The Funcanny Valley: A Study of Positive Emotional Reactions to Strangeness

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ABSTRACT

The uncanny valley hypothesis states that an artificial character creates an unsettling impression if it resembles a real human too closely. In previous literature, uncanniness has usually been interpreted as a single feature that manifests itself in two ways: the character is perceived as strange, and it arouses emotions with negative valence in the viewer. The present study contradicts this view by demonstrating that strangeness and negative valence are not necessarily associated with each other. We showed people images of facial expressions that had already been rated for strangeness in a previous experiment. This time, we measured the viewers' emotional reactions using facial electromyography and self-assessment. Our results demonstrated that high strangeness was associated with positive emotional reactions instead of negative ones. When our participants saw strange faces, they smiled instead of frowning, and they reported experiencing amusement instead of negatively valenced emotions. We conclude that for human-like characters, strangeness is not always accompanied by emotions with negative valence, but these characters can also be uncanny in a funny way.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation (e.g., HCI)**]: Multimedia Information Systems; I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism—*animation, virtual reality*

Keywords

Uncanny valley, facial expressions, EMG, emotion

AcademicMindTrek'15, September 22-24, 2015, Tampere, Finland

ISBN 978-1-4503-3948-3/15/09...$15.00
DOI: http://dx.doi.org/10.1145/2818187.2818292

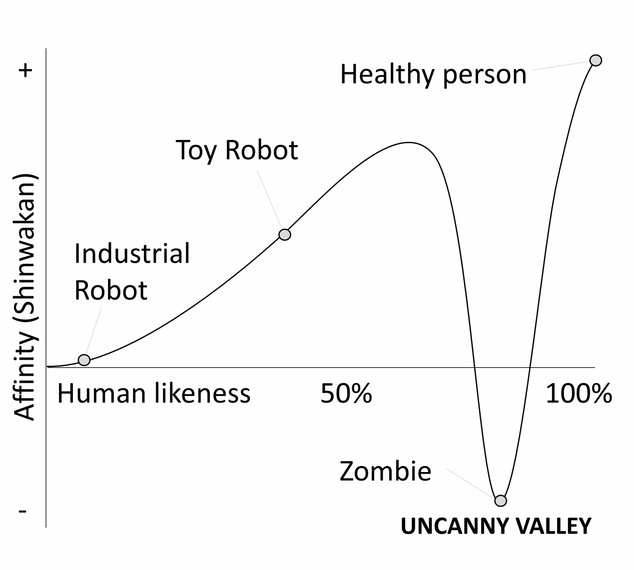

Figure 1: The uncanny valley. Adapted from Mori's original illustration [20].

1. INTRODUCTION

1.1 The Uncanny Valley

The uncanny valley hypothesis states that when the human-likeness of an artificial character increases, the sense of affinity first increases but then drops when the human-likeness gets too close to a real human [20]. This is illustrated in Fig. 1. Designers of animated characters are often advised to beware of the uncanny valley. The uncanny valley theory was originally designed to describe robots, but the same phenomenon has more recently been thought to be responsible for negative emotional reactions to many animated characters. Characters in films such as *The Polar Express*, *Beowulf*, and *Final Fantasy* have been described to elicit negative emotional reactions simply by resembling humans too closely [7] [23] [19]. Although the uncanny valley has received increasing research attention, it is not entirely clear how the two dimensions, human-likeness and affinity, should be understood [11]. The present study is an investigation of what it means to be "uncanny".

Mori's vague definition of the valence dimension may in part explain why the findings of uncanny valley studies have remained inconsistent [5] [11]. In Mori's original paper, the y-axis was labeled with the Japanese word *shinwakan*, which has been translated to familiarity [16], likability [1] [2], or affinity [20]. The negative y-axis was called *bukimi*, which translates to eeriness [9], but also the words creepiness and strangeness have been used [10]. A typical interpretation of the theory has been that when human-likeness approaches the level of a real human, uncanniness increases. The increase in uncanniness is thought to manifest itself in two ways: eeriness or strangeness of the character increases, and correspondingly, emotional reaction of the viewer turns from positive to negative. In empirical uncanny valley studies, uncanniness is usually measured by asking people to evaluate certain properties of the character. Evaluated properties include, for instance, strangeness–familiarity [18] [26] [25], eeriness [18] [17] [22], and acceptability [21]. These studies have usually not measured the emotional reaction elicited by the stimuli. However, it has been assumed that attributions of eeriness and creepiness are strongly associated with negatively valenced emotions, such as fear, disgust, and nervousness [10], or fear, unattractiveness, and disgust [3].

The present study focuses on emotional reactions elicited by stimuli that have already been rated for strangeness in our previous study [19]. The stimuli were images with varied levels of exaggeration and realism. The highest strangeness ratings were given to faces with a high level of exaggeration combined with a high level of realism.

1.2 Measuring Emotional Valence

We investigated the relationship between perceived strangeness of the image and the emotion experienced by the viewer. We used facial electromyography (EMG) along with self-assessment, because EMG is known to be useful in differentiating emotional valence [4]. In facial EMG, emotional valence is usually determined by measuring the activation of the muscles *zygomaticus major*, which raises the corners of the mouth to produce a smile, and *corrugator supercilii*, which draws the eyebrows together to produce a frown. Zygomaticus major is associated with positive valence (pleasantness) and corrugator supercilii is associated with negative valence (unpleasantness) [4].

Several studies have shown that corrugator supercilii and emotional valence have a negative linear correlation [13] [14] [24]. For zygomaticus major and emotional valence, there is evidence for both positive linear correlation [24] and quadratic correlation [13] [14]. In the studies where quadratic correlation was observed, there was high zygomaticus major activity for stimuli with positive valence, but also increased zygomaticus major activity for some of the most extremely negative stimuli. The latter was, however, accompanied with very high corrugator supercilii activity, and therefore is likely to be a sign of a grimace instead of a smile.

Since the stimuli in the present study are images of facial expressions of emotions, the facial expression is expected to affect both the facial muscle activity of the participant and the emotion experienced by the participant. It has been shown that seeing a happy face increases zygomaticus major activity, and seeing an angry face increases corrugator supercilii activity [6] [15]. To balance out the effect of the valence of the shown emotion, we used facial expressions of one positive emotion (happy), one negative emotion (angry) and one emotion that is neutral in valence (surprised). To be able to check for emotional contagiousness also for surprise, we measured *frontalis* (which raises the eyebrows) along with zygomaticus major and corrugator supercilii activations. Frontalis is associated with the facial expression of surprise, and there is evidence of activation of frontalis in response to seeing images of surprised faces [15].

As there were several possibilities for which specific emotions different images might evoke (due to emotional contagion, emotional reaction to the seen emotion, or emotional reaction to strangeness), we used a multiple choice questionnaire as a self-assessment tool rather than a simple positive-negative continuum. This also allowed us to differentiate the specific kind of a positive reaction (happiness, amusement) or a negative reaction (fear, anger, sadness, disgust) elicited by strangeness.

1.3 Hypotheses

Based on previous research, one might expect that higher strangeness ratings would be associated with more negative emotional experiences, and this would be observed in both EMG and self-assessment. It is also possible, however, that facial expressions that are exaggerated beyond biologically plausible norms would elicit incredulity and amusement in the observers. Hence, an alternative, opposite hypothesis would be that strange stimuli are associated with more positive emotional experience. These hypotheses are formulated as follows.

H1 Strangeness is associated with increase in self-reported *negative* emotions, increase in corrugator supercilii activity, and decrease in zygomaticus major activity.

H2 Strangeness is associated with increase in self-reported *positive* emotions, increase in zygomaticus major activity, and decrease in corrugator supercilii activity.

2. METHODS

2.1 Participants

The participants were recruited among students and staff of the Aalto University. The sample consisted of 14 male and 20 female participants, with mean age of 26.8 years (SD = 10.8). The participants received one movie ticket as a compensation for their participation.

2.2 Stimuli

As stimuli, we used images of happy, angry and surprised facial expressions. For each emotion, the stimuli varied on two dimensions: level of realism and magnitude of the facial expression. The images were edited using Adobe Photoshop software.

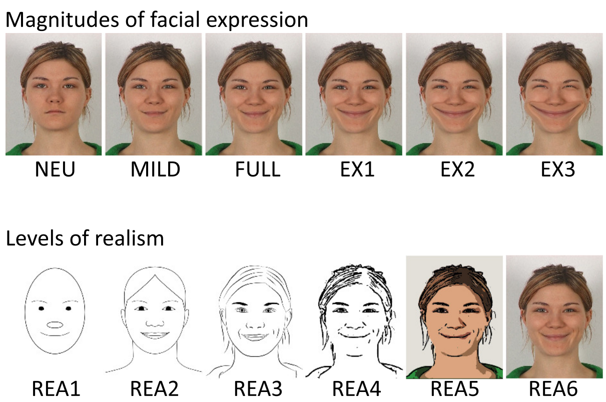

Figure 2: The magnitudes of facial expressions and the levels of realism illustrated for the facial expression of happiness. Original images copyrighted to BECS Dept., Aalto University.

The levels of realism and the magnitudes of facial expression are illustrated in Fig. 2. The characters with different levels of realism were created so that the positions of the eyes, eyebrows, lips and other facial features are the same, but the level of detail increases from REA1 to REA6. The magnitude of facial expression ranged from neutral to extremely exaggerated. First three levels were still images captured from a video clip showing the unfolding of a facial expression from a neutral to an emotional expression. The first level NEU corresponded to a neutral expression, the second level MILD corresponded to a facial expression of low magnitude, and the third level FULL corresponded to an emotional expression of full magnitude without exaggeration. The remaining three levels were artificially exaggerated versions of the same expressions, called EX1, EX2, and EX3. They corresponded to a slightly exaggerated, a heavily exaggerated, and an extremely exaggerated expressions of emotion, respectively.

All stimulus images had been rated for strangeness in a previous study [19]. In that study, 32 participants rated the images using a slider ranging from not strange at all to extremely strange. The position of the slider was converted to a number between 0 and 100. Figure 3 illustrates the average strangeness ratings of the images.

2.3 Procedure

The participants performed the experiment individually in a small experiment room. A laptop computer was used to present the stimuli and collect the data. The participants were told that they will see images of facial expressions and after each image they will be asked to evaluate their own emotional state. It was emphasized to the participants that they are not expected to evaluate the emotion of the character in the image, but instead their own emotional reaction. After the electrodes were attached, the participants first completed a practice session that included three images, after which the actual experiment started.

Stimulus presentation order was randomized for each participant. Each stimulus image was preceded by a fixation cross for the duration of 6 seconds, after which the image

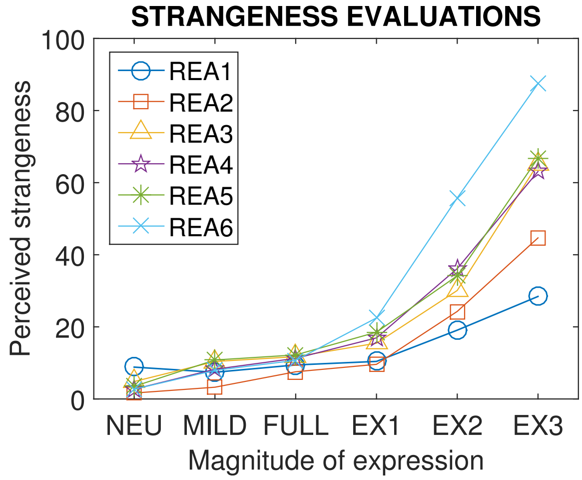

Figure 3: Average evaluated strangeness for each magnitude of facial expression at each level of realism, as reported in an earlier study [19].

was shown for the duration of 6 seconds. After each image, the participant was asked on the computer screen to select one emotion word that most accurately described his or her emotional state at the moment. The alternatives were: neutral, happy, sad, angry, fearful, disgusted, surprised, and amused.

2.4 Data Collection

Facial EMG activity was recorded using a Varioport recorder system (Becker Meditec, Karlsruhe, Germany). EMG signals were recorded over zygomaticus major, corrugator supercilii, and frontalis, on the left side of the face. Fridlund and Cacioppo's guideline for human EMG research [8] was used for placing the electrodes, but the placement of corrugator supercilii and frontalis electrodes was adjusted to avoid cross-talk between these electrodes observed in pilot experiments.

The EMG signal was filtered by using a 50 Hz notch filter and a 28 Hz high-pass filter, and then rectified. The measure for EMG activity for each image was calculated by subtracting the mean activity during 3 s preceding picture onset (local baseline) from the average response during the 6 s picture viewing interval.

3. RESULTS

3.1 Facial EMG

Figure 4 illustrates the zygomaticus major, corrugator supercilii, and frontalis activations during the presentation of happy, angry, and surprised facial expressions. They are all plotted against perceived strangeness of the image. For zygomaticus major, we found a significant positive correlation with strangeness for all facial expressions. The trend was most prominent for happy expressions ($r(34) = 0.91, p < 0.001$), but significant also for angry expressions ($r(34) = 0.71, p < 0.001$) and surprised expressions ($r(34) = 0.43, p < 0.01$). Also the negative correlation between strangeness and corrugator supercilii activity was significant for happy expressions ($r(34) = -0.41, p < 0.05$), but not for other facial expressions. The correlation between strangeness and

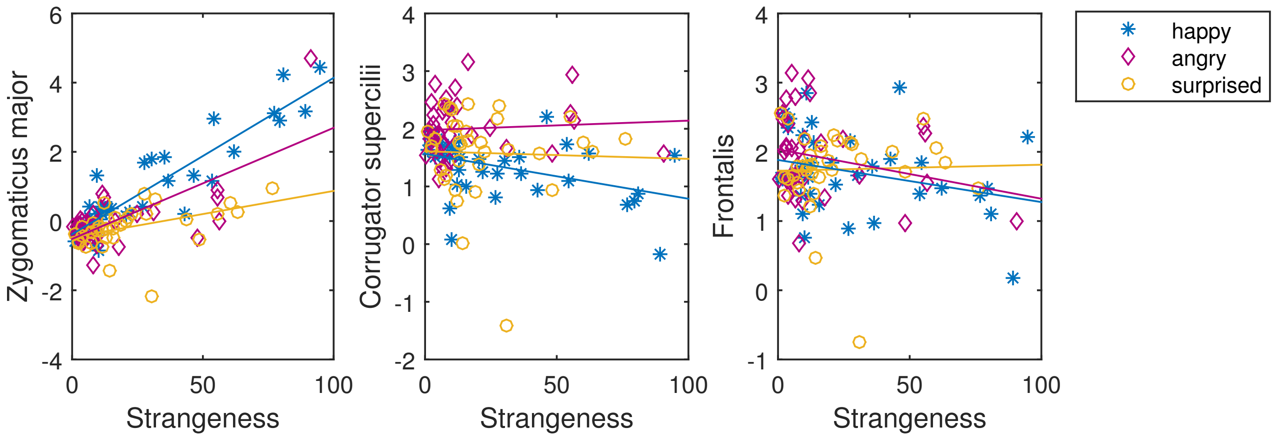

Figure 4: Activation of the muscles zygomaticus major, corrugator supercilii and frontalis plotted against strangeness. Each point represents one stimulus. The markers and colors indicate type of stimulus expression.

frontalis activity was not significant for any of the facial expressions.

We also compared the muscle activations to the perceived intensity of the emotions in the stimulus images (which was also measured in a previous study [19]). Based on the previous research findings that have shown correlations between stimulus valence and facial muscle activations [13] [14] [24], and the observation that facial expressions are contagious [6] [15], we expected strong correlations between muscle activations and the perceived intensity of the facial expression. Instead, we found out that only the correlation between zygomaticus major and intensity of the happy expression ($r(34) = 0.73, p < 0.001$) and the correlation between corrugator supercilii and intensity of the happy expression ($r(34) = -0.5, p < 0.01$) were significant. Frontalis did not correlate significantly with the perceived intensity of any facial expressions, and zygomaticus major and corrugator supercilii did not correlate significantly with the perceived intensity of anger or surprise.

We used a nested model comparison to determine whether perceived intensity and perceived strangeness combined would predict the zygomaticus major and corrugator supercilii muscle activations more accurately than strangeness alone. Since zygomaticus major has in some studies been reported to have a quadratic correlation with valence [13] [14], we included the quadratic component in the model. For zygomaticus major, the difference between the full model including strangeness, intensity and intensity squared ($R^2 = 0.86, F(3, 32) = 65.28, p < 0.001$) and the nested model with strangeness only ($R^2 = 0.83, F(1, 34) = 169.2, p < 0.01$) was not significant ($F = 3.05, p = n.s$). Similarly for corrugator supercilii, the full model ($R^2 = 0.28, F(3, 32) = 4.15, p < 0.05$) was not better than the nested model ($R^2 = 0.17, F(1, 34) = 6.726, p < 0.05$) in predicting corrugator supercilii activity ($F = 2.56, p = n.s$).

It should be noted that since perceived strangeness correlates with perceived intensity (extreme exaggerations were often rated high in both intensity and strangeness), we cannot completely rule out the effect of intensity. However, the analysis strongly suggests that perceived strangeness is a better predictor for both zygomaticus major and corrugator supercilii activity than perceived intensity. This would indicate that it was the strangeness of the images that made people smile, instead of the emotions that were seen in the facial expressions.

3.2 Self-assessment

The self-assessment question was a multiple choice question where participants selected the emotion word that best described their own emotion after viewing the image. To analyse the relationship between the self-assessment data and strangeness, we calculated the percentage of participants that had selected each emotion, and compared these numbers to strangeness ratings for each image. In Fig. 5, these percentages are plotted against strangeness.

There were statistically significant linear correlations between sadness and strangeness ($r(106) = -0.37, p < 0.001$), between fear and strangeness ($r(106) = 0.24, p < 0.05$), between disgust and strangeness ($r(106) = 0.35, p < 0.001$), between surprise and strangeness ($r(106) = 0.3, p < 0.01$) , and between amusement and strangeness ($r(106) = 0.84, p < 0.001$). However, it can be seen from both the correlation coefficients and the graph in Fig. 5, that amusement was much more strongly correlated with strangeness than any of the other emotions.

4. DISCUSSION

Our results showed that the emotional reaction of the participants to strange stimuli was positive instead of negative. The results from facial EMG did not provide any support for H1. Instead, H2 was supported for happy facial expressions (zygomaticus major activation increased with strangeness and corrugator supercilii activation decreased when strangeness increased), and partially supported for angry and surprised facial expressions (zygomaticus major activation increased with strangeness, but corrugator supercilii activity did not increase or decrease significantly). In the self-assessment results, we found slight evidence for hypothesis H1: there was a significant positive correlation between

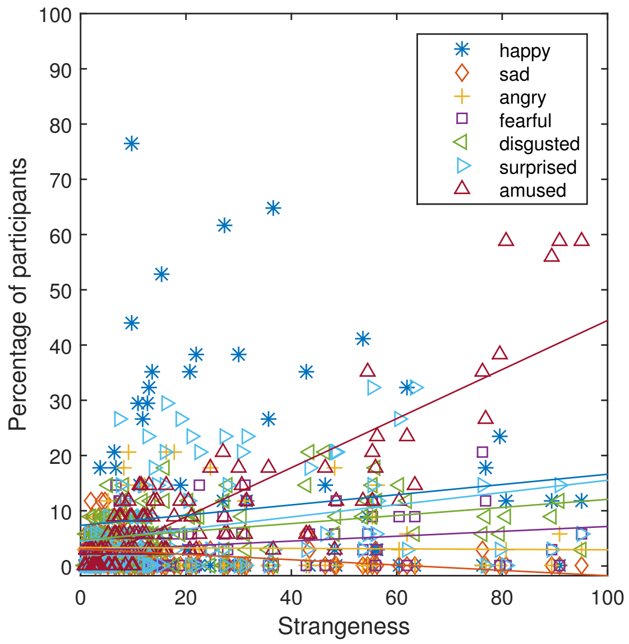

Figure 5: Self-assessment results plotted against strangeness. Each point represents one stimulus, and each marker and color denote the emotions that were reported by participants. The position of each point along y-axis represents the percentage of participants that reported experiencing this emotion.

strangeness and fear, and between strangeness and disgust, which is congruent with previous research [10] [3]. However, the correlation between amusement and strangeness was much stronger, and thus also the self-assessment results give more support to H2.

These results question the interpretation of uncanniness as a single property that manifests itself as high strangeness or eeriness combined with a negatively valenced evoked emotional response. We have shown that contrary to this interpretation, there are cases where stimuli that are rated high in strangeness produce a positive emotional response, i.e. smiling and a feeling of amusement. In our study, this positive response was accompanied with a small but statistically significant negative response (reported as fear and disgust). However, emotional response was clearly dominated by amusement.

“Uncanniness” is a concept that has turned out to be difficult to define. If we defined uncanniness as a combination of strangeness and a negative emotional response, it would mean that our stimuli were not uncanny after all. We could say that they were strange and amusing images, but they were not representative of the uncanny valley. If we took this perspective, we should require that empirical uncanny studies always measure both strangeness and emotional response in order to determine whether uncanniness occurs. A majority of uncanny studies so far have not measured emotional response, which would question their validity. Alternative perspective on uncanniness could be that uncanny characters are always perceived as strange or eerie, but the emotional response of the viewer can vary depending on the character. For some characters, negative emotions such as fear and disgust may dominate the emotional response, but in other cases the most dominant emotion can be positive, such as amusement. Furthermore, even though the emotional reactions to strange images were almost completely positive in the present study, it is possible that other uncanny stimuli will elicit both strong positive and strong negative emotions simultaneously.

Based on our results and earlier research, we have observed that neither of the axes in the uncanny valley graph (Fig. 1) is unambiguous. As already discussed in previous research papers [5] [11], familiarity and eeriness are not direct opposites, and as this research shows, strangeness is not always associated with negative affect. On the other hand, the human-likeness axis is ambiguous because there are many different ways in which a character can be almost human. Some of these ways produce more repulsive characters (such as zombies), whereas others produce characters that are better characterized as funny or amusing.

Designers of animated characters are often advised to choose less realistic characters to avoid unintentional negative feelings. Considering the results of this study, designers might actually want to use more realistic characters when the character is intended to be funny. However, further research is needed to determine what makes a closely human-like character funny or uncanny.

Due to the limitations of our study, we can not tell what determines whether a certain character will evoke positive or negative feelings. We used images of only one actor, and we chose one way to produce increasingly human-like characters (while there are countless different ways to do this). Moreover, we used static images, and therefore we do not know whether our results can be generalized to moving images. The self-assessment was done using a force-choice question, while there would have been other tools for self-assessment that allow the participants to describe their emotions in more detail.

Considering that facial expressions are contagious [6] [15] and have emotional valence on their own, it can be argued that the emotions that are depicted in the images bring a confounding variable into this experiment. However, we balanced the effect of the presented facial expression by using one facial expression with positive valence (happy), one with negative valence (angry), and one with neutral valence (surprise). In fact, it turned out that the emotion in the facial expression had little effect on the relationship between strangeness and the facial muscle activations. Our participants smiled at strange angry faces and strange surprised faces as well as strange happy faces. However, smiling was most intense for happy faces, and also the decrease of corrugator supercilii activity was observed only for happy faces. This indicates that there may have been some emotional contagion for the happy faces on top of the amused reaction.

Some earlier studies have shown elevated zygomaticus major activity for both very pleasant and very unpleasant stimuli [13] [14]. Therefore, it could be questioned whether the observed zygomaticus major activity for the strange images in this study should be interpreted as a sign of a positive emotion or as a sign of a negative emotion. However, in those earlier studies, increased zygomaticus major activation was accompanied with increased corrugator supercilii activation for unpleasant stimuli, and decreased corrugator supercilii activation for pleasant stimuli [13] [14]. In our study, increased zygomaticus major activation was accompanied with either decreased corrugator supercilii activation (for happy faces) or no change (angry and surprised faces), which is an indication that our participants actually smiled instead of grimacing. Moreover, the self-assessment data supports this interpretation.

Another confounding factor that might explain the increase in zygomaticus major activation for strange faces, is that there is evidence of cross-talk between zygomaticus major and *levator labii*, a muscle that wrinkles the nose and is associated with disgust [15]. If the strange stimuli elicited disgust, as would be expected based on earlier research literature, this would also come out as an increase in measured zygomaticus major activity. Since we did not measure levator labii activity, we can not check whether the increase in measured zygomaticus major activity was actually due to levator labii. However, from the self-assessment results we can see that increase in experienced disgust was very small compared to the increase in amusement, and thus it is highly unlikely that the increase in measured zygomaticus major would be caused by the facial expression of disgust instead of smiling.

Finally, as we have shown that uncanniness may in fact sometimes be more funny than scary or disgusting, we contemplate a little on the essence of funniness. Some theories of humour state that laughter is the result of an ambivalent emotional experience, and humour is based on the conflict between simultaneous pleasant and unpleasant feelings [12]. From this perspective, we might consider the possibility that the funniness (amusingness) in our stimulus images was actually a result of simultaneous positive and negative affects. In fact, the facial EMG results could be seen as supporting this interpretation. Larsen, Norris, and Cacioppo [14] have speculated that as they observed positive curvilinear relationship between zygomaticus major and valence, and negative linear relationship between corrugator supercilii and valence, ambivalent stimuli might show increase over zygomaticus major accompanied with no change in corrugator supercilii. (They suggested that ambivalent stimuli could have antagonistic effects on corrugator supercilii activity and this would result in no change.) These changes in muscle activations were exactly what we observed, with the exception of decreased corrugator activity for happy stimulus faces, which could be explained by emotional contagion. Also the results of the self-assessment questionnaire indicated some ambivalent emotions, even though the increase in negative emotions for strange faces was very small. Thus, it is a plausible suggestion that the negative affective reaction predicted by the uncanny valley theory could in some cases merge with other feelings of positive valence, to produce a sensation of amusement, funniness, and humorousness. Future studies might test this suggestion to further increase our understanding about emotional reactions caused by the uncanny valley.

5. CONCLUSION

We studied the relationship between strangeness and emotional response for stimuli that had been rated for strangeness in a previous experiment. Contrary to what might be expected based on previous research, the images that had received high strangeness ratings evoked only little negative emotions such as fear or disgust. The main emotional response was positive, which was evident in both objective and subjective measurements. Objectively, we measured smiling as response to strange images. Subjectively, participants reported amusement. These results question the interpretation of uncanniness as being always associated with negative emotions. We propose that future uncanny research should take into account that measuring strangeness alone does not provide information of whether the emotional reaction is positive or negative.

Acknowledgments

This work has been supported by UCIT graduate school and Finnish Cultural Foundation (MM), Emil Aaltonen Foundation (JK), and HeCSE graduate school (KF). We thank Kenta Kusumoto for support with the EMG measurements, Nelli Myllylä and Hanna Stenhammar for their contribution in experiment execution, and Olli Salo for help in statistical analyses.

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