Animated Agents' Facial Emotions: Does the Agent Design Make a Difference?

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Abstract. The paper reports ongoing research toward the design of multimodal affective pedagogical agents that are effective for different types of learners and applications. In particular, the work reported in the paper investigated the extent to which the type of character design (realistic versus stylized) affects students' perception of an animated agent's facial emotions, and whether the effects are moderated by learner characteristics (e.g. gender). Eighty-two participants viewed 10 animation clips featuring a stylized character exhibiting 5 different emotions, e.g. happiness, sadness, fear, surprise and anger (2 clips per emotion), and 10 clips featuring a realistic character portraying the same emotional states. The participants were asked to name the emotions and rate their sincerity, intensity, and typicality. The results indicated that for recognition, participants were slightly more likely to recognize the emotions displayed by the stylized agent, although the difference was not statistically significant. The stylized agent was on average rated significantly higher for facial emotion intensity, whereas the differences in ratings for typicality and sincerity across all emotions were not statistically significant. A significant difference in ratings was shown in regard to sadness (within typicality), happiness (within sincerity), fear, anger, sadness and happiness (within intensity) with the stylized agent rated higher. Gender was not a significant correlate across all emotions or for individual emotions.

Keywords: Affective animated agents · Character animation · Character design · Facial emotions · Affective multimodal interfaces

1 Introduction

Research has shown that animated pedagogical agents (APA) can be effective in promoting learning, but many questions still remain unanswered, particularly concerning the design of APAs. For instance, it is unclear which specific visual features of an agent, types of emotional expression, degree of embodiment and personalization, modes of communication, types of instructional roles and personas benefit a particular leaner population and why. To advance knowledge in this field and maximize the agent's positive impact on learning, there is a need to further investigate the effects of certain agent's features, and whether they are moderated by learner characteristics, learning topics, and contexts.

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Although the preponderance of research on pedagogical agents tends to focus on the cognitive aspects of online learning and instruction, our research work explores the less-studied role of affective aspects. In particular, one of the research goals is to determine how to design agents that exhibit emotions that are believable and clearly recognizable, and that best foster student learning. With the growing understanding of the complex interplay between emotions and cognition, there is a need to develop life-like, convincing agents that not only provide effective expert guidance, but also convincing emotional interactions with the learners. The goal of our research is to improve the visual quality of the agents by identifying the design and animation features that can improve perception and believability of the emotions conveyed by the agents. The work described in the paper is a step in this direction. Its objective was to investigate the extent to which the agent's visual style, and specifically its degree of stylization, affects the perception of facial emotions and whether the effects are moderated by subjects' gender.

2 Related Work

2.1 Affective 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 [29], Herman [30, 31], STEVE [24], PETA [47], and the "Thinking Head" [14]. Animated signing agents have also been used to teach mathematics and science to young deaf children [2].

Affective agents are animated characters that display a specific emotional style and personality, and emotional intelligence, e.g. they can respond to the user emotional state. A few affective agents systems have been developed so far. The system by Lisetti and Nasoz [34] includes a multimodal anthropomorphic agent then adapts its interface by responding to the user's emotional states, and provides affective multi-modal feedback to the user. The IA3 system by Huang et al. [21] was an early attempt at developing Intelligent Affective Agents that recognize human emotion, and based on their understanding of human speech and emotional state, provide an emotive response through facial expressions and body motions. Autotutor [12, 13] and Simsei [40] use a multimodal sensing system that captures a variety of signals that are used to assess the user's affective state, as well as to inform the agent so she/he can provide appropriate affective feedback.

Many studies confirm the positive learning effects of systems using these agents [20, 25, 32, 33, 42, 52]. Studies also indicate that the manipulation of the APAs' affective states can significantly influence learner beliefs and learning efficacy [61]. A study by Kim et al. [28] showed that an agent's empathetic responses to the student's emotional states had a positive influence on learner self-efficacy for 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 affect in APAs has a significant and moderate impact on students' motivation, knowledge retention and knowledge transfer [19].

Some researchers have investigated the effect of different APA's features on student's learning, engagement, and perception of self-efficacy. Mayer and DaPra [37] examined whether the degree of embodiment of an APA had an effect on students learning of science concepts. Findings showed that students learned better from a fully embodied human-voiced agent that exhibited human-like behaviors than from an agent who did not communicate using these human-like actions. A study by Adamo-Villani et al. [3] revealed that the visual style of an animated signing avatar had an effect on student engagement. The stylized avatar was perceived more engaging than the realistic one, but the degree of stylization did not affect the students' ability to recognize and learn American Sign Language signs. Other studies suggest that agent's features such as voice and appearance [15, 36], visual presence [49], non-verbal communication [7], and communication style [57] could impact learning and motivation.

A few researchers have investigated whether APAs are more effective for certain learner populations as compared to others. Kim and Lin's study [26] revealed that middle grade females and ethnic minorities improved their self-efficacy in learning algebraic concepts after working with the APA, and improved learning significantly compared to white males. High school students preferred to work with an agent with the same ethnicity more than with a different one [27, 41] College students of color felt more comfortable interacting with a similar agent than with a dissimilar one [41].

2.2 Stylized Versus Realistic Agent Design

In the book "The Illusion of Life" [54], Thomas and Johnston discuss how designers should construct the characters carefully, considering all features a character has, from its costume, body proportions, facial features, to surrounding environment. Some studies suggest that characters should be designed to look realistic [43, 48], while others suggest the opposite [3, 38, 50, 60]. In character design, the level of stylization refers to the degree to which a design is simplified and reduced. Several levels of stylization (or iconicity) exist, such as iconic, simple, stylized, realistic [6]. A realistic character is one that closely mimics reality and often photorealistic techniques are used. For instance, the body proportions of a realistic character closely resemble the proportions of a real human, the level of geometric detail is high and the materials and textures are photorealistic. A stylized character often presents exaggerated proportions, such as a large head and large eyes, and simplified painted textures. Figure 1 shows the realistic and stylized agents used in the study.

Both realistic and stylized agents have been used in interactive environments. A few researchers have conducted studies on realistic versus stylized agents with respect to interest and engagement effects in users. Welch et al. [58] report a study that shows that pictorial realism increases involvement and the sense of immersion in a virtual environment. Nass et al. [43] suggest that embodied conversational agents should accurately mirror humans and should resemble the targeted user group as closely as possible. McCloud [38] argues that audience interest and involvement is often increased by stylization. This is due to the fact that when people interact, they sustain a constant awareness of their own face, and this mental image is stylized. Thus, it is easier to identify with a stylized character. Mc Donnell et al. [39] investigated the effect of rendering style on perception of virtual humans. The researchers considered 11 types of rendering styles that ranged from realistic to stylized and used a variety of implicit and explicit measures to analyze subjects' perception. Results showed that cartoon characters were considered highly appealing, and were rated as more pleasant than characters with human appearance, when large motion artifacts were present. In addition, in general they were rated as more friendly than realistic characters, however not all stylized renderings were given high ratings. One of the stylized renderings used in the study evoked negative reactions from the participants, probably due to the lack of subjects' familiarity with the style. An interesting result of the study was that the speech and motions contributed to the interpretation of the characters' intention more than the rendering style. This finding suggests that rendering style does not play a major role in the interaction with virtual characters and therefore a realistic rendering style could be as effective as a cartoon one.

Fig. 1. Stylized agent (left); realistic agent (right)

2.3 Facial Emotion in Animated Agents: Expression and Perception

Several approaches for representing facial expressions in animated agents exist. Some computational frameworks are based on discrete representation of emotion; others on dimensional models; and others on appraisal theories [46]. Approaches that are based on the expression of standard emotions [17] compute new expressions as a mathematical combination of the parameters of predefined facial expressions [8, 45]. Approaches based on dimensional models use a 2 dimensional—valence and arousal [18] or 3 dimensional—valence, arousal, and power [5] representation of facial emotions. A few approaches use fuzzy logic to compute the combination of expressions of the six standard emotions, or the combination of facial regions of several emotions [46]. Some approaches are based on Scherer's appraisal theory [51] and model a facial expression as a sequence of the facial articulations that are displayed consecutively as a result of cognitive estimates [44].

Ongoing research suggests that the human vision system has dedicated mechanisms to perceive facial expressions [9] and categorizes facial perception into three types: holistic, componential and configural perception. Holistic perception models the face as a single unit whose parts cannot be isolated. Componential perception assumes that the human vision system processes different facial features individually. Configural perception models the spatial relations among different facial components (e.g. left eye-right eye, mouth-nose). It is possible that we use all these models when we perceive facial expressions [4].

Ekman and Friesen [16] suggest that there are three types of signals produced by the face: Static, Slow and Rapid. The static signals are the permanent or semi-permanent aspects of the face such as skin pigmentation, shape, bone structure. The slow signals include facial changes that occur gradually over time, such as permanent wrinkles, changes in muscle tone, skin texture, and even skin coloration. The rapid signals are the temporary changes in facial appearance caused by the movement of facial muscles [16]. The rapid signals are what the majority of people consider when thinking of emotion, for instance, the physical movement of the face to a smile or a frown. All three of these signals play an important role in how a viewer perceives the facial emotion of another being or character. In our study we are concerned with how the static signals of the face (e.g. face appearance and in particular the size, shape, and location of facial features such as brows, eyes, nose, mouth) affect perception of emotions, as in our experiment the slow and rapid signals were kept the same for both characters (the age of the agents is assumed to be approximately the same and the animation, e.g. the rapid signals, is identical for both characters).

A few studies that examined perception of emotion in animated characters can be found in the literature. A study by Mc Donnel et al. [39] examined perception of 6 basic emotions (sadness, happiness, surprise, fear, anger and disgust) from the movements of a real actor and from the same movements applied to 5 virtual characters (e.g. a low and high resolution virtual human resembling the actor, a cartoon-like character, a wooden mannequin, and a zombie-like character). Results of the experiment showed that subjects' perception of the emotions was for the most part independent of the character's body style. Although this study focused on perception of emotion from body movements (not from facial articulations), its findings suggest that character visual design might not affect perception of emotions in general, including facial emotions.

A study by Cissell [10] investigated the effect of character body style (cartoon and realistic) on perception of facial expressions. The study used a selection of animated clips featuring realistic and cartoon characters exhibiting 5 standard emotions. The clips were extracted from commercial animated movies. Results of the study showed that character body style did not have a significant effect on recognition of facial emotions; the emotions displayed by the cartoon characters were perceived on average more intense and sincere, while the ones displayed by the realistic character were perceived as more typical. The study is interesting, however, in our opinion, it has a flaw, as the pairs of animated clips used as stimuli did not show the same animation data for both character types. Hence, the differences in perception could be due to differences in static as well as rapid facial signals, and it is not possible to claim with confidence that the differences are due only to character design. Our study uses a similar evaluation framework as Cissell's experiment but improves on the design by comparing only static signals.

A study by Courgeon et al. [11] examined the effects of different rendering styles of facial wrinkles on viewers' perception of facial emotions. Findings showed that realistic rendering was perceived more expressive and was preferred by the subjects, however the rendering style did not have an impact on recognition of the facial emotions. A study by Hyde et al. [22] investigated the perceptual effects of damped and exaggerated facial motion in realistic and cartoon animated characters. In particular the researchers examined the impact of incrementally dampening or exaggerating the facial movements on perceptions of character likeability, intelligence, and extraversion. The results of the study are surprising, as they seem to contradict the principle of exaggeration. Participants liked the realistic characters more than the cartoon characters. Likeability ratings were higher when the realistic characters showed exaggerated movements and when the cartoon characters showed damped movements. The realistic characters with exaggerated motions were perceived as more intelligent, while the stylized characters appeared more intelligent when their motions were damped. Exaggerated motions improved perception of the characters as extraverted for both character styles. While Hyde's study focused on exaggerated versus damped facial motions, our study focuses on facial design and explores the effect of the exaggeration afforded by the degree of stylization on perception of emotion.

3 Description of the Study

The study examined the extent to which the degree of stylization of an animated affective agent (low versus high) affects the perception of facial emotions. The study used a within subjects design and a quantitative research approach. Data was collected in the form of answers to rating questions, which asked subjects to rate the typicality, sincerity, and intensity of the facial emotions exhibited by the agents. The study also collected data in the form of correct/incorrect answers to questions that asked the subjects to name the various facial emotions. In addition, the study investigated whether there was a significant difference in ratings by participants' gender.

The independent variable in the study was the degree of character stylization (low versus high), the dependent variables were recognition, typicality, intensity, and sincerity. Typicality refers to, "how often different variants of a facial expression are encountered in the real world" [56]. In other words, is the facial expression something you would see every day or is it in some way unusual? Typicality is also defined as, "having the distinctive qualities of a particular type of person or thing" [55]. So, to what extent does this expression of emotion have the distinctive qualities of a human's expression of this emotion? Intensity refers to, "Having or showing strong feelings…" [23]. In other words, how well does the character facial emotion strength match that of a human facial emotion strength? Sincere means, "free from pretense or deceit; proceeding from genuine feelings" [53]. Do the subjects feel the emotion being displayed is genuine or do they perceive it as not genuine, or deceitful?

3.1 Null Hypotheses

H1The level of stylization does not have an effect on the subject's perceived typicality of the agent's emotion
H2 The level of stylization does not have an effect on the subject's perceived sincerity of the agent's facial emotion
H3 The level of stylization does not have an effect on the subject's perceived intensity of the agent's facial emotion
H4 The level of stylization does not have an effect on the subjects' ability to recognize the agent's facial emotion
H5 Subjects' gender is not a significant correlate

3.2 Subjects

Eighty-two subjects age 19–25 years, 42 males and 40 females participated in the study. All subjects were students at Purdue University in the departments of Computer Graphics Technology and Computer Science. None of the subjects had color blindness, blindness, or other visual impairments.

3.3 Stimuli

The characters used in the study were rigged using identical facial skeletal deformation systems. The facial skeleton, comprised of 30 floating joints with 55 DOF, is based on best practices in character animation, on the Facial Action Coding System (FACS) [17], on the AR Face Database [35] and on research on keyboard encoding of facial expressions [1].

The layout of the skeletal joints (represented in Fig. 2, frame 1) is derived from 4 face regions (Head, Upper Face, Nose, Lower Face) and 15 articulators: Head; Eye-brows, Upper Eyelids, Lower Eyelids, Eye gaze, Nose, Cheeks, Upper Lips, Lower Lips, Both Lips, Lip Corners, Tongue, Teeth, Chin, Ears. We control each articulator with 1 or more joints whose rotations and/or translations induce facial deformations or movements. The facial model allows for representing 36 Action Units (AU) of the FACS +tongue/teeth/chin/ears movements with naturalness and believability. Table 1 shows the list of face articulators, the number of joints controlling them, the joint DOFs, and the induced facial movements/deformations.

The animations were created by an expert animator with more than 20 years of experience in character animation. The expert animator animated the facial emotions on the realistic agent; the animation data was then retargeted to the stylized agent. Although the animation data was identical for both agents, some differences in facial deformations (especially in the eyebrows) can be noted. They are due to differences in facial design and facial geometry (e.g. facial proportions and mesh topology). Each animation clip was 2 s long, was rendered with a resolution of 720 $\times$ 480 pixels and was output to Quick Time format with a frame rate of 24 fps. Ten animation clips featured the stylized character, (2 for each of the 5 emotions) while the other 10 featured the realistic character (2 for each of the 5 emotions). The animations did not include any sound (speech was muted) and the characters were framed using the same camera angle and same lighting scheme. Figure 2 (frames 2–6) shows 5 pairs of frames extracted from the stimuli animations (one pair per emotion).

Table 1. List of face articulators, number of joints controlling them, joint DOFs, and induced facial movements/deformations

Articulator	Number of joints	Horizontal: R/L	Vertical: Up/Down	In/Out: z axis	AU (Induced facial movement/deformation)
Head	2	X	X	X	51, 52, 53, 54, 55, 56 (Head turn left, right, up, down, tilt left, right)
Eyebrows	6	X	X		1, 2, 4 (Inner and Outer Brow Raiser, Brow Lowerer)
Upper Eyelids	2		X		41, 42, 43, 44, 45, 46 (Lid droop, Slit, Eyes Closed, Squint, Blink, Wink)
Lower Eyelids	2		X		7, 44 (Lid tightener, Squint)
Eye gaze	2	X	X		61, 62, 63, 64
Nose	3		X		9 (Nose wrinkler)
Cheeks	2		X	X	6, 13 (Cheek raiser, Cheek Puffer)
Lips: Upper	1		X		10 (Upper Lip Raiser)
Lips: Lower	1	X	X	X (pout)	16, 20 (Lower Lip Depressor, Lip Stretcher)
Lips: Both	1	X	X	X	22, 23, 24 25, 26, 27 (Lip Funneler, Tightener, Pressor, and Part, Jaw Drop, and MouthStretch)
Lip corners	2	X	X		20, 15, 12 (Lip Stretcher, Lip Corner Depressor and Puller)
Tongue	2	X	X	X (forward)	No corresponding AU
BottomTeeth (jaw)	1	X	X	X (forward)	No corresponding AU
Chin	1			X (forward)	No corresponding AU
Ears	2		X		No corresponding AU

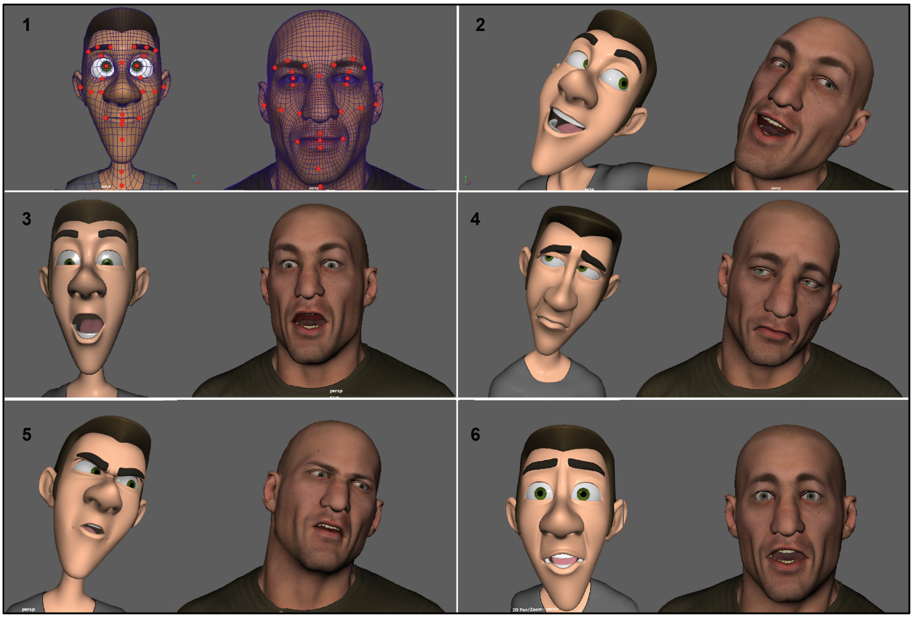

Fig. 2. Facial joints placement (frame 1); screenshots extracted from the stylized character and realistic character animations of the 5 emotions considered in the study: happiness (frame 2); surprise (frame 3); sadness (frame 4); anger (frame 5); fear (frame 6)

3.4 Procedure and Evaluation Instrument

Volunteers were recruited on the Purdue campus via email. Those who agreed to participate in the study were sent a link to an online survey they could access from any computer, and were asked to read about the research and complete a pre-survey, determining if they were eligible for participation. If eligible for participation, they proceeded to the full survey which included 21 screens: 1 screen with instructions and 2 demographics questions (age and gender) and 20 screens, each one showing one of the 20 animation clips followed by a series of questions. The order of presentation of the 20 screens was randomized. One question asked the participants to identify the emotion exhibited by the agent, and three questions asked the participants to rate the typicality, sincerity and intensity of the emotion using a 7-point scale (1 = low and 7 = high). Participants completed the on-line survey using their own computers and the survey remained active for 2 weeks. Two screenshots of the survey (and two videos) used in the study can be accessed at http://hpcg.purdue.edu/idealab/faceexpression.html.

3.5 Findings

For the analysis of the subjects' typicality, sincerity and intensity ratings we conducted a series of paired sample T-tests. With 10 pairs of animations for each subject, there were a total of 820 rating pairs.

Typicality. The mean of the ratings across all 5 emotions for animations featuring the realistic agent was 5.49, (SD = 1.76) and the mean of the ratings for animations featuring the stylized character was 5.41 (SD = 1.56). Using the statistical software SPSS, a probability value of .068 was calculated. At an alpha level of .05, H1 (e.g. stylization does not have an effect on the user's perceived typicality of agent's emotion) could not be rejected.

T-tests conducted for each individual emotion revealed a significant difference in typicality ratings for sadness, with the stylized agent rated significantly higher M (stylized) = 6.13; SD(stylized) = 1.4; M(realistic) = 5.6; SD(realistic) = 1.5; p-value = 0.04; the percentage of increase in rating scores for the stylized character was 7.5%. Gender was not a significant correlate, e.g. it did not have significant effect on typicality ratings across all emotions (p-value = 0.74) or for individual emotions.

Sincerity. The mean of the ratings across all 5 emotions for animations featuring the realistic agent was 5.69, (SD = 1.44) and the mean of the ratings for animations featuring the stylized character was 5.81 (SD = 1.65). Using the statistical software SPSS, a probability value of .057 was calculated. Since p-value > .05, H2 (e.g. stylization does not have an effect on the user's perceived sincerity of agent's emotion) could not be rejected.

T-tests conducted for each individual emotion revealed a significant difference in sincerity ratings for happiness, with the stylized agent rated significantly higher M (stylized) = 6.32; SD(stylized) = 1.5; M(realistic) = 5.8; SD(realistic) = 1.5; p-value = 0.041; the percentage of increase in rating scores for the stylized character was 7.8%. Gender did not have a significant effect on intensity ratings across all emotions (p-value = 0.67) or for individual emotions.

Intensity. The mean of the ratings across all 5 emotions for animations featuring the realistic agent was 5.78, (SD = 1.51) and the mean of the ratings for animations featuring the stylized character was 6.34 (SD = 1.73). Using the statistical software SPSS, a probability value of .045 was calculated. Since p-value < .05, H3 (e.g. stylization does not have an effect on the user's perceived intensity of agent's emotion) was rejected. Subjects perceived the emotions conveyed by the stylized agent significantly more intense than those exhibited by the realistic agent. The percentage of increase in rating scores for the stylized character was 7.6%.

T-tests conducted for each individual emotion revealed a significant difference in intensity ratings for fear, anger, and happiness. For fear, the stylized agent was rated significantly higher M(stylized) = 6.22; SD(stylized) = 1.5; M(realistic) = 5.62; SD (realistic) = 1.5; p-value = 0.04; the percentage of increase in rating scores for the stylized character was 9%. For anger, the stylized agent was rated significantly higher, M(stylized) = 6.27; SD(stylized) = 1.6; M(realistic) = 5.88; SD(realistic) = 1.6; p-value = .041; the percentage of increase in rating scores for the stylized character was 5.5%. For happiness the stylized agent was rated significantly higher, M(stylized) = 6.19; SD(stylized) = 1.34; M(realistic) = 5.67; SD(realistic) = 1.53; p-value = 0.042; the percentage of increase in rating scores for the stylized character was 7.5%. Gender did not have a significant effect on intensity ratings across all emotions (p-value = .09) or for individual emotions.

Emotion Recognition. The subjects were asked to enter the name of the emotion displayed by the agent in a text box. Based on the Feeling wheel [59], we considered the following terms correct: joy, excitement, glee, intrigue, and awe for happiness, frustration, hurt, disappointment, rage for anger, worried, depression, shame, boredom for sadness, and helplessness, insecurity, anxiety, confusion, for fear. For the emotion surprise, which is not included in the Feeling wheel, we considered the following terms acceptable, as they are commonly used synonyms of surprise: astonishment, bewilderment, amazement, consternation.

The emotion recognition rate for the stylized character was 96% across all emotions (happiness = 97%; surprise = 92%; sadness = 98%; anger = 96%; fear = 97%). The emotion recognition rate for the realistic agent was 94% across all emotions (happiness = 95%; surprise = 93%; sadness = 94%; anger = 93%; fear = 95%). The McNemar test, a variation of the chi-square analysis, which tests consistency in responses across two variables, was used to determine if the difference in emotion recognition between the two agents was statistically significant. Using SPSS software a p-value of .062 was calculated. At an alpha level of .05, a relationship between realistic and stylized agents and the subjects' ability to identify the emotions could not be determined. Our null hypothesis H5(0) (e.g. the presence of stylization does not affect the subjects' ability to recognize the facial emotion) could not be rejected. Gender was not a significant correlate for emotion recognition (p-value = .75) (nor for emotion ratings).

4 Discussion and Future Work

In this paper we have reported a study that explored the extent to which an animated agent's visual design affects students' perception of facial emotions. Findings show that subjects found the facial emotions exhibited by the stylized agent significantly more intense than those exhibited by the realistic one. In addition, subjects were more likely to recognize the emotions displayed by the stylized agent, even if the difference in recognition was not statistically significant. Analyses of ratings for individual emotions show that the stylized character was rated significantly higher in typicality in regard to sadness, in sincerity in regard to happiness, and in intensity in regard to happiness, anger, and fear. No significant differences in perception of typicality and sincerity across all emotions and no gender effects across all emotions or for individual emotions were found.

The overall higher ratings received by the stylized agent might be due to the fact that facial deformations appear more exaggerated on the stylized character because of its design, even if both agents use the same skeletal deformation system and same animation data (retargeted from the realistic character to the stylized one). Exaggeration, one of the 12 principles of animation, was used by Disney animators to present characters' motions and expressions in a wilder, more extreme form, while remaining true to reality. Exaggeration is often used with stylized characters for comedic effects, but also as a means to achieve the principle of staging, e.g. the presentation of an idea so that it is completely and unmistakably clear [54]. Stylized characters present a lower level of visual detail compared to realistic ones, especially in the face. Facial deformations that appear exaggerated are a way to compensate for the lack of facial details by making the expression clearly perceivable. The findings from our study suggest that the exaggeration effect afforded by the stylized character design is more effective at conveying facial emotions and their intensity than the higher level of visual detail of the realistic agent (e.g. realistic facial geometry and textures).

Overall, the recognition rate and the participants' ratings were high for both characters. These results suggest that both stylized and realistic character designs could be effective at conveying facial emotions and could be used for developing effective affective agents. However, the higher ratings of the stylized character suggest that a more simplified, caricatured design could benefit students' perception of the agent facial emotion. The results of our experiment are consistent with prior research [3, 10, 39] and we are inclined to believe that they would hold true for different types of stylized and realistic agents (e.g. agents showing different ages, facial features, ethnicity and gender), and for subjects from different age groups and educational backgrounds. However, in order to state with confidence that the benefit of a stylized design will generalize to most animated agents and for most participants, additional research is needed to address the limitations of the current study.

The study included a relatively small sample size, and a fairly homogenous group of participants in regard to age and educational background (college students enrolled in Computer Science and Technology programs). In the future, it would be interesting to conduct additional experiments with larger pools of subjects to farther investigate how the agent visual design effect is moderated by subjects' characteristics such as age, educational interest (interest in humanities and social sciences versus interest in STEM disciplines), and cultural backgrounds. Another intriguing future direction of research would be to investigate at what level of stylization the advantages of a stylized design disappear and a realistic design becomes more effective at conveying facial emotions. For instance would the same results hold true for an "iconic" character, e.g. a character that show a very high degree of stylization?

The cartoon character used in the study is not an exact stylized version of the realistic one, as the two characters look different. Hence, it is possible that the differences in expressivity between the two characters might be due to the intrinsic characteristic of the stylized design, rather than to the stylization of the realistic one. In other words, one could argue that the same differences in emotion expressivity could be found across two realistic characters, or across two stylized ones. To better control this variability, in future experiments, we will conduct a pre-test on the characters' design to assess the similarities between the two in order to verify to what extent the second character is recognized as a stylized version of the realistic one, rather than another different character.

The findings of the study have direct practical implications for character artists and instructional designers, as they can help them make more informed agent design decisions. The overall goal of our research is to develop an empirically grounded research base that will guide the design of affective pedagogical agents that are effective for different types of learners. Toward this goal, we will continue to conduct research studies to identify key design, modeling, and animation features that make up ideal affective animated pedagogical agents, and examine the extent to which the effects of these features are moderated by the learners' characteristics.

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