



Testing the ‘uncanny valley’ hypothesis in semirealistic computer-animated film characters: An empirical evaluation of natural film stimuli



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ABSTRACT

The uncanny valley (UV) hypothesis, which predicts that almost but not fully humanlike artificial characters elicit negative evaluations, has become increasingly influential. At the same time, the hypothesis has become associated with many computer-animated films that have aimed at high realism. In the present investigation, we tested whether semirealistic animated film characters do in fact elicit negative evaluations. Fifty-four participants were asked to evaluate five matched film excerpts from each of cartoonish, semirealistic, and human-acted films. Mixed model analyses were conducted to reduce the effects of participant and stimulus related confounds. Explicit selections made after the experiment confirmed that participants associated semirealistic film characters correctly with the UV. Semirealistic animated characters also received higher eeriness ratings than the other film characters. In particular, two semirealistic films ‘*Beowulf*’ and ‘*The Polar Express*’ were selected the most often explicitly, and ‘*Beowulf*’ also received higher eeriness ratings than any other film. Somewhat unexpectedly, cartoonish characters received the highest strangeness ratings and (after confound correction) the lowest likability ratings. Taken together, the present findings demonstrate that semirealistic animated film characters are more eerie than cartoonish characters or real actors, and hence provide evidence for the existence of the UV in animated film characters.

1. Introduction

Masahiro Mori, a Japanese robotics professor, predicted already in the 1970s that although increasingly humanlike robots would elicit positive affects, robots and other artificial devices that reached a threshold of being almost but not fully humanlike could elicit a profound sense of eeriness (Mori, 1970/2012) (Fig. 1). Based on the shape of this hypothetical evaluative curve, Mori coined his hypothesis as the uncanny valley (UV). The UV hypothesis has been rediscovered during the ongoing millennium (Brenton et al., 2005; Gee et al., 2005; Hanson, 2005; MacDorman, 2005), and it is at the present particularly relevant for computer graphics and animation technologies, which can arguably be used to produce the most realistic humanlike characters of today (e.g., Alexander et al., 2010). Although realistic computer-generated faces and characters are not necessarily interactive; realistic, emotionally expressive, and virtually interactive animated characters can already be found in the cinema. In the present empirical study, we investigate whether semirealistic animated film characters show evidence of the UV hypothesis.

The UV hypothesis would predict that some animated film char-

acters that are intended to appear realistic elicit negative affective reactions in viewers. Consistently, computer-animated films using state-of-the-art animation techniques, such as *Final Fantasy: The Spirits Within* (Aida et al., 2001), *The Polar Express* (Goetzman et al., 2004), and *Beowulf* (Rapke et al., 2007), have aroused critical reviews in the media. For example, the critics have noted that the characters of *Final Fantasy* “look so real that it's creepy” (Kempley, 2001), that “watching the humans in *The Polar Express* is like watching people through a smeary car windshield” (Savlov, 2004), and that “motion capture [the animation technique used] in *Beowulf* comes across as an unsatisfying compromise between animation and live action” (Ansen, 2007). These and other similar films have been explicitly considered in the UV context in later film reviews (e.g., Gleiberman, 2011; Hill, 2011; Phillips, 2011; Robinson, 2007; Stevens, 2011) and technologically oriented magazine articles (e.g., Plantec, 2007; Perry, 2014; Weschler, 2002). Such observations from film and technology experts provide anecdotal evidence for the existence of the UV in computer-animated films. Although anecdotal, this association has been repeatedly mentioned in empirical research as well (e.g., Bartneck et al., 2009; Brenton et al., 2005; Burleigh et al., 2013;

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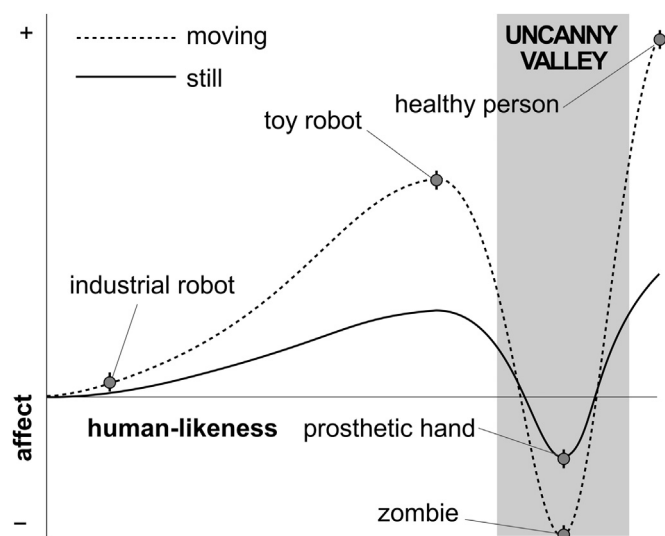


Fig. 1. The characteristic uncanny valley curve between affective evaluations and human-likeness, as predicted by Mori (1970/2012). Some of Mori's original examples have been highlighted on the curve for moving characters.

Chaminade et al., 2007; Kaba, 2013; Looser and Wheatley, 2010; MacDorman et al., 2009; McDonnell et al., 2012; Misselhorn, 2009; Piwek et al., 2014; Pollick, 2010; Saygin et al., 2012; Steckenfinger and Ghazanfar, 2009; Tinwell et al., 2011; Tondur, 2012), which indicates considerable academic interest in such possibility.

Demonstrating that semirealistic animated film characters do elicit negative affective reactions in viewers would strengthen the UV hypothesis, which has to date received inconsistent empirical evidence (for recent reviews, see Kätsyri et al., 2015; Pollick, 2010; Wang et al., 2015). This inconsistency may originate from the lack of consensus on the conceptual and operational definitions of the UV hypothesis – in fact, a characteristic of the original UV formulation is that it is a “broadly applicable guidepost to designers in a variety of domains” (Pollick, 2010, pp. 70–71) rather than a precisely defined experimental hypothesis. We will first consider evidence from studies that have used strictly controlled stimulus continua ranging from fully artificial to fully realistic, such as those generated by image morphing (e.g., Cheetham et al., 2011; MacDorman, 2006; Yamada et al., 2013), computer-generated imagery (CGI) (e.g., Burleigh et al., 2013; MacDorman et al., 2009), and motion manipulation methods (e.g., Piwek et al., 2014; Thompson et al., 2011). Although the earliest image morphing studies provided evidence in favour of the UV hypothesis (Hanson, 2006; MacDorman and Ishiguro, 2006), these findings could also be explained by uncontrolled image morphing artifacts (cf. MacDorman et al., 2009). The majority of recent studies have demonstrated that, contrary to the UV hypothesis, increasing human-likeness elicits increasingly positive evaluations (e.g., Experiment 1 in Burleigh et al., 2013; Cheetham et al., 2014; Looser and Wheatley, 2010; MacDorman et al., 2009; Piwek et al., 2014; Seyama and Nagayama, 2007; Thompson et al., 2011). However, a minority of studies have demonstrated nonlinear changes that are consistent with the UV hypothesis (Experiment 2 in Burleigh et al., 2013; Ferrey et al., 2015; Yamada et al., 2013).

The inconsistency of the above findings could possibly originate from the fact that the UV would manifest itself only under very specific experimental conditions. A careful reading of Mori's original article (Mori, 1970/2012) reveals that he did not explicitly state that all kinds of possible human-likeness manipulations would lead to the UV. One possibility is that the UV is caused by a perceptual mismatch between artificial and realistic features. This suggestion is consistent with Mori's illustrative examples, such as a myoelectric hand that looks but does not feel human, and it has also received support from empirical studies

(for a review, see Kätsyri et al., 2015). For example, Seyama and Nagayama (2007) showed that a greater mismatch between the realism of the eyes and the rest of the face elicits more negative evaluations, with the most negative evaluations occurring for fully artificial eyes placed on a fully realistic face or vice versa. The authors also demonstrated that unrealistically large eyes appeared the most eerie on the most realistic faces. MacDorman et al. (2009) demonstrated similar eyes–face mismatch and eye enlargement effects for CGI faces. Mäkäräinen et al. (2014) found that exaggerated facial expressions are acceptable on cartoonish faces but appear increasingly strange on increasingly humanlike faces. Recently, MacDorman and Chattopadhyay (2016) demonstrated that inconsistency between computer animated and real features causes humans and animals, but not objects, to appear eerier and colder. Other studies have demonstrated that individuals show increasing consensus when judging the range of aesthetic facial proportions on increasingly realistic faces (Green et al., 2008; MacDorman et al., 2009).

Although the above findings could be taken to imply that the UV exists and can be caused by either a perceptual mismatch between realistic and artificial features or a heightened sensitivity to deviations from human norms in highly realistic characters, this suggestion is not without problems. First, one should be careful in generalizing results from these relatively few experimental manipulations to all possible kinds of perceptual mismatches. Second, the above explanations cannot exclude the possibility that the UV could also be caused by yet some other explanatory mechanisms. Third, it remains uncertain whether the above experimental results can be generalized to natural stimuli. Rigorously controlled experimental UV studies are by necessity tied to narrow stimulus manipulations; for example, the above studies have focused predominantly on facial feature modifications. Testing whether the UV is caused by a specific stimulus manipulation out of various imaginable possibilities could be said to represent a “bottom up” approach for testing the UV hypothesis. Given that the UV still remains poorly understood, the risk is that the adopted stimulus manipulations are not fully relevant for the phenomenon.

An alternative “top down” approach would be to first test whether the UV phenomenon exists for natural stimuli and then investigate which specific features have caused it. Two recent studies have already provided positive evidence for the UV in images of human, prosthetic, and robot hands (Poliakoff et al., 2013) and images of real-world robot faces (Mathur and Reichling, 2016). Other studies have already provided tentative evidence for the existence of the UV in video game characters. McDonnell et al. (2012) demonstrated that one of their most realistic rendering styles for computer-generated faces elicited low appeal. Schneider and Yang (2007) showed that almost but not fully human video game characters tend to receive low attractiveness ratings. Tinwell et al. (2010) showed that two of their studied video game characters that were not intended to appear eerie nevertheless received lower familiarity ratings than other similar characters. Furthermore, they also reported a negative correlation between audio-visual asynchrony and familiarity. Flach et al. (2012) studied the UV using animated film characters; however, they also included materials from various other sources, and their results were based only on visual inspection of data. Ho and MacDorman (2010) included film excerpts from two semirealistic animated films as a part of their questionnaire development; however, these films were not explicitly compared to other stimuli. To the best of our knowledge, no studies have yet studied the existence of the UV exclusively in animated film characters by comparing such characters to matched cartoonish and human stimuli.

To summarize, animated film characters could be used to test the validity of the UV hypothesis without making strict a priori assumptions about which specific features, mechanisms, or explanations cause the phenomenon. This is important because at the present the evidence for the UV appears to vary depending on the specific methods and assumptions (e.g., perceptual mismatch) adopted in each particular study. Although animated films are by no means the only possible

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