Effect of Emotion and Articulation of Speech on the Uncanny Valley in Virtual Characters

Angela Tinwell[1], Mark Grimshaw[1], and Debbie Abdel-Nabi[2]

[1] University of Bolton, Faculty of Arts and Media Technologies, Bolton, UK, BL3 5AB
{A.Tinwell, M.N.Grimshaw}@bolton.ac.uk
[2] University of Bolton, Faculty of Well Being & Social Sciences, Bolton, UK, BL3 5AB
A.Nabi@bolton.ac.uk

Abstract. This paper presents a study of how exaggerated facial expression in the lower face region affects perception of emotion and the Uncanny Valley phenomenon in realistic, human-like, virtual characters. Characters communicated the six basic emotions, anger, disgust, fear, sadness and surprise with normal and exaggerated mouth movements. Measures were taken for perceived familiarity and human-likeness. The results showed that: an increased intensity of articulation significantly reduced the uncanny for anger; yet increased perception of the uncanny for characters expressing happiness with an exaggeration of mouth movement. The practical implications of these findings are considered when controlling the uncanny in virtual characters.

Keywords: Emotion, Video Games, Uncanny Valley, Characters, Expression

1 Introduction

The Uncanny Valley [1] provides a rationale as to the variations in emotional response humans can experience when interacting with synthetic agents [2-6]. Mori observed that as the human-likeness for a robot increases, the viewer will maintain a positive emotional response to that robot (measured as perceived familiarity), until the robot appears close to full human-likeness. At this point, inconsistencies in the robot's appearance and behavior from the human norm evoke a more negative response from the viewer and the robot is regarded as strange [1].

The Uncanny Valley is now also recognized as a phenomenon not only in android science, but in realistic, human-like characters featured in film and video games [2], [3], [4], [7], [8]. Much work has been carried out to examine which factors may exaggerate the uncanny. Humans can experience a more positive affective response towards androids and realistic, human-like, virtual characters when the level of behavioral fidelity matches their human-like appearance [9], [10]. Empirical evidence collected so far shows that, various factors including: facial expression [6], [11]; proportion of facial features, [5], [7]; characteristics of speech [11], [12]; lip-synchronization [11], [12]; gesture, timing, quality of motion [9], jerkiness of movement [13]; and contingency of interaction when responding to others and events [14] can contribute to perception of the uncanny. The uncanny was also exaggerated for empathetic and antipathetic characters with a perceived over-exaggeration of mouth movement during speech [11]. This effect (and others) can work to the advantage of antagonist characters intended to be frightening [11].

Perception of the uncanny can vary depending on which emotion is being communicated [6]. This may be due to the adaptive function of that emotion (i.e. physical survival or social interaction) [6]. The results of a previous study show that the uncanny was exaggerated for realistic, human-like characters when emotional expressivity had been limited in the upper face region, including the brows and forehead, when expressing the emotions fear, sadness, surprise and disgust. However, a lack of upper facial animation had a less noticeable effect on perceived 'uncanniness' for the emotions anger and happiness [6].

Given these findings, it was recommended that if designers wished to avoid the uncanny, particular attention should be paid to modeling the upper face region for the emotions fear, sadness and surprise [6]. Overall sadness was regarded more favorably than the other emotions when presented in virtual characters with full or restricted animation in the upper face. This was attributed to people's ability to anthropomorphize virtual characters and express sympathy towards them despite perceived flaws in facial expression [6]. Despite that disgust can serve as a warning signal to avoid an unpleasant object, it was assumed more likely that limitations in the graphical fidelity of the 'nose wrinkler' action [15] in facial animation software accounted for the significant increase in perceived uncanniness for this emotion [6]. It was suggested that disgust may remain significantly more uncanny than other emotions until the graphical realism for this distinctive facial feature is improved [6].

As the lower facial features are of greater importance when communicating the emotions anger and happiness [16-18], these emotions were less noticeably affected by a lack of expressivity in the upper face region. Surprisingly, despite happiness being a more positive emotion, it was rated most uncanny in characters with full facial animation [6]. It was suggested this may have been due to a person's sensitivity to a false smile [19] thus, increasing the uncanny for this emotion [6].

1.1 Articulation and the Expression of Emotion

During speech, facial movement is primarily driven by articulation and one's intensity of articulation is influenced by the desired intensity of emotion that one wishes to communicate [16]. Importantly, this intensity of articulation differs depending on which emotion is being presented [16]. When compared to neutral speech, lower facial features were found to be significantly more active for anger and happiness, while less active for sadness [16].

Facial expression is used in primates to communicate how they feel and their likely, intended behavior [20], [21]. Primates can use the mouth to communicate anger either when the jaws are clenched, lips pressed tightly together (referred to as *Anger Type 1*), or when the lips are retracted, jaws open, exposing the teeth (referred to as *Anger Type 2*) [15], [20]. For example, a monkey can display a round or open mouth with exposed teeth to communicate intense fear, blended with anger [21]. Both these expression-types serve the same functions, regarded as a subordinate threat.

Due to the muscular constraints of the smile shape on the inner and outer lip features, the pronunciation of vowels during smiled speech necessitates the use of physiological mechanisms that are also involved in speech production [22]. In non-smiled speech, lip protrusion lengthens the vocal tract, aiding the pronunciation of rounded vowels [22], [23]. However, in smiled speech, a shortened vocal tract occurs as the lips retract and the mouth shape widens; resulting in a conflicting demand placed upon the lip shape when pronouncing rounded vowels [22]. Both larynx lowering [22] and the position of the tongue [22] can compensate for a reduction of lip rounding in the pronunciation of speech. When comparing non-smiled to smiled speech, the stretched lips that create a smile shape, result in a smaller difference of lip movement between vowels and the vertical lip opening is significantly reduced on vowel pronunciation [22], [23].

1.2 Articulation of Speech in Video Games

One of the most complex challenges for designers when creating realistic, human-like, virtual characters is modeling the mouth and lower face region during speech [3], [12], [24]. The dynamics of each individual muscle in the lower face region may be well understood [15], yet their combined effect is more difficult to simulate accurately. High-fidelity facial expression and animation can be recorded using motion capture techniques; however the mouth area remains one of the more intricate areas to modify once the recorded motions are applied to a 3D model [3], [12]. A designer may take a substantial amount of time to edit individual key frames of recorded motion capture data for parts of a video game that use full motion video, such as cut scenes and trailers. However, visual material for in-game play is generated in real time. Automated processes are required for facial animation and the synthesis of lip movement with speech. A predetermined set of visual mouth shapes (visemes) is available for each phoneme sound modeled on the International Phonetic Alphabet. As default, a viseme class entitled *normal* is available where mouth shapes represent a normal articulation of speech. In the facial animation software *FacePoser* (as part of the SDK video game engine developed by Valve) classes, entitled *strong* and *weak* are also available to represent mouth shapes used for an increased or reduced emphasis of articulation. Interpolated motion is then generated automatically between each phoneme animating the character's speech.

This present study investigated the implications of exaggerating mouth movement during speech across the six basic emotions [17], on perception of the uncanny in virtual characters. On the basis of results from previous studies investigating the uncanny it was predicted that, humans would be perceived as more familiar and human-like (less uncanny) than those virtual characters in the normal and over condition across all emotions (H1). Also, as the results of previous experiments have revealed that the lower facial features may be of greater importance in the successful communication of the emotions anger and happiness [6], [15], [16], [18], the emotions anger and happiness would be rated more familiar and human-like (less uncanny) in the over state than when compared to the normal condition (H2).

2 Method

A 3 x 6 repeated-measures analysis of variance (ANOVA) design was used. The independent variables were: (1) the type of character (a) human (a male human actor), (b) normal (a male, virtual character with normal articulation of speech), and (c) over (the same virtual character with an increased intensity of articulation); and (2) the emotion type (anger, fear, disgust, happiness, sadness, and surprise [17] expressed facially and orally by the human or virtual character (Figure 1). A neutral state, in which the human and virtual character presented a neutral facial expression and tone of voice, was included as a seventh level of emotion type. This was employed as a control measure with the purpose to ensure participants could identify neutrality within a face and that they were responsive to different emotions when presented in the stimuli. Apart from analysis of participant accuracy and selection, neutral data was not included as an independent variable in the statistical model. The dependent variables were ratings of perceived: (1) familiarity and; (2) human-likeness as the characters presented the six emotions (and neutral) in the videos. Nine-point scales were used so that results could be compared with previous experiments that used 9-point scales to measure viewer response to the uncanny [6], [8], [11], [25].

Fig. 1. A human and Barney from *Half-Life 2*, pronouncing "c" in the 3 conditions for anger

2.1 Participants

Previous experiments have revealed conflicting evidence that perception of the uncanny differs between gender and levels of experience in interacting with synthetic agents. Some previous studies found no significant effect of gender on perception of the uncanny in robots [14], yet others found that females were more likely to rate robots as more human-like than males [7]. It has also been found that female participants were more accepting and tolerant of realistic, human-like, virtual, female characters than male participants [13]. Previous authors suggested that sensitivity to the uncanny would be reduced for those used to interacting with realistic, human-like characters on a regular basis [2]. However, another study found no significant difference in perception of the uncanny between participants with a high level of experience in playing video games and using 3D modeling software compared to those with none or a lesser amount of experience [25]. Male participants were used only in this present study to control potential disparities in gender. Forty, male, university students took part with a mean age of 20.9 years (SD = 5.50 years). To control the potential confounding impact of levels of experience in interacting with synthetic agents on perception of the uncanny, students were selected from the areas of: video game art, video game design and video game software development. It was expected that students from these subject areas would have an equivalent level of experience in exposure to realistic, human-like virtual characters.

2.2 Procedure

Video footage was taken of the actor reciting the line, "The cat sat on the mat", whilst using appropriate facial expressions and intonation of speech for each emotion. Apart from the neutral state (for which the actor was instructed to show no facial expression or intonation of voice), the actor portrayed moderate to high intensity facial expression and prosody for each emotion. The software *FacePoser* was used to synchronize the actor's speech with the character's mouth movement and replicate the actor's facial movement for each emotion. The same choreographed facial animations and sound files were used as in the normal condition for the over condition, but the phoneme class *strong* was used instead of *normal* for all phonemes extrapolated within the sentence. For example, in the over condition, mouth shapes in the *strong* class were used to replace mouth shapes from the *normal* class for the sounds "m" "ae" and "t" in the word mat. A dark background was used in all videos.

The survey was conducted in a computer lab with an individual computer station available for each participant. Experience levels of both playing video games and using 3D modeling software were taken with participants required to rate their level of experience as either, (1) *none*, (2) *basic*, or (3) *advanced*. Participants were then presented with a total of twenty videos, played in random order, via an online questionnaire. Participants used *Speed Link, Ares² Stereo PC* headphones for the sound and *Dell E207WFPc 20.1 inch Widescreen* monitors to watch the videos. Eighteen videos presented the six basic emotions: anger, disgust, fear, happiness, sadness and surprise [16], in the human, normal and over conditions. Two showed a neutral expression of the virtual character and human. On watching each video, participants selected which facial expression best described the character from: (a) *anger*, (b) *disgust*, (c) *fear*, (d) *happiness*, (e) *sadness*, (f) *surprise*, and (g) *neutral*. Participants then rated the character using a 9-point likert scale for perceived familiarity[1] from 1 (*very strange*) to 9 (*very familiar*) and how human-like or non-human-like they judged it to be from 1 (*nonhuman-like*) to 9 (*very human-like*).

3 Results

Ninety percent of participants had an advanced level of playing video games, with 10% a basic level of experience. For experience of using 3D modeling software:

[1] As the word familiarity is the common translation of the Japanese neologism that Mori originally used to describe the uncanny (*shinwakan*) and previous authors have used this word as a dependent variable to measure the uncanny [11], [14], the word familiarity was also used in this experiment.

47.5% had no experience, 32.5% had a basic level, and 20% an advanced level. Despite that emotion recognition was not the main purpose of this study, the recognition rates of perceived emotion were compared for both the human and virtual character to ensure that the animation in the virtual characters replicated (as accurately as possible) that of the human stimuli. A mean recognition rate of 88.33% (SD = 12.62%) was achieved for the human, with a mean recognition rate of 78.33% (SD = 20.10%) achieved for the animated character with a normal articulation of speech. Participants also demonstrated the ability to recognize when no emotion was being presented with high recognition rates achieved for the neutral state in both the human (97.5%) and virtual character (95%). Due to restrictions of facial movement with current facial animation software, it was expected that the virtual character would achieve a lower mean value for emotion recognition than the human.

The mean ratings (and SD) for familiarity and human-likeness associated with each emotion for each condition are represented in Table 1. Consistently, videos of humans were rated as more familiar and human-like across the six emotions than virtual characters with normal and an over articulation of speech (see Table 1). The mean ratings for each dependent variable are also shown in Figures 2 & 3 with standard error bars. Inspection of the mean values for perceived familiarity (Figure 2) and human-likeness (Figure 3), show that: anger was the only emotion to be rated as more familiar and human-like in the over condition; happiness was rated as the most uncanny (least familiar and human-like) in the normal and over conditions; and disgust was rated highest for human-likeness in the human, though achieved the second lowest rating for human-likeness in the virtual character with normal articulation. Whilst rated as one of the least familiar and human-like emotions in the human, sadness achieved the highest ratings for perceived familiarity and human-likeness in the virtual character with normal articulation of speech, and the highest rating for familiarity in the over condition (see Figures 2 & 3). To assess the significance of these results, two 3 x 6 repeated-measures ANOVA were applied to the data. A main effect of character type was shown for both familiarity, $F(1.34, 52.08) = 155.55$, $p < .001$, and human-likeness, $F(1.08, 42.01) = 182.01$, $p < .001$. Regardless of emotion type, Bonferroni post-hoc tests revealed that human videos were rated higher for familiarity and human-likeness when compared to virtual characters with normal articulation (both ps < .001) and when compared to characters with an over articulation of speech (both ps < .001). This finding shows the existence of the uncanny in virtual characters, as was expected (H1).

Table 1. Mean familiarity and human-likeness ratings for each character (*N* = 40).

	Familiarity						Human-likeness					
Condition	Human		Normal		Over		Human		Normal		Over	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Emotion												
Anger	7.64	1.44	3.80	1.87	4.10	1.68	8.30	1.02	4.05	2.02	4.40	1.81
Disgust	7.75	1.37	4.05	1.87	3.80	2.07	8.55	0.68	3.95	1.80	3.83	2.00
Fear	7.32	1.70	3.98	1.69	3.78	1.90	8.20	1.42	4.08	1.99	4.08	2.04
Happiness	7.13	1.99	3.73	2.05	3.38	2.02	8.03	1.78	3.93	1.89	3.78	2.06
Sadness	7.34	1.53	4.93	1.80	4.50	2.10	8.05	1.34	4.80	2.09	4.35	2.15
Surprise	7.60	1.61	4.20	1.71	4.18	1.78	8.35	1.10	4.43	1.92	4.20	1.86

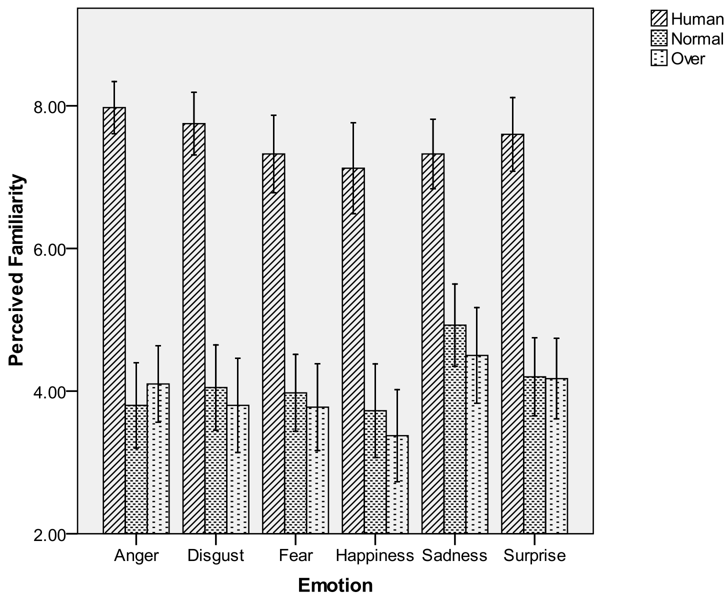

Fig. 2. Mean ratings and std. error bars (95% confidence level) for perceived familiarity for the three conditions, across emotion types.

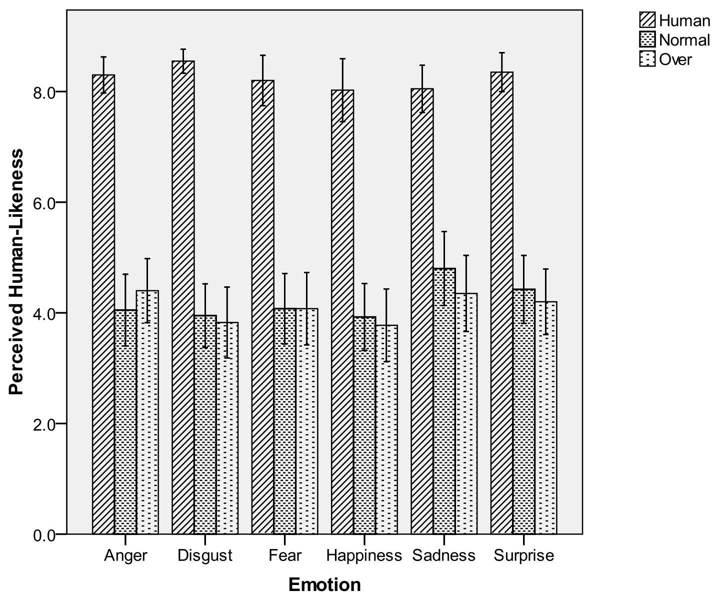

Fig. 3. Mean ratings and std. error bars (95% confidence level) for perceived human-likeness for the three conditions, across emotion types.

A significant main effect of emotion was found for both familiarity, $F (4.33, 168.90) = 5.751$, $p < .001$, and human-likeness, $F (4.44, 173.25) = 2.925$, $p < .05$, indicating that emotions were rated differently for familiarity and human-likeness irrespective of character type. Within-subject contrasts revealed a significant difference between the overall experimental effect and the emotion: happiness for both familiarity, $F (1, 39) = 12.296$, $p < .001$, and human-likeness, $F (1, 39) = 6.695$, $p < .05$; and sadness, just for familiarity, $F (1, 39) = 10.901$, $p < .05$.

A significant interaction effect was found between Character Type x Emotion for both familiarity, $F (8.56, 333.84) = 2.857$, $p < .05$, and human-likeness ratings, $F (5.31, 207.004) = 2.503$, $p < .05$. This finding indicates that emotion type had different effects on people's ratings for familiarity and human-likeness depending upon which type of character (human, normal or over) was presented. Within-subject contrasts showed that anger was perceived as significantly more familiar in the over state, $F (1, 39) = 4.377$, $p < .05$, offering partial support for the second hypothesis (H2). Disgust was regarded as significantly less human-like in the normal condition when compared to the human, $F (1, 39) = 7.005$, $p < .05$.

4 Discussion

This study investigated how the magnitude of mouth movements during speech influenced perception of the Uncanny Valley phenomenon in realistic, human-like virtual characters and has revealed that this factor significantly affects expressions of anger and happiness. It was predicted that, due to the importance of the lower facial features in communicating the emotions anger and happiness, that the uncanny would be reduced for anger and happiness for characters with exaggerated mouth movement. As expected, anger was perceived as significantly more familiar (and considerably more human-like) when the intensity of articulation was increased in the virtual character (see Figures 2 & 3). An increased exposure of the teeth and exaggerated lower facial movement sends a clear warning sign that intense anger is felt [15], [17], [20]. When anger is clearly communicated, the perceiver can respond accordingly to this emotion to prevent potential harm or threat. More subtle communication of this emotion (i.e. with a normal articulation of speech) is potentially more unsettling for the viewer. The perceiver may be uncertain as to how to react or what the anticipated behavior of that character will be. Such ambiguity raises alarm and exaggerates the uncanny for that character. Based on this finding, designers hoping to reduce the uncanny may exaggerate mouth movement during speech when communicating anger. Such modifications increase the salience of this emotion so it is perceived as more conspicuous and human-like, and less uncanny. A normal articulation of speech is recommended when portraying anger, if a designer wishes to increase the uncanny for an antipathetic character, as this is likely to make the viewer feel more uncomfortable. A reduced intensity of articulation that displays a clenched jaw with gritted teeth and lips pressed together (characteristic of *Anger Type 1* behavior) [15], [20] may also be perceived as less uncanny than characters with normal articulation when communicating anger. Reduced lip movement may be recognized as a more salient display of anger, hence increasing perceived familiarity and human-likeness.

A surprising finding was that not only was happiness perceived as less familiar and human-like when intensity of articulation was increased in the virtual character, but, overall, happiness was rated significantly as the most uncanny emotion (least familiar and human-like) across all three conditions: human, normal and over. This result was unexpected, given that happiness is renowned as a positive emotion and that lower facial features are predominantly more important when communicating this emotion than the upper face [15], [16], [18]. Humans find alternate ways to compensate for reduced lip rounding (protrusion) during smiled speech such as a lowering of the larynx and positioning of the tongue [22], [23]. Perception that the character's lip movement was exaggerated whilst maintaining a smile shape may have appeared strange and possibly 'wrong'. For example, an increased protrusion of the lips when pronouncing the vowel "a", when one may otherwise expect a widening of the mouth shape and decrease in vertical lip opening. However, it is more likely that this finding supports the previous notion that happiness is regarded less favorably as a viewer suspects they are being presented with a false smile [6]. Despite full muscle movement and animation in the upper face, low-polygon counts in the character's skin texture results in a lack of detail around the eye area, reducing the appearance of wrinkles or bugles below and beside the eye. Without this detail, the viewer cannot distinguish if a spontaneous emotion is actually felt [19]. Even when the smile is extreme (as with an increased articulation of speech), the absence of the wrinkled skin below and around the eyes indicates that the eyes are not involved in the smile. This may confuse the viewer as a deliberate attempt to communicate a positive emotion when other more negative emotions may be felt [19], thus exaggerating the uncanny. Until the graphical realism of skin texture is improved around the eye area, happiness may continue to be perceived as uncanny despite strategic design modifications to the lower face. To prevent the uncanny, it may be recommended to reduce the intensity of mouth movement and animation in the lower facial features when expressing happiness. However, exaggerated articulatory motion during speech may make an antipathetic character appear more insincere. Perception of fabricated versus spontaneous facial expression may influence perception of the uncanny for other emotions as well as happiness. This is a matter for future investigation.

Disgust was perceived as significantly less human-like in virtual characters with normal articulation, than in humans. This finding supports the previous notion that the realism of the 'nose wrinkler' action, characteristic of disgust, is not sufficient to communicate this emotion in virtual characters [6]. Sadness was found to be regarded more favorably when presented in a virtual character than in a human. This finding supports previous evidence that this emotion is regarded less uncanny due to a human's ability to anthropomorphize virtual characters [6]. Increasing the range of characters used within the experiment by age and gender would provide greater support for this assumption as other faces communicating this emotion may have differential levels of response. Including male and female actors and characters in future experiments may also increase validity and allow further investigation into the effect of gender, emotion and perception of the uncanny. The range of sentences can also be increased. The word 'familiarity' could be construed as how well-known a character is in popular culture [25]. Alternative measures of the Uncanny Valley may be used in future experiments to avoid potential misinterpretation of this word. Words such as coldness and eeriness [4] may be better descriptors in this context.

References

1. Mori, M.: Bukimi No Tani [The Uncanny Valley]. Energy 7, 33--35 (1970)
2. Brenton, H., Gillies, M., Ballin, D., Chatting, D.: The Uncanny Valley: does it exist? In: HCI Annual Conference: Animated Characters Workshop, Edinburgh, UK (2005)
3. Plantec, P.: Crossing the Great Uncanny Valley, http://www.awn.com/articles/production/crossing-great-uncanny-valley, (Dec 19, 2007)
4. Ho, C.-C., MacDorman, K. F.: Revisiting the uncanny valley theory: Developing and validating an alternative to the Godspeed indices. CHB. 26, 1508--1518 (2010)
5. MacDorman, K. F., Green, R. D., Ho, C. -C., Koch, C. T.: Too real for comfort? Uncanny responses to computer generated faces. CHB, 25, 695--710 (2009)
6. Tinwell, A., Grimshaw, M., Abdel-Nabi, D., Williams, A.: Facial expression of emotion and perception of the Uncanny Valley in virtual characters. CHB. 27, 741--749 (2011)
7. Green, R. D., MacDorman, K. F., Ho, C. -C., Vasudevan, S. K.: Sensitivity to the proportions of faces that vary in human likeness. CHB, 24, 2456--2474 (2008)
8. Tinwell, A.: The Uncanny as Usability Obstacle. In: Ozok, A. A., Zaphiris P. (eds.), HCI International 2009. LNCS, vol. 5621, pp. 622--631. Springer, Heidelberg (2009)
9. Ho, C. -C., MacDorman, K. F., Pramono, Z. A.: Human emotion and the uncanny valley. A GLM, MDS, and ISOMAP analysis of robot video ratings. In: The Third ACM/IEEE International Conference on Human-Robot Interaction. pp. 169--176, Amsterdam, 2008
10. Vinayagamoorthy, V., Steed, A., Slater, M.: Building characters: Lessons drawn from virtual environments. CogSci 2005. pp. 119--126, Italy, 2005
11. Tinwell, A., Grimshaw, M., Williams, A.: Uncanny behaviour in survival horror games. J. of Gaming and Virtual Worlds, 2, 23--25 (2010)
12. Tinwell, A., Grimshaw, M., Williams, A.: Uncanny speech. In: Grimshaw, M. (ed.) Game sound technology and player interaction. pp. 213--234, IGI Global, Hershey, PA (2011)
13. MacDorman, K. F., Coram, J. A., Ho, C.-C., Patel, H.: Gender differences in the impact of presentational factors in human character animation on decisions in ethical dilemmas. Presence: Tel. and Vir. Env. 19, 213--229 (2010)
14. Bartneck, C., Kanda, T., Ishiguro, H., Hagita N.: (2009). My robotic doppelganger - A critical look at the Uncanny Valley theory.: In 18th IEEEIS, pp. 269--276, Japan, 2009
15. Ekman, P., Friesen W. V.: Facial action coding system: A technique for the measurement of facial movement. Consulting Psychologists Press, Palo Alto, CA (1978)
16. Busso, C., Narayanan, S.S.: Interplay between linguistic and affective goals in facial expression during emotional utterances. In: 7th ISSP. pp. 549--556, Brazil, 2006
17. Ekman, P.: An argument for basic emotions. Cognition and Emotion 6, 169--200 (1992)
18. Ekman, P.: About brows: emotional and conversational signals. In: Von Cranach, M., Foppa, K., Lepenies, W., Ploog, D. (eds.) Human ethology: claims and limits of a new discipline. pp.169--202, CUP, New York (1979)
19. Ekman, P., Friesen W. V.: Felt, false and miserable smiles. J. of NVB, 6, 238--252 (1982)
20. Darwin, C.: The expression of the emotions in man and animals. University of Chicago Press, Chicago (1965) (Original work published 1872)
21. Chevalier-Skolnikoff, S.: Facial expression of emotion in nonhuman primates. In: Ekman P. (Ed.). Darwin and facial expression. pp. 11--83. Academic Press, New York (1973)
22. Fagel, S.: Effects of Smiling on Articulation: Lips, Larynx and Acoustics. In: COST 2102 Training School 2009. pp. 294--303
23. Shor, R.E.: The production and judgment of smile magnitude. Gen. Psy. 98, 79--96 (1978)
24. Cao, Y., Faloustsos, P., Kohler, E., Pighin, F.: Real-time Speech Motion Synthesis from Recorded Motions. In: ACM SIGGRAPH/Eurographics, pp. 345--353, France, 2004
25. Tinwell, A., Grimshaw, M.: Bridging the uncanny: an impossible traverse? In: Sotamaa, O., Lugmayr, A., Franssila, H., Näränen, P., Vanhala, J. (eds.) 13th Int. MindTrek Conf.: Everyday Life in the Ubiquitous Era, pp. 66--73. ACM (2009)