Individual Differences in Expressive Response: A Challenge for ECA Design (Short Paper)

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ABSTRACT
To create realistic and expressive virtual humans, we need to develop better models of the processes and dynamics of human emotions and expressions. A first step in this effort is to develop means to systematically induce and capture realistic expressions in real humans. We conducted a series of studies on human emotions and facial expression using the Emotion Evoking Game (EVG) and a high-speed video camera. In this paper, we discuss a detailed analysis of facial expressions in response to a surprise situation. We provide details on the rich dynamics of facial expressions, along with data useful for animation of virtual human. The analysis of the data also revealed considerable individual differences in whether surprise was evoked and how it was expressed.

Categories and Subject Descriptors
I.2.11 [**Distributed Artificial Intelligence**]: Intelligent agents
I.3.7 [**Three-Dimensional Graphics and Realism**]: Animation

General Terms
Measurement, design, experimentation, human factors, theory.

Keywords
Facial expression, emotions, virtual human expressiveness.

1. INTRODUCTION
The expression of emotion promises to be the elixir that can make an embodied agent come to life. It is not surprising that as work on embodied agents has progressed, there has been an increasing interest in creating agents with human-like emotions and expressive facial expressions. Significant progress has been made in this area, but the promise has not been fully realized.

What's wrong with embodied agent's facial expression and how can we improve it? One approach is to draw on research on human emotions and emotional expression. Existing research in psychology often has not looked at human emotions and facial expression at the level of detail needed to inform agent design. For example, questions concerning the dynamics of emotional expression have largely not been addressed. In our work we have undertaken to closely study human emotions and emotional expression to develop improved ways of modeling emotions and their expression. The methodology we employ requires first a systematic method for emotion evocation and second a method to record in detail the facial expression.

Traditionally, researchers have employed a wide range of stimuli to evoke emotions. These include displaying images or videos with emotional impact (Lang et al., 1999), recall emotional events (Frijda et al., 1989), interacting with a human confederate (Stemmler et al., 2001), and etc. In this study, we used a computer game called Emotion Evoking Game (Wang, Marsella 2006). EVG allows researchers to systematically explore factors that elicit emotion. The use of computer video games promises several benefits over the traditional approaches such as inducing task-related emotions and social emotions. Previous study found that EVG can reliably induce emotions and facial expressions (Wang, Marsella 2006).

Given EVG to systematically evoke emotions, we still need a way to record in detail the resulting facial expression. Earlier work on EVG clearly identified the weakness of using standard video cameras to record facial expressions. Much of the fine detail in the dynamics was lost at standard frame rates. This is not too surprising. Some facial expressions can be fleeting. Ekman (1985) argues that micro-expressions can be on the order of 40 ms. We also know that they can be subtle (Ekman 1985), with dynamic properties that can impact human interpretation (Parkinson et al., 2005). To study human facial expression closely, we need a high speed camera to capture the richness and subtlety of facial expression at a fine grain level.

Armed with EVG and a high-speed camera, we have begun to study facial expressions in earnest. In this paper, we discuss further evaluation of EVG's ability to evoke emotions systematically. We investigate what are the dynamics of human facial expression and what do those dynamics tell us about modeling embodied agents. The study reported here reveals the highly dynamic nature of facial expression, providing detailed timing information that can guide animation design.

2. Related Work
There is a large body of research that addresses questions concerning the relation of facial expressions to underlying emotions, and the impact of facial expressions as a communicative function that mediates social interaction. Studies by Ekman, et al. (1982) indicate that facial expressions can provide accurate information about emotion. Fridlund (1994)

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argues that expressions do not correlate to underlying emotions and rather has evolved to elicit behaviors from others. He contends that expressions are inherently social.

Research by Ekman (1982) shows that facial expression is a pattern of activities across the face. Darwin (1872) suggested that surprise is a biologically determined facial display consisting of three components: eyebrow raise, widening of the eyes, and opening of the mouth/jaw drop. Other research argues that facial expressions of emotion are more often partial than complete (Carroll, Russell 1997; Reisenzein 2000). Studies by Reisenzein (2006) find that surprise doesn't correspond to the three component display model.

EVG (Wang, Marsella 2006) is built on the ideas first realized in the GAME (Kaiser, Wehrle 1996). As a platform for conducting facial expression experiments, EVG provides us with the opportunity to study these different theories and explore the significance for embodied agents design.

3. EVG: The Emotion Evoking Game

EVG is adapted from a game called Egoboo (2000). It is implemented as a role-playing dungeon adventure game. The current setup includes events targeted to evoke five emotions: boredom, surprise, joy, anger and disappointment, in order. The story in the current study is that the player, accompanied by a teammate (a non-player character), starts out in an underground palace to collect 2000 units of gold. In the end, the player defeats the enemies and successfully collects 2000 units of gold. Then the teammate betrays the player by killing him and stealing the gold. There are five main emotion evoking phrases of this setup. This paper focuses on the stage called "Shock-and-Awe", during which the player faced sudden appearance of powerful enemies for the first time. Detailed descriptions of the other four stages can be found in Wang, Marsella (2006).

4. EVG Study

The focus of the study is emotions and expressions of player during Shock-n-Awe. We had the following hypotheses.

H1: Shock-n-awe event will induce self-reported surprise.

H2a: Subject would display raised eye-brow in response to Shock-n-awe event.

H2b: Subject would display mouth open / jaw drop in response to Shock-n-awe event.

H2c: Subject would display widened eyes in response to Shock-n-awe event.

H3: There is a correlation of self-report of surprise and display of surprise facial expression in response to Shock-n-Awe event.

4.1 Method

Participants: Thirty-five people (40% women, 60% men) participated in this study. They were recruited from craigslist.com and were compensated $20.

Procedure: Subject first read and signed the consent form and then filled out the pre-questionnaire packet. Next, the subject sat in front of the experiment computer and read the following message shown on the welcome screen of EVG:

"*Collect gold in the underground palace. Your goal is to collect 2000 gold. Your name is Louis. Alexis is your team member. Alexis can help you heal. Alexis has the key to the last chamber.*"

The subject then went through a training level to get familiar with the game controller. Next the subject started to play EVG. After that, the subject filled out the post-questionnaire packet.

Apparatus: A Vision Research Phantom v10 camera was used to capture facial expression at 240 fps. To produce enough light for the camera, the computer room was lit by 15 floor lamps with 3 100-Watt equivalent florescent light bulbs on each lamp.

Measures: Self-report of appraisal and emotion is measured using five copies of a questionnaire modified from Geneva Appraisal Questionnaire (GAO). Subjects were asked to report five events or moments that he/she felt emotions during the game. Two minutes of subject's facial expression (last two minutes before the game ends) was captured. A certified FACS coder viewed the video and marked appearance of raised eyebrows (AU1 and AU2), widened eyes (AU5) and mouth open/jaw drop (AU25, 26 and 27) after Shock-n-Awe event.

4.2 Result

4.2.1 Testing of Hypothesis

Data from 6 subjects are excluded due to technical difficulties. As a result, data from 29 subjects are reported.

In the post-questionnaire, 65.5% of the subjects reported feeling surprise at Shock-n-awe. Table 1 compares the display of different components of surprise facial expression between all the subjects and those subjects who reported feeling surprise. Out of the three components of the surprise facial expression, mouth open and jaw drop was displayed most often. But only 5 subjects showed widened eyes with low intensity. Interestingly, even though over half of the subjects displayed at least one of the components of the surprise facial expression, no subject showed all three components described by Darwin (1872). In addition, 47.4% of the subjects who reported surprise didn't show any of the three components.

Table 1: Percentage of the subjects that displayed different components of surprise facial expression

	Overall	Reported Surprise
Raised Eyebrow	20.7%	21.1%
Widened Eyes	17.2%	10.5%
Mouth Open/Jaw Drop	41.4%	52.6%
Raised Eyebrow + Widened Eyes	3.4%	0
Raised Eyebrow + Jaw Drop	17.2%	21.1%
Widened Eyes + Jaw Drop	6.9%	10.5%
Any one component	51.7%	52.6%
Any two components	24.1%	31.6%
All three components	0%	0%
None of the three components	48.3%	47.4%

4.2.2 A Closer look at surprise facial expression

In our data, we noticed great richness and dynamics of expressions across all subjects. Figure 1 shows one subject's response to the Shock-n-Awe event. The subject started with slightly parted lips and tightening of the eyebrows as he first walked into the last chamber (frame 0). We noticed a very high percentage of the subjects displayed tightening of the eyebrows at this stage. This could probably due to confusion or the lighting in the room. As the subject in Figure 1 saw the enemy appear, his eyes started to widen (frame 25), followed by raising eyebrows, further tightening of eyebrows and opening his mouth (frame 55). Then, the subject appeared to realize that he is under attack by more powerful enemies. We start to see funneling of the lips and further tightening of eyebrows (frame 110). Next, the subject looked down on his game controller to search for the attack button (frame 215), probably because he's still not very familiar with the controller. After finding the attack button, the subject's inner eyebrows were more relaxed and lips were less funneled (frame 265). As he getting ready to fight the enemy, subject's eyebrows started to raise (frame 295), lips started to tighten (frame 340) then funneled again (frame 370). Gradually, subject returned to a face similar to when he started (frame 425 to 505). All these happened within 506 frames, slightly over 2 seconds.

To further analyze the timing of different components of the facial expression, we annotated the start, apex, sustain and end of each facial expression. Onset is the time between start and apex. Offset is the time between end of sustain and the end. In

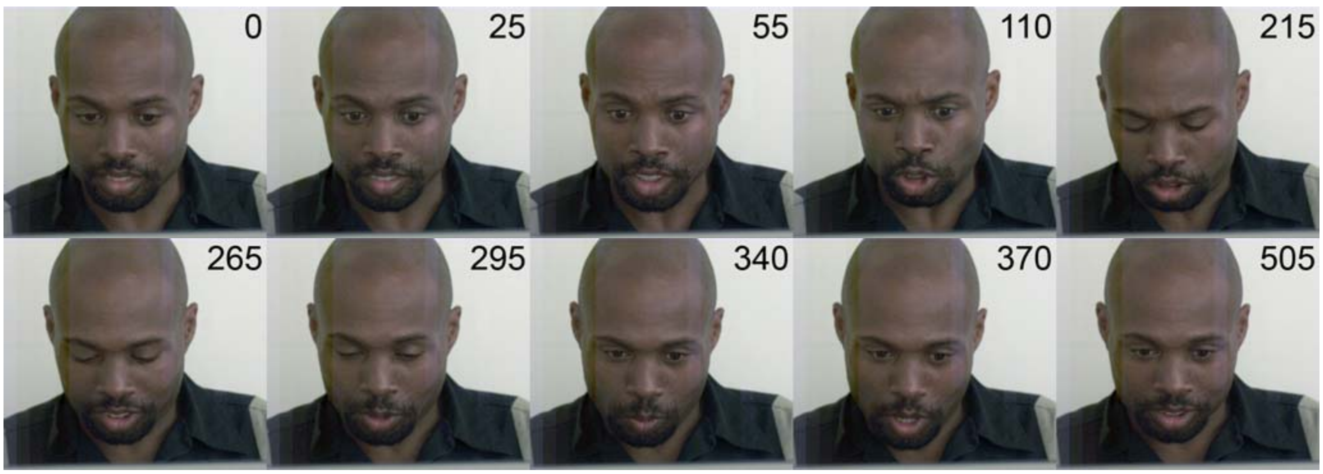

Figure 1. Richness dynamics of facial expression change in response to Shock-n-Awe event

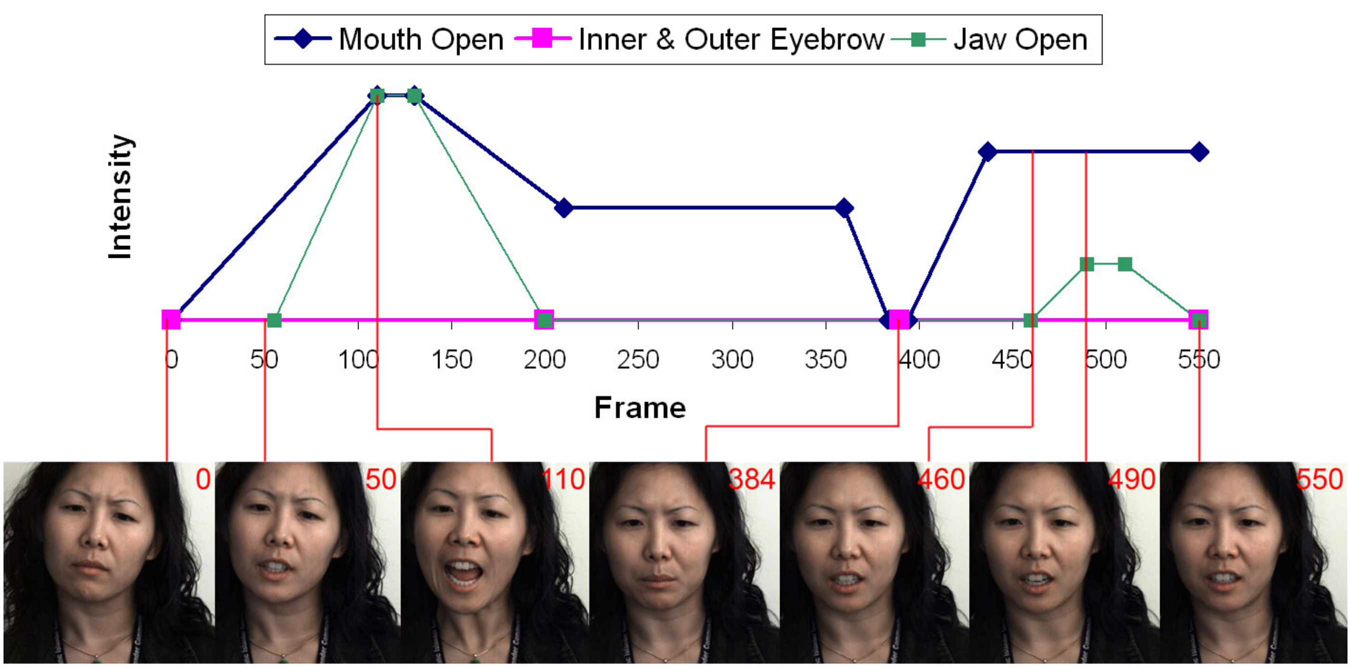

Figure 2. Timing of different components of surprise facial expression in reaction to Shock-n-Awe event

our sample, the average onset of mouth open / jaw drop is .49 seconds. The average onset of eyebrow raise is also about .49 seconds. Both onsets range from 1/10 of a second to just over a second. Even though the average onsets of mouth opening and eyebrow raise are the same, in most cases, the onsets of these two components are different. We didn't have enough data to compute the average onset of eyes widen or the difference between the start of different facial components.

In our data, some subjects "completed" the surprise facial expression. Their face returned to what it was before the surprise expression started. However, there is great diversity in the offset of the surprise facial expression. For the subject in Figure 2, after the expression reaches the apex, the intensity of the components that involved in the expression gradually decrease but don't return to the intensity before they started. They either drop to a lower intensity, stay that intensity for a long time, or other facial components start to take action and change the facial expression. For example, instead of closing the mouth, the open mouth would morph into a smile.

5. Conclusion

Overall, the results reveal considerable differences across subjects in terms of the emotions evoked and expressed. For example, in subjects who reported surprise, 47.4% showed none of Darwin's three components of surprise. And no one showed all three components. Only 17.2% of subjects showed widened eyes. In some cases, instead of showing widen eyes (AU5), subjects showed a decrease in intensity of eye closer (AU43). This means that the eye lids changed from a relaxed more closed state to a relaxed more open state instead of tightened more open state. Sometimes the subject's head is much higher than the computer monitor. This probably made the subject to look down by dropping the eye lids.

Careful study of these high-speed captures reveals remarkable dynamics and variability of the facial expression over time. This suggests that a repository of such capture will be a valuable asset for animating and/or computer modeling of facial expression.

In conclusion, we evaluated EVG and explored the relation between emotion and emotional expression. We found EVG was very successful in evoking emotions and a wide range of facial expression. We found considerable variability between surprise and facial display of surprise. Our data also reveals the highly dynamic nature of facial expression and that emotions are expressed differently from one individual to another. These results suggest that virtual humans can't be one-size-fits-all. We need to design embodied characters in more flexible ways that accommodate and convey individual differences. More importantly, these results argue that more emphasis on the dynamics of facial expression is required and we may need to evolve beyond fixed, canned animations.

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