The contribution of different body channels to the expression of emotion in animated pedagogical agents

Saikiran Anasingaraju
Purdue University, West Lafayette, IN, USA
sanasing@purdue.edu

Nicoletta Adamo
Purdue University, West Lafayette, IN, USA
nadamovi@purdue.edu

Hazar Nicholas Dib
Purdue University, West Lafayette, IN, USA
hdib@purdue.edu

Abstract.
Pedagogical agents are animated characters embedded within an e-learning environment to facilitate learning. With the growing understanding of the complex interplay between emotions and cognition, there is a need to design agents that can provide believable simulated emotional interactions with the learner. Best practices from the animation industry could be used to improve the believability of the agents. A well- known best practice is that the movements of limbs/torso/head play the most important role in conveying the character's emotion, followed by eyes/eyebrows/face and lip sync, respectively, in a long shot. Our study tested the validity of this best practice using statistical methods. It investigated the contribution of 3 body channels (torso/limbs/head, face, speech) to the expression of 5 emotions (happiness, sadness, anger, fear, surprise) in a stylized agent in a full body shot. Findings confirm the biggest contributor to the perceived believability of the animated emotion is the character's body, followed by face and speech respectively, across 4 out of 5 emotions.

Key words: *Animation of Emotions, Body Channel, Conversational Agents, Affective Pedagogical Agents*

1. Introduction

The potential of emotional interaction between human and computer has recently become an area of great interest for researchers in human- computer interaction. With the advance of technology, it is now possible to design computer-based learning environments that support simulated social interactions between learner and computer (Kim et al. 2007). Pedagogical agents with emotional capabilities can provide such interactions with the learner. According to Kim, Baylor and Shen, it is "*the provision of such simulated social interactions that may distinguish pedagogical embodied agents from traditional computer-based tutoring, seemingly offering a unique instructional impact*"(Kim et al. 2007).

Although a few researchers have equipped intelligent agent systems with affective capabilities (Lisetti & Nasoz 2002; D'Mello & Graesser 2012; Morency et al., 2015), the animation quality of existing affective pedagogical agents is low. The agent often appears robotic, with mechanical motions and without personality or clear emotional state; learners fail to connect with such agent and fail to engage in the learning activity. On the other hand, animated agents that captivate and engage by displaying believable personality and emotions are now possible, as demonstrated by the enormous popularity of computer graphics applications in entertainment, such as movies and games. Nonetheless, these highly engaging characters have not made their way into the educational domain yet.

Best practices and principles from the animation industry could be applied to the development of embodied agents in order to improve their believability and life-like appearance. However, the authors believe that such best practices and principles should be scientifically tested and quantified before they can be accepted as animation rules, and hence implemented in new algorithmic approaches for animating embodied agents. The study reported in the paper is a first step in this direction. It used a group of 100 participants and statistical methods to test the validity of a well-known best practice in animation of emotion, e.g., *the movements of limbs, torso and head contribute the most to the believability of the emotional state of the character, followed by eyes/eyebrows/face and lip sync, respectively, in a full body shot.*

The paper is organized as follows. Section 2 presents a review of current research on Animated Pedagogical Agents, including affective agents, and discusses expression of emotions in acting and character animation. The study and findings are described in section 3; conclusion and future work are included in section 4.

2. Literature Support

2.1 Animated Pedagogical Agents

Pedagogical Agents are animated characters embedded within a computer based learning environment to facilitate student learning. Early examples of Animated Pedagogical Agents (APA) are Cosmo (Lester et al. 1997) a cosmonaut who explains how the internet works, Herman (Lester et al. 1999a; 1999b), a bug-like creature that teaches children about biology, and STEVE (Johnson & Rickel, 1988) who trains users in operating complex machinery using speech, gestures, and gaze behavior. PETA is a 3-D computer animated human head that speaks by synthesizing sounds and can convey different facial articulations (Powers et al., 2008). It allows children to acquire a new language in a spontaneous, unconscious manner. A similar example is the "Thinking Head" (Davis et al., 2007) a virtual anthropomorphic agent able to speak and to display emotion through facial expressions, vocal prosody, and gestures. Animated signing agents have also been used to teach mathematics and science to young deaf children using sign language, e.g. Mathsigner and SMILE (Adamo-Villani & Wilbur, 2008).

Many studies confirm the positive learning effects of systems using these agents (Lester et al., 1997; Holmes, 2007; Moreno & Mayer, 2007; Lusk & Atkinson, 2007). Cassell (2000), one of the first researchers who studied the use of animated agents in learning and communication, developed the Embodied Conversational Agent, an interactive virtual agent that can speak and exhibit nonverbal behaviors. Cassell argued that well-designed embodied pedagogical agents could enrich one's learning experience and foster motivation. A fairly recent meta-analytic review of 43 papers shows that APAs enhance learning in comparison with learning environments that do not feature agents (Schroeder et al., 2013). Studies also suggest that APAs could be employed in e-learning environments to enhance users' attitude towards online courses (Annetta & Holmes, 2006). Agents interacting using multiple modalities appear to lead to greater learning than agents that interact only in a single channel (Alseid & Rigas, 2010; Lusk & Atkinson, 2007).

2.1.1 Affective Agents

Over the past few years, researchers have started to consider the learners' affective states when designing educational tools and have attempted to design systems and devices that can recognize, interpret, process, and stimulate human affect, as well as express affect. A few affective agents systems have been developed to date. The system by Lisetti and Nasoz (2002) combines facial expression and physiological signals to recognize a limited set of user's emotions, like fear and anger. A multimodal anthropomorphic agent then adapts its interface by responding to the user's emotional states, and provides multi-modal feedback to the user. The IA3 system by Huang et al. (2000) was an early attempt at developing Intelligent Affective Animated Agents that recognize human emotion, and based on their understanding of human speech and emotional state, decide on how to respond. Affective Autotutor (D'Mello & Graesser, 2012) is a tutoring system that detects the learner emotional state from a combination of signals and helps students regulate their affective states so that positive states persevere, while negative states are prevented or regulated when they arise. Emotion regulation is provided by the agent's emotional response operationalized with respect to facial expressions and speech feedback. SimSensei (Morency et al., 2015) is a virtual agent that engages in interviews with the user in order to elicit behaviors that can be automatically measured and analyzed. SimSensei uses a multimodal sensing system that captures a variety of signals such as smile intensity, head position, intensity of facial expressions, speech patterns, gaze direction etc. These signals are used to assess the user's affective state as well as to inform the agent so she/he can provide an appropriate emotional response.

Research indicates that the manipulation of the APAs' affective states can significantly influence learner beliefs and learning efficacy (Zhou et al., 2012). For instance a study by Kim and Baylor (2007) showed that an agent's empathetic responses to the student's emotional states while learning had a positive influence on learner self-efficacy in the task, whereas an agent's happy smiles per se did not have such an effect. A meta-analytic review that examined findings from studies on the efficacy of affective APAs in computer-based learning environments shows that the use of emotion in APAs has a significant impact on students' motivation, knowledge retention and knowledge transfer (Guo & Goh, 2015).

2.2 Expression of emotion in acting and animation

There is a significant amount of literature on the importance of different body channels in an acting performance in both live-action and theatre. Research has also been conducted on the importance of these body channels with respect to character animation. However, none of prior studies looked at the relative importance of the different body channels in making a believable character animation. This review discusses the existing literature and provides the necessary foundation for the study reported in the next section.

According to Bartneck (2001), the main components of body language are facial expressions, gestures and body movement. Larsson argues that non-verbal cues make up the majority of a conversation (Larsson, 2014, pp. 6-7), and Driver (2008), a body language expert, claims it to be a whole 93%. These non- verbal cues include the tone and pitch of voice, posture, micro expressions on the face, as well as different gestures. According to Larsson (2014), body language is sectioned into three bodily attributes, the face, the body and the tone of voice. Although it has been widely assumed, there is no real evidence that the face is a stronger communicator than the body (Larsson, 2014, pp. 6-7). Aviezer, Trope and Todorov (2012) believe that during peak intensities of emotion, positive and negative situations were successfully discriminated from isolated bodies but not faces.

A significant amount of research shows that some affective expressions may be better communicated by the body than by the face (Argyle, 1988; Bull, 1987; De Gelder, 2006). Body expressions may provide more information than the face when discriminating between fear and anger (Meeren et al., 2005) or fear and happiness (Van den Stock, Righart, & De Gelder, 2007). For an acting performance, bodily movements can sometimes signal an intention that cannot be derived from facial expressions (e.g., approach and avoidance behaviour) (McDonnell et al., 2009; Nijholt, 2001).

Cohen (2011) points to the importance of the eyes in an acting performance, and McNeill (2000) states the importance of the eyebrows in signalling different emotions, "*The eyebrow is the great supporting player of the face…. without eyebrows the surprise expression almost disappears. The eyebrows are such active little flagmen of mind-state it's amazing anyone can wonder about their purpose. We use them incessantly*" (McNeil, 2000, p. 199).

Much like acting, character animation involves movement in different channels of the character's body. It is well known in the animation industry that each of these different body channels provides varying contributions to the believability of an acting performance. According to S. Kelly (2008) the body language and pantomime are by far the most important aspect of the overall acting performance in a medium shot or wider. In a full body shot, an established rule in the field of character animation is that the movement of limbs, torso and head is the most important, followed by eyes/eyebrows, face and lip sync in the decreasing order of importance. John Lasseter states that when the main idea of an action is being told in the movement of the body, the facial expression become subordinate to the main idea (Lasseter, 1987). Kelly (2008) adds that one can break down an acting performance into four categories of exponentially decreasing importance: the body, then the eyes, then the face, then the lip-sync. Ward (2014) feels that it is important to concentrate on the body language initially, as it plays a huge role in the way we read what a character is trying to say and can convey how they are feeling. Roberts (2011) states that when animating a character, it is always best to work out the body language first and then add the facial expressions, as facial expressions could be ambiguous and misleading.

According to Keith Lango (2004), after the body, the eyes play a key role in emotional communication. In a medium to wide shot, body language in animation represents the most important element of an acting performance (Kelly et al., 2009).

On the other hand, Volkova et al. (2014) argue that the amount of information expressed through the body alone should not be sufficient for an observer to recognize the emotion, since most of the information is expressed through the facial expressions, the speech prosody and, importantly, verbal content.

According to Hohnstadt (2013), while the face can provide a wealth of story-telling data with just a simple expression, the story does not come just from the head. By using the entire body, and really pushing the character poses, it is possible to achieve a better sense of story and scene than with faces alone. Hooks (2013) argues that a character's body language transmits a more powerful message visually than his dialogue, and Bird (2010) explains how bodily expression becomes much more important when the character is framed in a full body shot. Bartošová (2011) explains how gestures can help to express emotions clearly and emphasize a point, while the movements of the eyes, mouth, and facial muscles contribute to creating a connection with the audience.

In the context of animated pedagogical agents, several researchers are starting to consider the importance of body language in the expression of the agent affective state, although facial expressions and speech are the modalities that have been studied the most until now. Lester et al. (1998) say that animated pedagogical agents that are fully expressive are highly desirable for many domains, tasks, and target learner populations. According to Lester " *while emotions can be communicated solely with facial expressions, employing a body including arms enables the agent to gesture emotively*" (Lester et al., 1998, p.281).

Karg et al. (2013) argue that body movements are particularly important for expressing emotions that are less susceptible to social editing, or to communicate affective states that are conveyed more clearly through movement rather than facial signals. Bodily cues have been shown to be very effective for discriminating between intense positive and intense negative affective states (Aviezier et al., 2012).

3. Description of the study

The goal of the study was to investigate the contribution of 3 different body channels (torso/limbs/head, face, and speech) to the perceived believability of 5 emotions, happiness, sadness, anger, fear and surprise in an animated stylized pedagogical agent in a full body shot. Figure 1 shows the APA used in the study framed in a full body shot delivering an intro to statistics lecture.

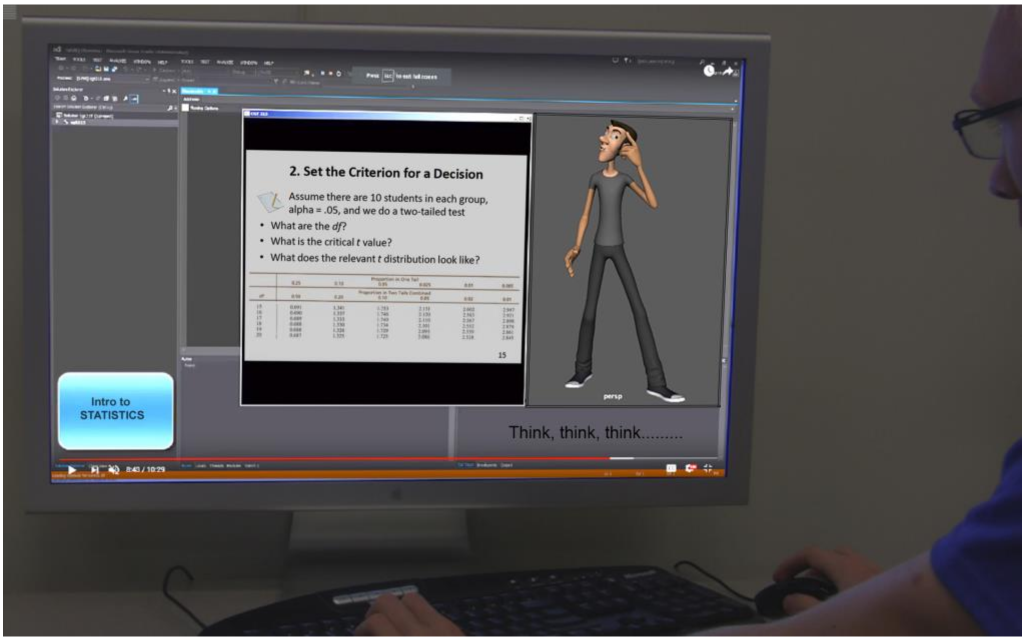

Figure 1. Affective APA delivering a statistic lesson and interacting with the learner

3.1 Stimuli

The stimuli were 20 animation clips featuring a single character, 4 clips for each of the 5 emotions. All clips made use of the same character, type of camera shot and lighting conditions. For each emotion, one of the 4 animations had all the body channels animated. The other 3 animations had animation of one of the following body channels “toned down”:

(1) limbs/torso/head, (2) eyes/eyebrows/face and (3) lip sync. The “toning down” was achieved by reducing the magnitude of all the keyframes on one of the channels by 50%. In other words, for gestures, body motions, lid movements and gaze direction we reduced the translation and rotation values by 50%, for facial deformations including eyebrows and speech mouth shapes (e.g. visemes), we reduced the deformation values by 50%. Each of the 4 animations was about 10 seconds in duration. Figure 2 shows the frames extracted from the four animation clips for each of the five emotions. Each row in the figure corresponds to each of the five emotions. The four frames shown from left to right as follows: all body channels animated to 100%, limbs/torso/head reduced to 50%, eyes/eyebrows/face reduced to 50% and lip sync reduced to 50%.

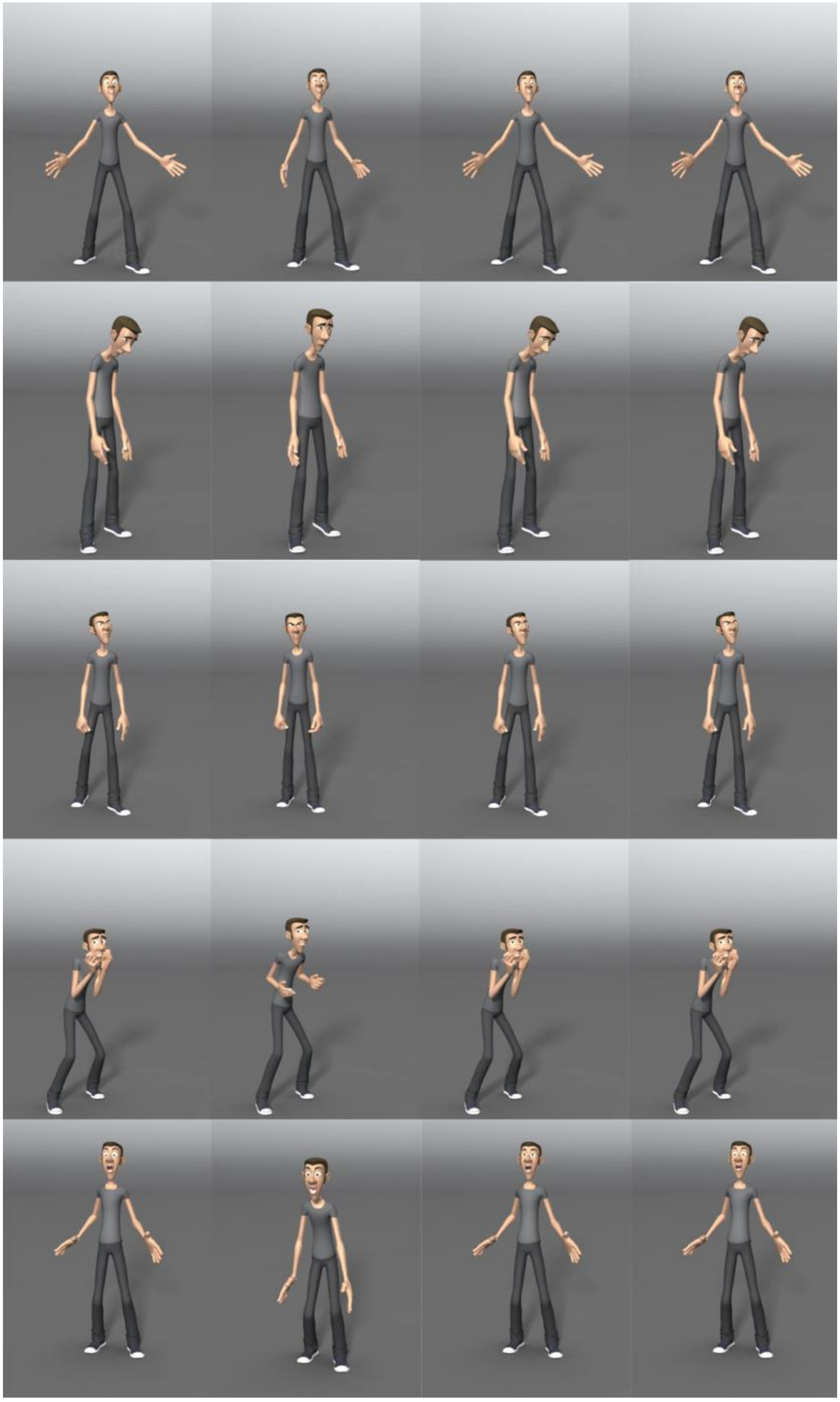

Figure 2. Frames extracted from the four animations for each of the five emotions. Emotions from top to bottom: happiness, sadness, anger, fear and surprise. Variations from left to right: all channels animated to 100%, limbs/torso/head reduced to 50%, eyes/eyebrows/face reduced to 50% and lastly, lip sync reduced to 50%.

3.1.1 Choice of shot, character style and rig

A full body shot was chosen for the agent animations. In general, most animation shots do not cut close to face. Roberts (2004) explains the difficulty with close up shots in 3D character animation, "*Whereas film acting requires a certain amount of restraint, the camera can cut right into somebody's face and a whole range of emotions can be put over with the movement of an eyebrow. This is something that animation finds very difficult to do. The closer you cut into the face of your character, the more obvious it is that your character is artificial*" (Roberts, 2004, p. 160).

In regard to character visual style, a stylized character was selected for the animations. The decision of using a stylized character was based on findings from a research study by Cissell (2013) that indicated that participants were more likely to recognize the emotion displayed by a stylized character, as compared to a realistic one, although the difference in recognition was not statistically significant. In addition, stylized characters were on average rated higher for sincerity and intensity. The "Malcolm character" (AnimSchool, 2015) was selected for the study because it is capable of strong silhouettes and has a very flexible and expressive face rig. In addition, Malcolm has a fairly large head with long limbs, which make him highly expressive in all the body channels.

3.2 Population, Sampling and Variables

The subjects of the study were students (18-24 years old) from the departments of Computer Graphics Technology, Computer Science, Aeronautics & Astronautics, and Electrical & Computer Engineering at Purdue University. The study used simple random sampling and a total of 100 responses were collected while the survey was active. However, 29 of the responses were either incomplete or faulty and were discarded. About 44% of the respondents were from the department of Computer Graphics Technology.

The independent variable was the "body channel". The dependent variable was "perceived animation believability". Animation believability rating was obtained from an online survey (described in the next section). Performance was measured using the steps discussed in the statistical analysis section (3.4).

3.3 Procedure & evaluation Instrument

The participants were sent an email with a brief summary of the research study and a link to the online survey. The web survey consisted of 2 demographics questions and 5 screens, one screen per emotion. The demographics questions related to subjects' age and subjects' background (CGT; non CGT). Each screen included a set of 4 animation clips showing one of the 5 emotions. Figure 3 shows a screen extracted from the web survey. Subjects had the ability to view all the 4 clips simultaneously (figure 3, bottom video) or one at a time (figure 3, top videos). Subjects were asked to rate the believability of each video clip using a 4-point scale (1 star= lowest believability; 4 stars= highest believability). The screens were presented in random order. Data collection was embedded in the survey; in other words, a program running in the background recorded all subjects responses and stored them in an excel spreadsheet.

3.4 Statistical Analysis & Performance Measurement

For each emotion, pairwise t-test were performed to check if the differences between ratings of the four animation clips are statistically significant. The four animation clips are described below.

- Clip 1 has all the body channels animated to 100% (hereby referred to as 'o')
- Clip 2 has the animation of body (e.g. limbs, torso, head) toned down to 50% (hereby referred to as 'b')
- Clip 3 has the animation of face, eyes toned down to 50% (hereby referred to as 'f')
- Clip 4 has the lip sync animation toned down to 50% (hereby referred to as 'l')

Below are the six null hypotheses tested for each emotion.

- H_{01}: $o - b \leq 0$
- H_{02}: $o - f \leq 0$
- H_{03}: $o - l \leq 0$
- H_{02}: $f - b \leq 0$
- H_{02}: $l - b \leq 0$
- H_{02}: $l - f \leq 0$

These tests helped in providing the final rankings for the four animations for a particular emotion. The same procedure was followed for the animations under each of the five emotions.

3.5 Results

The following table shows the results for the five emotions.

Table 1. P-values for the six hypotheses

Emotion	p-value for H_{01}	p-value for H_{02}	p-value for H_{03}	p-value for H_{04}	p-value for H_{05}	p-value for H_{06}
Happiness	0	0.967	0.232	0	0.0002	0.9962
Sadness	0.009	0.0943	0.0199	0.1285	0.116	0.5735
Anger	0	0.0065	0.0213	0	0	0.2268
Fear	0	0.0038	0.0169	0	0	0.3563
Surprise	0	0.0021	0.018	0	0	0.1499

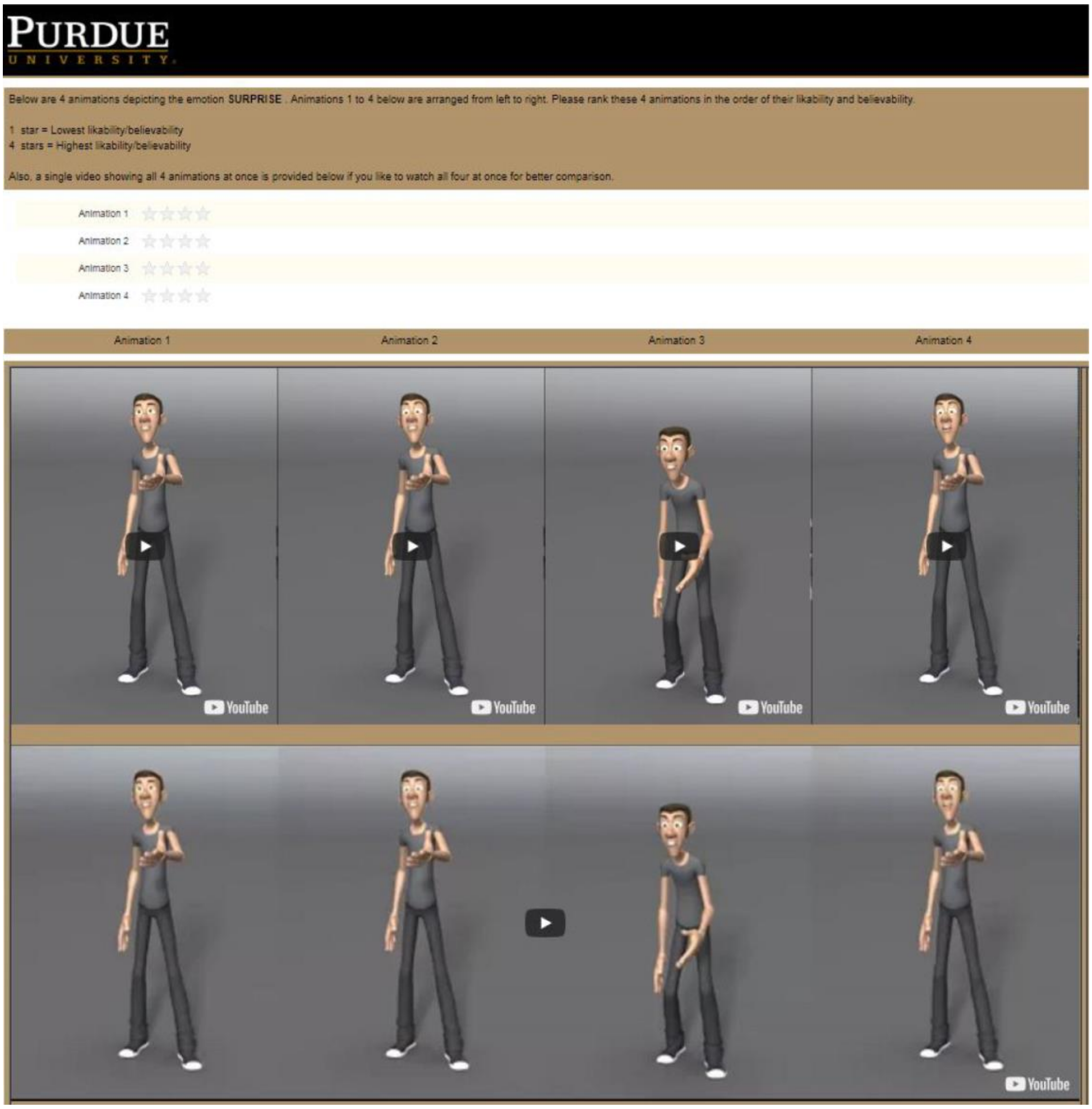

Figure 3. Screen extracted from the web survey for the "surprise" emotion

3.5.1 Happiness

The p-values for H_{01}, H_{02}, H_{03}, H_{04}, H_{05} and H_{06} are 0, 0.967, 0.232, 0, 0.0002 and 0.9962 respectively. So, H_{01}, H_{04} and H_{05} are rejected but H_{02}, H_{03} and H_{06} could not be rejected. Below are the findings:

- There is enough evidence to claim that μ_o is greater than μ_b.
- There is not enough evidence to claim that μ_o is greater than μ_f.
- There is not enough evidence to claim that μ_o is greater than μ_l.
- There is enough evidence to claim that μ_f is greater than μ_b.
- There is enough evidence to claim that μ_l is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_f.

Figure 4 shows a box plot of "body channel", Table 2 gives the mean believability ratings for the four animation clips.

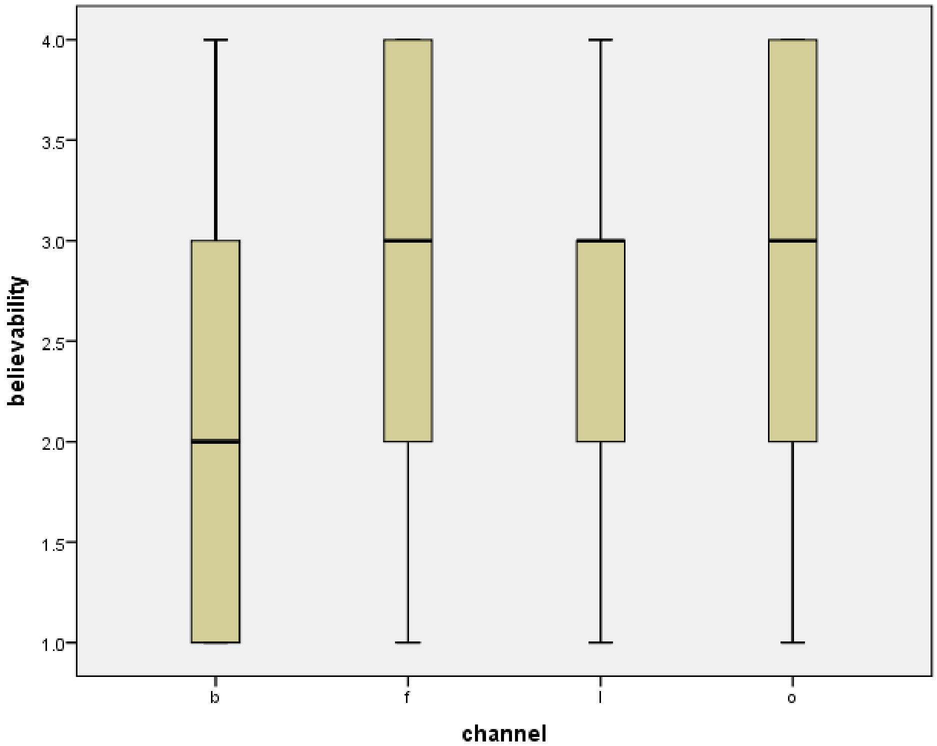

Figure 4. Box plot of 'body channel' for Happiness

Table 2. Means of believability ratings for Happiness

Channel	Mean
b	2.06
f	3.03
l	2.72
o	2.8

3.5.2 Sadness

The p-values for H_{01}, H_{02}, H_{03}, H_{04}, H_{05} and H_{06} are 0.009, 0.0943, 0.0199, 0.1285, 0.116 and 0.5735 respectively. So, H_{01} and H_{03} are rejected but H_{02}, H_{04}, H_{05} and H_{06} could not be rejected. Below are the findings:

- There is enough evidence to claim that μ_o is greater than μ_b.
- There is not enough evidence to claim that μ_o is greater than μ_f.
- There is enough evidence to claim that μ_o is greater than μ_l.
- There is not enough evidence to claim that μ_f is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_f.

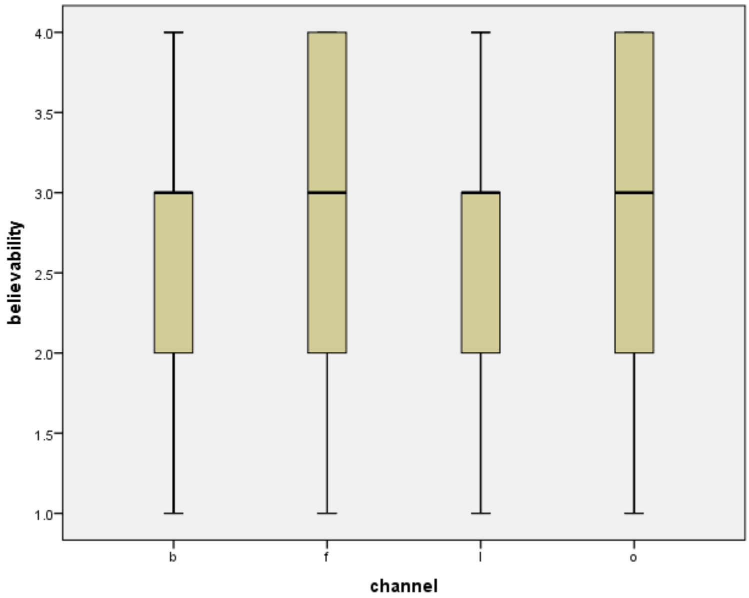

Figure 5. Box plot of 'body channel' for Sadness

Figure 5 shows a box plot of 'body channel' for Sadness. Table 3 gives the mean believability ratings for the four animation clips.

Table 3. Means of believability ratings for Sadness

Channel	Mean
b	2.59
f	2.8
l	2.77
o	3.01

3.5.3 Anger

The p-values for H_{01}, H_{02}, H_{03}, H_{04}, H_{05} and H_{06} are 0,0.0065,0.0213,0,0 and 0.2268 respectively. So, H_{01}, H_{02}, H_{03}, H_{04} and H_{05} are rejected but H_{06} could not be rejected. Below are the findings:

- There is enough evidence to claim that μ_o is greater than μ_b.
- There is enough evidence to claim that μ_o is greater than μ_f.
- There is enough evidence to claim that μ_o is greater than μ_l.
- There is enough evidence to claim that μ_f is greater than μ_b.
- There is enough evidence to claim that μ_l is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_f.

Figures 6 shows the box plots for the independent variable 'body channel'. Table 4 gives the mean believability ratings for the four animation clips.

Table 4. Means of believability ratings for Anger

Channel	Mean
b	2.08
f	2.89
l	3
o	3.3

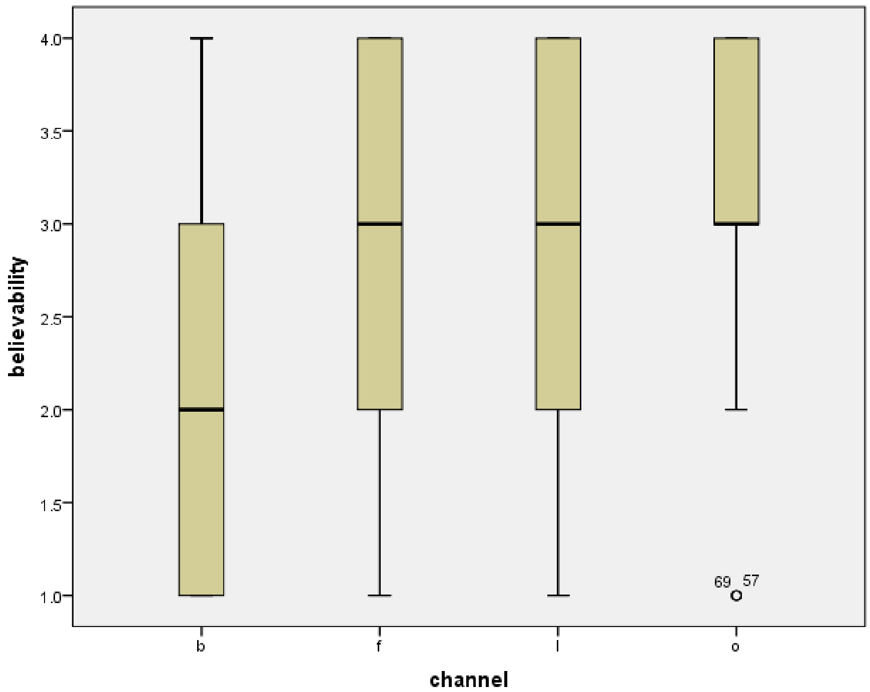

Figure 6. Box plot of 'body channel' for Anger

.

3.5.4 Fear

The p-values for H_{01}, H_{02}, H_{03}, H_{04}, H_{05} and H_{06} are 0,0.0038,0.0169,0,0 and 0.3563 respectively. So, H_{01}, H_{02}, H_{03}, H_{04} and H_{05} are rejected but H_{06} could not be rejected. Below are the findings:

- There is enough evidence to claim that μ_o is greater than μ_b.
- There is enough evidence to claim that μ_o is greater than μ_f.
- There is enough evidence to claim that μ_o is greater than μ_l.
- There is enough evidence to claim that μ_f is greater than μ_b.
- There is enough evidence to claim that μ_l is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_f.

Figures 7 shows the box plots for the independent variable 'body channel'. Table 5 gives the mean believability ratings for the four animation clips.

Table 5. Means of believability ratings for Fear

Channel	Mean
b	2.06
f	2.92
l	2.96
o	3.23

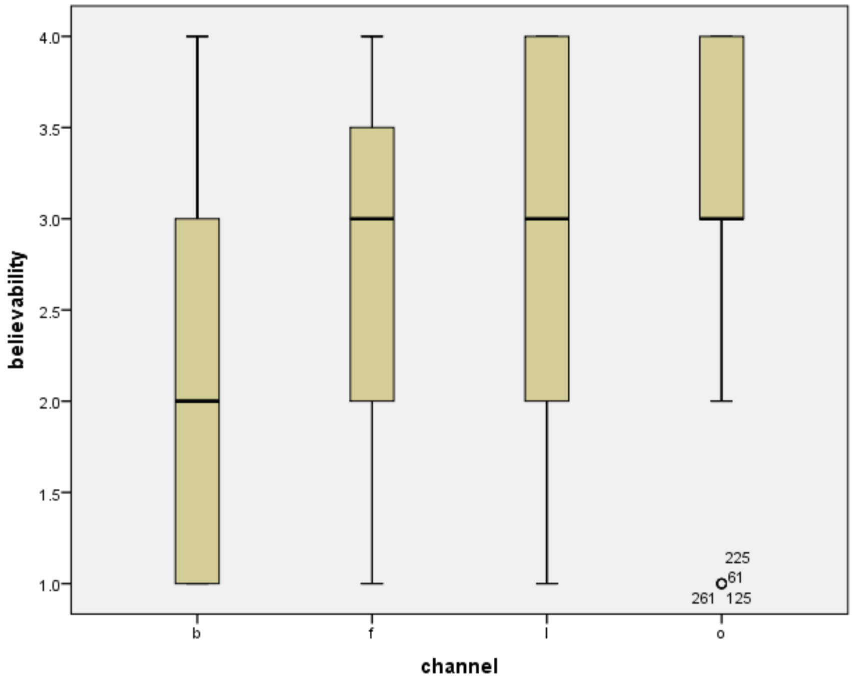

Figure 7. Box plot of 'body channel' for Fear

3.5.5 Surprise

The p-values for H_{01}, H_{02}, H_{03}, H_{04}, H_{05} and H_{06} are 0,0.0021,0.018,0,0 and 0.1499 respectively. So, H_{01}, H_{02}, H_{03}, H_{04} and H_{05} are rejected but H_{06} could not be rejected. Below are the findings:

- There is enough evidence to claim that μ_o is greater than μ_b.
- There is enough evidence to claim that μ_o is greater than μ_f.
- There is enough evidence to claim that μ_o is greater than μ_l.
- There is enough evidence to claim that μ_f is greater than μ_b.
- There is enough evidence to claim that μ_l is greater than μ_b.
- There is not enough evidence to claim that μ_l is greater than μ_f.

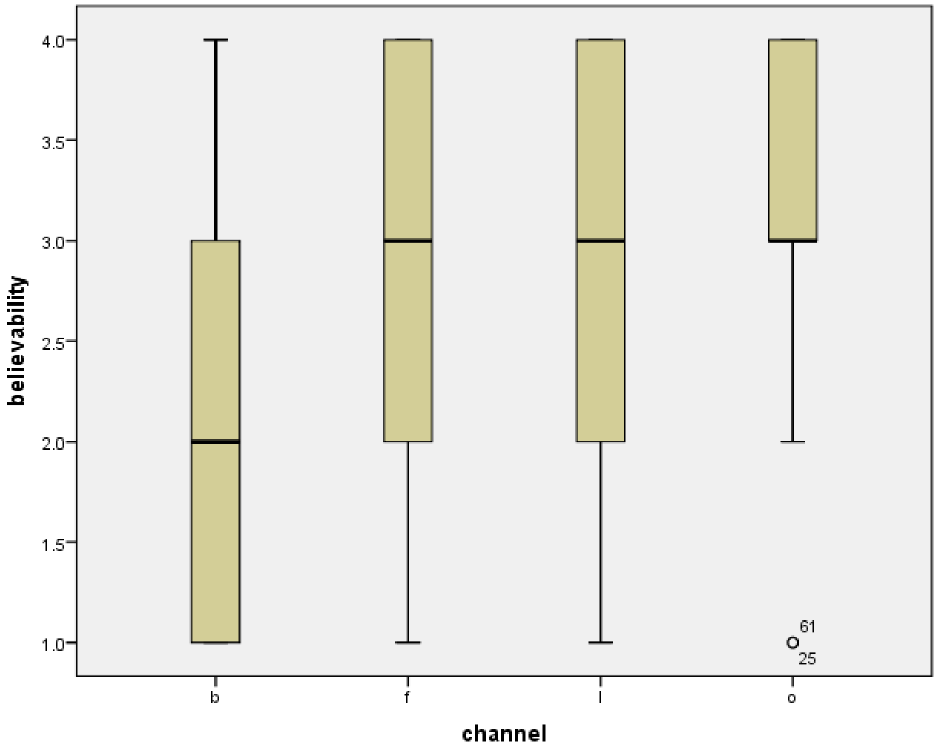

Figure 8. Box plot of ‘body channel’ for Surprise

Figure 8 shows the box plot for ‘body channel’ for surprise; Table 6 gives the mean believability ratings for the four animation clips.

Table 6. Means of believability ratings for Surprise

Channel	Mean
b	2.07
f	2.82
l	2.97
o	3.24

3.6 Discussion

Out of the three channels, it was found that the one with reduction in torso/limbs/head animation received the lowest believability ratings for the emotions happiness, anger, fear and surprise. Sadness is an exception to this observation. For the emotions angry, fear and surprise, the reduction in the animation of eyes/eyebrows/face caused a dip in believability compared to the original animation. Similarly, the toning down in the animation of lip sync decreased the believability compared to the original animation. Happiness and Sadness are the exceptions to this observation.

Sadness seems to be an exception overall, as the differences were not significant. This can be attributed to the fact that an action feels “sadder” if the overall body motions are reduced, e.g. they appear less energetic and vigorous. Hence the reduction of torso/limbs/head movements by 50% enhanced the perceived believability of sadness for most participants.

In summary, the findings of the study suggest that in an animation featuring a stylized male character framed in a full body shot, the biggest contributor to the perceived believability of the emotion expressed by the character are the torso/limbs/head motions. The reduction in facial and lip sync animation does not impact the believability ratings as much as the reduction in body language.

4. Conclusion and Future Work

The paper reports a study that investigated the contribution of different body channels (torso/limbs/head, eyes/face and speech) to the expression of emotion in animated agents. Findings show that body gestures (e.g., movements of torso, limbs and head) contribute the most to the perceived believability of the emotional state of a stylized agent framed in a full body shot. For three of the five emotions, it is found that toning down of animation for eyes/face and speech reduced the perceived believability when compared to the original animation. These findings are important, as they can help animators and instructional technologists design effective affective pedagogical agents that display clear and believable emotional states. However, additional research is needed in order to generalize the findings and apply them to different types of agents and camera shots, and across a larger spectrum of emotions.

For instance, pedagogical agents are often framed in a medium shot (e.g. from waist up), hence it would be interesting in future work to see how the three body channels examined in this study differ in importance in a medium shot.

The agent used in the experiment reported in the paper is a stylized character with human like body proportions. Future research could investigate whether the results from this study apply to characters that have different visual styles (e.g. realistic or iconic) and different body proportions.

Also, sadness came out as an exception in this research. Though reduction in body movements caused the biggest dip in believability ratings for the other emotions, it slightly increased the believability of sadness, even if the increase was not statistically significant. Future work could focus on the interplay of different body channels in the perceived believability of other emotions, especially the ones relevant to learning, such as interest, boredom, satisfaction, frustration, curiosity.

REFERENCES

Adamo-Villani, N. & Wilbur, R. (2008). Two novel technologies for accessible Math and Science Education. *IEEE Multimedia – Special Issue on Accessibility*, 38-46.

Alseid, M., & Rigas, D. (2010). Three Different Modes of Avatars as Virtual Lecturers in Elearning Interfaces: A Comparative Usability Study. *The Open Virtual Reality Journal*, 2, 8-17.

AnimSchool. (2015). AnimSchool's Malcolm Rig. Retrieved from http://www.animschool.com/malcolmInfo.aspx

Annetta, L.A., & Holmes, S. (2006). Creating Presence and Community in a Synchronous Virtual Learning Environment Using Avatars. *Intern. J. Instruct. Technol. Dist. Learn.,* 3, 27-43.

Argyle, M. (1988). *Bodily communication*. New York: Methuen & Co.

Aviezer, H., Trope, Y., & Todorov, A. (2012). Body cues, not facial expression, discriminate between intense positive and negative emotions. *Science*, *338*, 1225-1229.

Baylor, A. L., & Ryu, J. (2003). The effects of image and animation in enhancing pedagogical agent persona. *Journal of Educational Computing Research*, *28*(4), 373-394.

Bartneck, C. (2001). How convincing is Mr. Data's smile: Affective expressions of machines. *User Modeling and User-Adapted Interaction*, *11*(4), 279-295.

Bartošová, L. (2011). *Body language and facial expressions; A design-based study of anthropomorphic, caricatured or cartooned characters in CG animation*. Master's thesis, The University of Edinburgh, United Kingdom.

Bird, R. (2010). 3D Character Animation (part 1). Retrieved from https://software.intel.com/sites/default/files/m/d/4/1/d/8/Character_Animation1-v1b_FINAL.pdf

Brahnam, S. (2009). Building character for artificial conversational agents: Ethos, ethics, believability, and credibility. *PsychNology Journal*, *7*(1).

Bull, P. E. (1987). *Posture and gesture*. Pergamon press.

Cassell, J. (2000). *Embodied conversational agents*. Cambridge, MA: The MIT Press.

Cissell, K. (2013). *A study of the effects of computer animated character body style on perception of facial expression*. Master's thesis, Purdue University, West Lafayette, IN.

Cohen, R. (2011, November). The Eyes Have It. Dramatics Magazine, Retrieved from http://www.robertcohendrama.com/other-writings/the-eyes-have-it/

Davis, C, Kim, J. Kuratate, T. & Burnham, D. (2007). Making a thinking-talking head. *Proc. of the International Conference on Auditory-Visual Speech Processing (AVSP 2007*). Hilvarenbeek. The Netherlands.

De Gelder, B. (2006). Towards the neurobiology of emotional body language. *Nature Reviews. Neuroscience*, *7*(3), 242-249.

D'Mello, S. & Graesser, A. (2012). AutoTutor and Affective AutoTutor: Learning by Talking with Cognitively and Emotionally Intelligent Computers that Talk Back. *ACM Transactions on Interactive Intelligent Systems*, 2(4), Article 23, Pub. date: December 2012.

Driver, J. (2008). *Secrets of Body Language*. A&E Networks.

Guo, Y.R., & Goh, D.H.L. (2015). Affect in Embodied Pedagogical Agents: Meta-Analytic Review. *Journal of Educational Computing Research*, 53(1), 124-149.

Hohnstadt, C. (2013). Acting with the entire body. Retrieved from http://www.animatorisland.com/acting-with-the-entire-body/

Holmes, J. (2007). Designing agents to support learning by explaining. *Comput. Educ.,* 48, 523-547.

Hooks, E. (2013). *Acting for animators*. Routledge.

Huang, T.S., Cohen, I., Hong, P., & Li, Y.(2000). IA3: Intelligent Affective Animated Agents. *Proc. of ICIG 2000.*

Johnson, W. L., & Rickel, J. (1998). Steve: An animated pedagogical agent for procedural training in virtual environments. *SIGART Bulletin*, 8, 16-21.

Karg, M., Samadani, A., Gorbet, R., K€uhnlenz, K., Hoey, J., & Kulic, D. (2013). Body Movements for Affective Expression: A Survey of Automatic Recognition and Generation. IEEE Transactions on Affective Computing, 4(4), October-December 2013.

Keefe, B. D., Villing, M., Racey, C., Strong, S. L., Wincenciak, J., & Barraclough, N. E. (2014). A database of whole-body action videos for the study of action, emotion, and untrustworthiness. *Behavior research methods*, *46*(4), 1042-1051.

Kelly, S. (2008). Reader's Question: Are Facial Expressions as Important as the Body on Acting Shots? Retrieved from http://www.animationtipsandtricks.com/2008/07/are-facial-expressions-as-important-as.html

Kelly, S., Baena, K., Sintay, K., Gilman, A., & Gilbert, W. (2009). Animation Tips and Tricks volume 2: Are Facial Expressions as Important as the Body on Acting Shots? pp. 28. Retrieved from: http://www.animationmentor.com/resources/ebooks/

Kim, Y., Baylor, A.L., & Shen, E. (2007). Pedagogical agents as learning companions: the impact of agent emotion and gender. *Journal of Computer Assisted Learning* (2007), *23*, 220-234.

Kim, Y., & Baylor, A. L. (2007). Pedagogical agents as social models to influence learner attitudes. *Educational Technology*, 47(01), 23-28.

Lango, K. (2004). 'Inspired 3D': Lip-Sync and Facial Animation — Part 2. Retrieved from http://www.awn.com/vfxworld/inspired-3d-lip-sync-and-facial-animation-part-2

Larsson, P. (2014). *Discerning emotion through movement*. Master's thesis, University of Gavle, Gavle, Sweden.

Lasseter, J. (1987). Principles of traditional animation applied to 3D computer animation. *Proceedings of the 14th annual conference on Computer graphics and interactive techniques*, 35-44.

Lester, J. C., Towns, S. G., & Fitzgerald, P. J. (1998). Achieving affective impact: Visual emotive communication in lifelike pedagogical agents. *International Journal of Artificial Intelligence in Education (IJAIED)*, *10*, 278-291.

Lester, J.; Converse, S.; Kahler, S.; Barlow, T.; Stone, B.; and Bhogal, R. (1997). The persona effect: Affective impact of animated pedagogical agents. *Proc.of CHI '97*, 359-366.

Lester, J., Stone, B., and Stelling, G. (1999a). Lifelike Pedagogical Agents for Mixed-Initiative Problem Solving in Constructivist Learning Environments. *User Modeling and User-Adapted Interaction*, 9(1-2), 1-44.

Lester, J., Towns, S.G., and FitzGerald, P.J. (1999b). Achieving Affective Impact: Visual Emotive Communication in Lifelike Pedagogical Agents. *The International Journal of Artificial Intelligence in Education*, 10 (3-4), 278-291.

Lisetti C.L., & Nasoz, F. (2002). MAUI: A Multimodal Affective User Interface. *Proc. 10th ACM Int'l Conf. Multimedia (Multimedia '02)*, 161-170.

Lusk, M. M., & Atkinson, R. K. (2007). Animated pedagogical agents: Does their degree of embodiment impact learning from static or animated worked examples? *Applied Cognitive Psychology*, 21, 747-764.

McDonnell, M. (2010). The importance of a good silhouette. Retrieved from http://theartcenter.blogspot.ca/2010/02/importance-of-good-silhouette.html

McDonnell, R., Jörg, S., McHugh, J., Newell, F. N., & O'Sullivan, C. (2009). Investigating the role of body shape on the perception of emotion. *ACM Transactions on Applied Perception (TAP)*, *6*(3), 14.

McNeill, D., & McNeill, D. (2000). *The face: a natural history*. Little, Brown and Company.

Meeren, H. K., van Heijnsbergen, C. C., & de Gelder, B. (2005). Rapid perceptual integration of facial expression and emotional body language. *Proc. of the National Academy of Sciences of the United States of America*, *102*(45), 16518-16523.

Morency, L.P., Stratou, G., DeVault, D., Hartholt, A., Lhommet, M., Lucas, G., Morbini, F., Georgila, K., Scherer, S., Gratch,J., Marsella, S., Traum, D., & Rizzo, A. (2015). Demonstration: A Perceptive Virtual Human Interviewer for Healthcare Applications. *Proc. of the Twenty-Ninth AAAI Conference on Artificial Intelligence.*

Moreno, R., & Mayer, R. (2007). Interactive Multimodal Learning Environments. *Educational Psychology Review*, 19, 309-326.

Nijholt, A. (2001). Agents, believability and embodiment in advanced learning environments. Introduction to a panel discussion. In *Advanced Learning Technologies, 2001. Proceedings. IEEE International Conference on* (pp. 457-459). IEEE.

Powers, D.M.W., Leibbrandt, R., Luerssen, M.H., Lewis, T.W., & Lawson, M. (2008). PETA-a Pedagogical Embodied Teaching Agent. *Proc. of PETRA08: 1st international conference on PErvasive Technologies Related to Assistive Environments*, Athens, 2008. ACM Digital Library.

Roberts, S. (2004). *Character animation in 3D: Use traditional drawing techniques to produce stunning CGI animation (Vol. 1)*. Taylor & Francis.

Roberts, S. (2011). *Character Animation Fundamentals: Developing Skills for 2D and 3D Character Animation*. (pp. 329-370). Waltham, MA: Focal Press.

Schroeder, N., Adesope, O.O., & Barouch Gilbert, R. (2013). How Effective are Pedagogical Agents for Learning? A Meta-Analytic Review. *Journal of Educational Computing Research*, 49(1).

Volkova, E. P., Mohler, B. J., Dodds, T. J., Tesch, J., & Bülthoff, H. H. (2014). Emotion categorization of body expressions in narrative scenarios. *Frontiers in psychology*, *5*.

Ward, A. (2014). How to speed up your animation workflow. Retrieved from http://www.creativebloq.com/3d/how-speed-your-animation-workflow-31410993

Zhou, L., Mohammed, A. S., & Zhang, D. (2012). Mobile personal information management agent: Supporting natural language interface and application integration. *Information Processing & Management*, 48(1), 23–31.