

# Categorization-based stranger avoidance does not explain the uncanny valley effect



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## ABSTRACT

The uncanny valley hypothesis predicts that an entity appearing almost human risks eliciting cold, eerie feelings in viewers. Categorization-based stranger avoidance theory identifies the cause of this feeling as categorizing the entity into a novel category. This explanation is doubtful because *stranger* is not a novel category in adults; infants do *not* avoid strangers while the category *stranger* remains novel; infants old enough to fear strangers prefer photographs of strangers to those more closely resembling a familiar person; and the uncanny valley's characteristic eeriness is seldom felt when meeting strangers. We repeated our original experiment with a more realistic 3D computer model and found no support for categorization-based stranger avoidance theory. By contrast, realism inconsistency theory explains cold, eerie feelings elicited by transitions between instances of two different, mutually exclusive categories, given that at least one category is anthropomorphic: Cold, eerie feelings are caused by prediction error from perceiving some features as features of the first category and other features as features of the second category. In principle, realism inconsistency theory can explain not only negative evaluations of transitions between real and computer modeled humans but also between different vertebrate species.

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## 1. 3D computer model is a distinct and familiar category

The crux of the commentators' argument is twofold. First, they claim categorization-based stranger avoidance explains our data and, thus, the uncanny valley effect. Their theory is that stranger avoidance "is triggered when an object has an improbable appearance and is therefore categorized into a novel class" (Kawabe, Sasaki, Ihaya, & Yamada, 2017). Second, they claim our experiment, which used stimuli varying from a person's 3D computer modeled face to a photograph, is not valid because *3D computer model* is not a distinct category; like the real person in the photograph, it is just another instance of the category *human being*, though an instance with computer modeled features. Therefore, they conclude that our stimuli do not transition between two different categories and advise us to "use a stimulus category dimension with a wider range containing a nonhuman entity, an ambiguous entity, and a human being."

Their argument is logically inconsistent. If our experiment did not entail a category transition (second claim) because a 3D computer model of a human being is still perceived as an instance of the category *human being*, there would be no "novel class" and, hence, per their theory, no uncanny valley effect (first claim). (As they note, there was an uncanny valley effect.)

We disagree that a hand-drawn cartoon or a doll are instances of *nonhuman* categories while a 3D computer model and a real person are instances of the category *human*. (In their first experiment, Yamada, Kawabe, & Ihaya, 2013, created morphs from the face of the Charlie Brown character to the face of a Japanese man.) A 3D computer model, hand-drawn cartoon, and doll can all be used to

depict humans—in which case they are all depictions within the category *human*.

Within the category *human*, in our original experiment, we instructed participants to distinguish the *real* from the *computer animated*. In the demographics survey, our US participants reported watching films, videos, and television programs with 3D computer-animated human characters 3.65 h per week on average ( $SD = 6.07$ ,  $n = 365$ ). They also reported playing video-games with 3D computer-animated human characters 4.54 h per week ( $SD = 7.54$ ) and having played them for 7.33 years ( $SD = 5.96$ ). Clearly our participants' long-term exposure should have been sufficient to establish *3D computer model* as a distinct category.

In our experiment, the 3D computer model (0% real) was eeriest, which we attributed to prediction error caused by its features being perceived as features of different categories (cf. Moore, 2012; MacDorman & Chattopadhyay, 2016); eeriness declined as the stimuli transition to 100% real. The commentators claim their theory explains this decline because as stimuli appear more human they "can be better categorized into a familiar class." This explanation is contradicted, however, by the fact that the 100% 3D computer model was categorized with the greatest certainty and rapidity (greater even than 100% real, figure 4 and 7, top left). This result indicates *3D computer model* is a familiar category with a probable appearance, distinct from *real*. Further evidence is the logistic, nearly symmetrical curve with tight confidence intervals for percentage categorized as *real* (figure 4, top left). This pattern is consistent with a transition from one known category to a different known category (figure 6a of Feldman, Griffiths, & Morgan, 2009; figure 19.1 of Harnad, 1987). In fact, if the labels were removed, it would be impossible to deduce whether the transition were from *3D computer model* to *real* or vice versa.

Furthermore, we are concerned when the commentators write, "stranger avoidance is not driven simply by categorization

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difficulty that can be quantified by measuring categorization latency.” In their earlier paper, categorization difficulty was operationalized as categorization latency, and their result—that the least likable stimulus in the transition was also the stimulus with the longest latency—was interpreted as supporting their theory (experiment 1 and 2 in Yamada et al., 2013). In repudiating the experimental methodology used to test categorization-based stranger avoidance theory, they must accept that the theory is no longer supported. Thus, the commentators should propose another way to test their theory’s predictions, assuming their theory is falsifiable.

## 2. Experiment

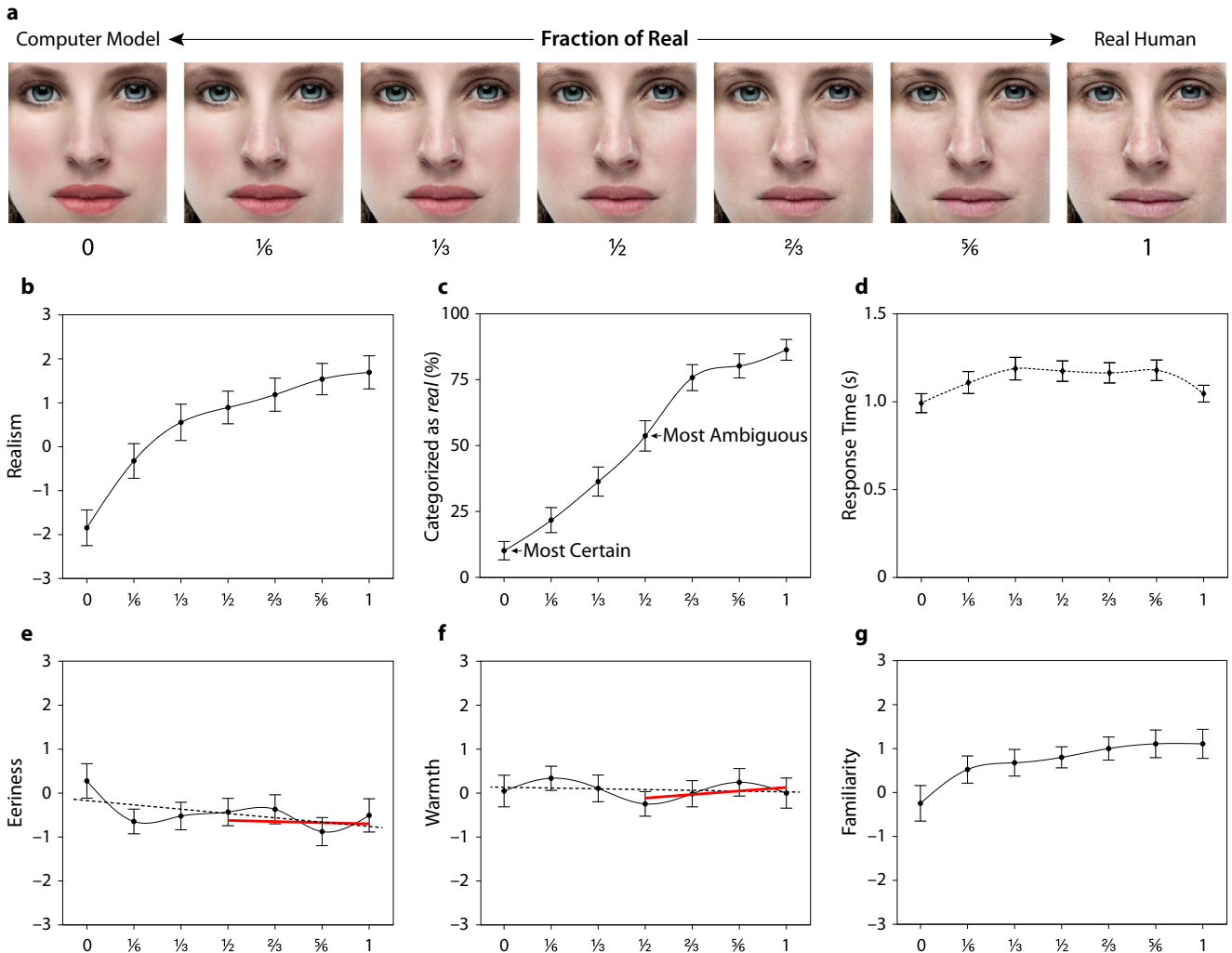
The commentators’ theory would predict that an improbable appearance elicits the uncanny valley effect (hypothesis 1) and the effect disappears as the appearance becomes more probable (hypothesis 2). They identified this trend along the control transition in our original experiment, with eeriness decreasing along the transition from 3D computer model (0% real) to photograph (100% real). However, we assume this trend was caused by inconsistency in the realism of the features of the 3D computer models. This is because some features were harder to model and, therefore, appeared less realistic than others. To address the issue of inconsis-

tent feature realism, we created a more realistic 3D computer model for this experiment.

To test the above hypotheses, we recruited 74 undergraduate and graduate students (37% female) from a Midwestern university ( $M_{age} = 23.8, SD = 5.1$ ) in September 2016 and conducted a within-group experiment following our prior methodology (Sections 2.4–2.6 of MacDorman & Chattopadhyay, 2016), though starting with image ratings, followed by a demographics questionnaire, and finishing with the categorization task. Each participant rated and categorized seven images of a woman varying by sixths from 0% real (3D computer model) to 100% real (photograph) as either *computer animated* or *real* (Fig. 1a).

Each image was categorized four times—twice in the first block and twice in the second—with presentation order randomized in each block. Each block started with two unrelated warm-up images and included 20 other images. “Categorize the face below as quickly and as accurately as you can” appeared above the image. The anchors *computer animated* and *real* appeared on opposite sides of the image and were left–right counterbalanced between blocks. “Press e” appeared below the left anchor and “Press i” below the right.

The independent variable (IV) was the woman’s fraction of real in the image (0,  $\frac{1}{6}$ ,  $\frac{1}{3}$ ,  $\frac{1}{2}$ ,  $\frac{2}{3}$ ,  $\frac{5}{6}$ , 1). All changes to the IV were of equal size. Dependent variables for each image were percentage categorized as *real*, response time, and ratings on the 7-point



**Fig. 1.** Stimuli ratings of subjective realism, eeriness, warmth, and familiarity are plotted against their fraction of real as are percentage categorized as *real* and response time. For eeriness and warmth, the regression line for 1/2–100% real is solid and for 0–100% real is dashed. Error bars indicate the 95% confidence interval.

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