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Brief article

Empirical evaluation of the uncanny valley hypothesis fails to confirm the predicted effect of motion

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ABSTRACT

The uncanny valley hypothesis states that the acceptability of an artificial character will not increase linearly in relation to its likeness to human form. Instead, after an initial rise in acceptability there will be a pronounced decrease when the character is similar, but not identical to human form (Mori, 1970/2012). Moreover, it has been claimed but never directly tested that movement would accentuate this dip and make moving characters less acceptable. We used a number of full-body animated computer characters along with a parametrically defined motion set to examine the effect of motion quality on the uncanny valley. We found that improving the motion quality systematically improved the acceptability of the characters. In particular, the character classified in the deepest location of the uncanny valley became more acceptable when it was animated. Our results showed that although an uncanny valley was found for static characters, the deepening of the valley with motion, originally predicted by Mori (1970/2012), was not obtained.

1. Introduction

With recent developments in robotics, character animation and virtual environments, the desire has increased for artificial characters to look and behave more like humans. Nevertheless, anecdotal reports indicate that realistic animated characters, like those in the movie *The Polar Express* (Zemeckis, 2004) have received negative reactions from viewers, who complain that the appearance and motion of those characters is uncomfortably realistic (Geller, 2008). Going beyond the scope of movies, observers of some realistic androids, such as those created by Ishiguro (2007), have reported finding them creepy. Indeed, Mori (1970/2012) hypothesised that following an initial rise in acceptability as characters approach a human-like appearance, their acceptability will then suddenly drop when the resemblance becomes too close, and this effect will be accentuated by motion (Fig. 1). The idea of 'acceptability' in this context refers to how acceptable one finds it to interact with a character on a regular basis. The term *uncanny valley* was coined to describe this effect of low acceptability for artificial characters that closely resemble humans, and it is already an established principle for animators and android designers that to avoid the uncanny valley one should focus efforts on the first summit of the curve shown in Fig. 1 (Fabri, Moore, & Hobbs, 2004; Fong, 2003; Mori, 1970/2012). Only recently, however, has psychological evaluation of this hypothesised curve begun to attract empirical scrutiny.

There are several convergent motivations for wanting to more precisely understand the uncanny valley. First, there is the practical benefit that a better understanding could lead to the development of more effective artificial characters. This advancement could arise from a better understanding of how to avoid falling into the valley as well as

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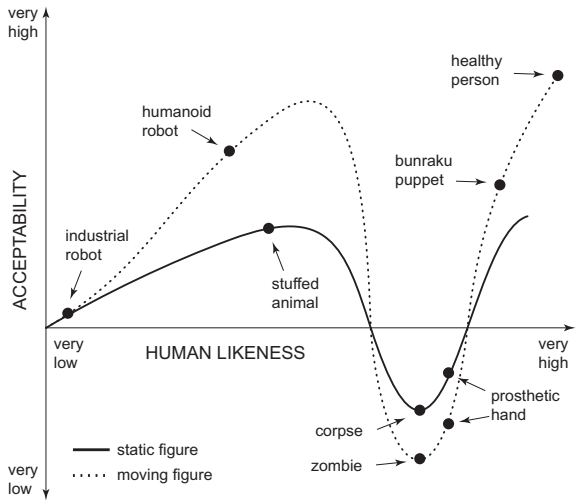

Fig. 1. Adapted from Mori (1970/2012). Hypothesised response of human subjects is plotted against human likeness of the characters. The uncanny valley is the region of negative response to characters that seem highly human like (i.e., zombie and corpse). Movement is hypothesised to change the response for all characters and in particular to deepen the uncanny valley (MacDorman and Ishiguro, 2006; Mori, 1970/2012).

from identifying the fundamental boundaries past which falling into the valley would be inevitable. Second, artificial characters are being used increasingly in perceptual and social interaction studies (Bailenson & Yee, 2005; Boker et al., 2011; Von der Pütten, Krämer, Gratch, & Kang, 2010; Zanbaka, Ulinski, Goolkasian, & Hodges, 2007). Although these artificial characters provide unsurpassed control over stimulus properties, the results obtained with highly realistic characters are often qualified by the possibility that the stimuli might have fallen into the uncanny valley. Finally, at a level fundamental to understanding the psychological phenomenon, there is the theoretical question of why increasing the realism of a configuration of features to levels near those found in natural stimuli produces unappealing results.

Several perceptual, cognitive, and social explanations of the uncanny valley have been advanced, involving a variety of factors including empathy, mate selection, threat avoidance, cognitive dissonance, psychological defences, expectation violation, mismatch of perceptual cues and category boundary effects (Gray & Wegner, 2012; Hanson, 2006; MacDorman, Green, Ho, & Koch, 2009; MacDorman & Ishiguro, 2006; Moore, 2012; Pollick, 2010; Saygin, Chaminade, Ishiguro, Driver, & Frith 2012; Tinwell, 2014). Experiments studying human reactions to original and altered static faces have supported the existence of an uncanny valley effect (MacDorman et al., 2009; Seyama & Nagayama, 2007), as have studies looking at the combination of faces and voices (Kuratate et al., 2009; Mitchell et al., 2011; Tinwell, Grimshaw, Nabi, & Williams, 2011). For example, Tinwell et al. (2011) showed that for speaking virtual characters, a lack of facial expression in the upper parts of the face during speech was found to exaggerate an uncanny valley effect. The explanation for this result was that the absence of upper facial animation accompanying speech elicits a sense of the virtual character resembling a waxwork figure, which makes it difficult to distinguish whether it is real or unreal, and alive or dead, thus producing the sense of uncanniness in the observer (Jentsch, 1906). An uncanny valley effect has also been found in studies using other primates; Steckenfinger and Ghazanfar (2009) examined the viewing preferences of macaque monkeys to static and animated monkey faces. Measuring the duration of eye fixation on the displays, the authors indicated that the monkeys preferred to look at both unrealistic synthetic faces and real faces for a longer period than realistic synthetic faces. Based on their results they concluded that monkeys also experience the uncanny valley phenomenon, making a strong case for the evolutionary origins of this effect (MacDorman et al., 2009). The authors' explanations for the uncanny valley effect in monkeys included such factors as perceived facial attractiveness and high sensitivity to facial abnormalities for realistic synthetic faces.

A number of studies have examined the uncanny valley effect using full body animations and different forms of characters. Chaminade, Hodgins, and Kawato (2007) used a set of animated characters (point-lights, ellipses, robot, alien, clown, jogger) and asked participants to categorise each character's motion as being biological or artificial. The authors reported that the particular form/type of character did not influence sensitivity (d') to motion. Nevertheless, participants judged the characters with the most simple form (point-lights) as moving more naturally than complex characters, which they judged as moving synthetically - a result that is consistent with the uncanny valley prediction (Chaminade et al., 2007). Saygin et al. (2012) used fMRI to assess brain activation by presenting participants with video clips of a human, an android modelled on this human and the same android with its "skin" removed to appear as a mechanical robot. They investigated whether the uncanny valley might be caused by a violation of the brain's prediction that a character that looks a certain way will be associated with particular movements. Indeed, the participants showed similar levels of brain activation when they watched the human and the robot, but increased activation when they watched the android. The authors argued that the android, which appeared human but did not move in a biological manner, violated perceptual expectations, and that this explained the increased brain activation.

Although the findings of Chaminade et al. (2007) and Saygin et al. (2012) support the idea that motion influences the uncanny valley, other studies have provided mixed results. Steckenfinger and Ghazanfar's (2009) study with macaque monkeys showed that the uncanny valley effect was more apparent for animated than static faces. However, the authors argued that facial motion was not a prominent cause of the uncanny valley, highlighting the influence of static facial features in eliciting an uncanny valley response. In another study, Thompson, Trafton, and McKnight (2011) parametrically manipulated three kinematic features of two different computer generated characters (human and mannequin) and examined the effects of those manipulations on judgments of humanness, familiarity, and eeriness. Participants rated those characters with more natural movement as being more