the state of the world. The modification is done by a set of handcrafted rules based on the literature (Wallbott and Scherer 1986; Wallbott 1998) that eventually generates an expressive multimodal behavior, ensuring that the final overall performance conveys the desired meaning (Bjoern Hartmann, Mancini, and Pelachaud 2005; Pelachaud 2009).

Expressive selection of nonverbal behaviors

Emotions do not only change the movement quality, but also the type of movements, such as a raised fist in anger, or yawning when too bored.

Several ECA architectures have modeled the influence of the emotional state on movement and gesture selection. They differ in their degree of automation.

Markup languages

GESTYLE is a markup language used to manually annotate the utterance text and represent the influence that individual style must have on the performance (Noot and Ruttkay 2004). Each ECA is given a unique style that contains specific behavior repertoires as well as performance characteristics in terms of amplitude, speed and smoothness. GESTYLE does not have specific tags for emotion, but the approach is generic enough to define new style categories that would implicitly represent emotions.

Mapping emotion to specific gestures

MAX is an ECA that uses a direct mapping between certain emotional state and specific behaviors (Becker, Kopp, and Wachsmuth 2004). MAX's behavioral level is driven by its mood (using the PAD model with the addition of a boredom dimension), that influences facial expressions and voice prosody. Moreover, when the level of boredom reaches a certain threshold, secondary actions such as yawning of stretching are triggered.

The Physical Focus Model uses the emotional state of a virtual human to drive a finite state machine that determine behavior selection (Marsella, Johnson, and LaBore 2000; Gratch and Marsella 2001). Four focus modes are defined (*strong body focus*, *body focus*, *transitional* and *communicative*) and transitions between modes are linked to changes of emotional state. Action tendencies, as well as the number and type of nonverbal behaviors, depend on the focus mode the virtual human is currently in. For example, the *body focus* mode represents emotional states like depression and guilt. It generates gaze aversion, inhibited verbal activity and self-adaptors (soothing or self-punitive), as well as minimal communicative gestures such as deictic and beats, following the nonverbal observations of (Freedman 1972).

Combining expressive selection and expressive realization

Currently, no system explicitly combines expressive selection and realization of nonverbal behavior, but such combination is implicitly realized.

Nonverbal behavior is tightly linked to the speech, and synchrony occurs at different levels of speech. At the most local level, gesture and words are aligned so the *stroke*, i.e. the most meaningful part of the gesture, occurs with or just before the accentuated syllable of the word. Gestures can also be aggregated into *gesture units* that span on longer parts of speech (Kendon 1983; D. McNeill 1992). Integrating such synchrony in ECA requires dynamically modifying and co-articulating animation gestures so they match the speech timings, whether because they are too close in time or require to be stretched out on a longer speech segment.

Therefore, changing the speed of speech according to the emotional state may also impact the gesture speed. In MAX for example, a high arousal emotional state (e.g. happy, angry, excited) increases the speed of the speech and leads to faster movements while a low arousal emotional state slows down the speech and the associated gestures (Becker, Kopp, and Wachsmuth 2004). The speed of the animation gesture is modified, but some of the other meaningful features (reported in table 2) such as the amplitude of the motion are left unchanged.

Discussion

In this chapter, we provided an overview of the psychological studies on the influence of emotion on posture and gesture and described some of the attempts within the ECA community to develop bodily expressive virtual characters behaviors. In the absence of a computational model of this influence, the results obtained so far are only partial. For example, no system integrates both expressive animation and selection of expressive behaviors.

The main issue to the creation of such model is the need for a formal methodology to study the expression of emotion. Recently, some progress has been made with the BAP coding system that objectively combines body and body-parts position, movements and gestures. Additionally, objective measurement of body movement has recently been made possible by modern technologies like motion tracking (Ma, Paterson, and Pollick 2006) and muscular activity instruments (e.g. accelerometer, electromyography).

Virtual humans have proven to be particularly convenient to conduct studies of human behavior, especially in the field of face-to-face interactions. Their behaviors can be easily manipulated and reproduced and they do not involve individual bias in the experimental process. Actually, some of the psychological studies of bodily expression of emotions that we reported here used virtual humans to encode expressive stimuli (e.g. (Coulson 2004; Tan et al. 2010).

But research is still restricted by human constraints: inducing a genuine emotional state and distinguishing the influence of emotion from the ones of other mental states components such as social relationships, culture or personality are enormous challenges that have to be addressed.

Solving these issues would benefit several fields, especially the psychological research on emotion. Studying the expression of emotion through the body will challenge, improve and enrich the existing emotion models, as well as impacting work on the effect of emotional expression on human behavior and social interaction. Moreover, virtual humans have proven to

A comprehensive computational model of the influence of emotion on posture and gesture would also benefit the ECA community. It would improve the automatic detection of the emotional state of the user (see Chapter 15), as well as the generation of bodily expression of emotion, leading to more believable and human-like ECAs and more effective social interactions with virtual humans.

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