The Tipping Point of Animacy: How, When, and Where We Perceive Life in a Face

Christine E. Looser and Thalia Wheatley
Dartmouth College

Abstract

Faces capture humans' attention; yet, beyond aesthetic appreciation, it is presumably not the face itself that interests people but the mind behind it. Minds think, feel, and act in ways that have direct consequences for well-being, but despite their importance, how minds are perceived in faces is not well understood. We investigated this mechanism by presenting participants with morphed images created from animate (human) and inanimate (mannequin) faces. Life and mind were perceived to "appear" at a consistent location on the morph continuum, close to the human endpoint. This location constituted a categorical boundary, as evidenced by increased sensitivity to differences in image pairs that straddled this tipping point. Additionally, the impression of life was gleaned from the eyes more than from other facial features. These results suggest that human beings are highly attuned to specific facial cues, carried largely in the eyes, that gate the categorical perception of life.

Given the choice, it is generally wiser to pay closer attention to a bear than to a rock. Indeed, psychological science has shown that biological stimuli, such as faces, capture attention faster than inanimate objects (Langton, Law, Burton, & Schweinberger, 2008; Ro, Russell, & Lavie, 2001; Theeuwes & Van der Stigchel, 2006), and this attentional capture is relatively indiscriminate—even a schematic face elicits this effect (Sagiv & Bentin, 2001; Tomalski, Csibra, & Johnson, 2009). However, the rapid, indiscriminate nature of face detection is only one aspect of human face processing. At some point, people must separate the false alarms from the hits, reserving social-cognitive resources for the faces that have minds "attached." This latter process might best be described as mind perception (Gray, Gray, & Wegner, 2007), and it is this process, rather than animate-form detection, that seems to be impaired in autistic spectrum disorder (New et al., 2010). In contrast to face detection, mind perception appears to be anything but indiscriminate.

Even as graphic representations of faces have become increasingly lifelike, they have failed to fool observers into thinking they are alive. The clearest examples of this come from recent computer-generated imagery (CGI) attempts. Millions of dollars were spent to make the characters for the movies *Polar Express* and *Beowulf* as lifelike as possible (Breznican, 2007) so as to make audiences forget they were watching characters created by computers rather than by DNA. The result? The CG characters were panned as "digital waxworks" (Chang, 2007, para. 1) and "lacking in humanity" (C. Smith,

2007, para. 8). As one *New York Times* journalist put it, "you see the cladding but not the soul" (Darghis, 2007, para. 6). It is clear that people are tough critics when it comes to animacy.

How tough are people? Where is the tipping point between appearing lifelike and appearing alive? Is this distinction gradual or rigidly categorical? What perceptual information is most important in determining animacy?

In order to answer these questions, we used morphing software to create an artificial visual continuum between pictures of mannequins at one extreme and well-matched pictures of real people at the other. Using these morphs, our research revealed that the tipping point is consistently close to the human end of the continuum, that it defines a firm categorical boundary, and that the appearance of the eyes is disproportionately informative in conveying whether something is alive.

Experiment 1: The Tipping Point at Which Life Appears in a Face

Method

Participants. Sixty students from Dartmouth College participated in Experiment 1a; 29 of those participants returned for

Corresponding Author:
Thalia Wheatley, Dartmouth College, Psychological and Brain Sciences, 6207 Moore Hall, Hanover, NH 03755
E-mail: wheatley@dartmouth.edu

Experiment 1b. An additional 46 participants who did not participate in Experiments 1a or 1b were recruited for Experiment 1c.

Stimuli: animacy morphs. Twenty inanimate faces (e.g., statues, dolls) were morphed with well-matched photographs of human faces using FantaMorph software (Version 3; Abrosoft Co., Beijing, China). The resulting image sets were the product of linear interpolation between the two original images, which kept the increments of physical change consistent across the morphing continuum (see Fig. 1).

Experiment 1a. Participants evaluated faces for two attributes: animacy and pleasantness. Each attribute was evaluated in a separate block that consisted of two sets of judgments. The order of the animacy and pleasantness blocks was counterbalanced across participants.

In the animacy block, participants first rated 220 images that were presented in a randomized order. These images were taken from 11 equidistant points within each of the 20 morph continua. Participants rated each image on a 7-point Likert scale (from 1, *definitely alive*, to 7, *definitely not alive*). Images appeared on a black background and remained on the screen until the participant responded. After completing this set of Likert ratings, participants scrolled freely through each morph continuum in 2% increments (50 images per morph) to determine the *animacy boundary*. As the animacy boundary would necessarily fall between two images, participants were instructed to pick the image "next to the boundary on the animate side." This constituted the *just-noticeable-animacy* (*JNA*) *image*. The direction of scrolling (e.g., from inanimate to animate or from animate to inanimate) alternated between trials, and which direction came first was counterbalanced across participants for each morph.

In the pleasantness block, the procedure was identical to the animacy block except for the attribute being evaluated. First, participants rated each image on a scale from 1, *very unpleasant*, to 7, *very pleasant*. Next, participants scrolled freely through each morph continuum in 2% increments (50 images per morph) to determine the most unpleasant image.

Experiment 1b: mind ratings. In order to test whether perceptions of animacy are coupled with perceptions of mind, we asked participants to return 2 months later to repeat the same procedure as in Experiment 1a but with three different judgments: whether the face "is able to formulate a plan" (*plan*), "is able to feel pain" (*pain*), and "has a mind" (*mind*; Gray et al., 2007). These participants viewed the same 220 images used in the animacy-ratings task (Experiment 1a). Each of the three judgments was made as a block for all 220 images. The mind ratings were performed last in order to avoid the possibility that this explicit judgment would serve as a heuristic for the other two ratings. The order of plan and pain judgments was counterbalanced across participants.

Experiment 1c: realism ratings. Experiment 1c investigated whether the animacy ratings and mind ratings of the morphed images were influenced by the realism of the doll faces used as the inanimate endpoints. Forty-six new participants rated how well the 20 inanimate faces approximated human form, on a scale from 1, *very unrealistic*, to 7, *very realistic*.
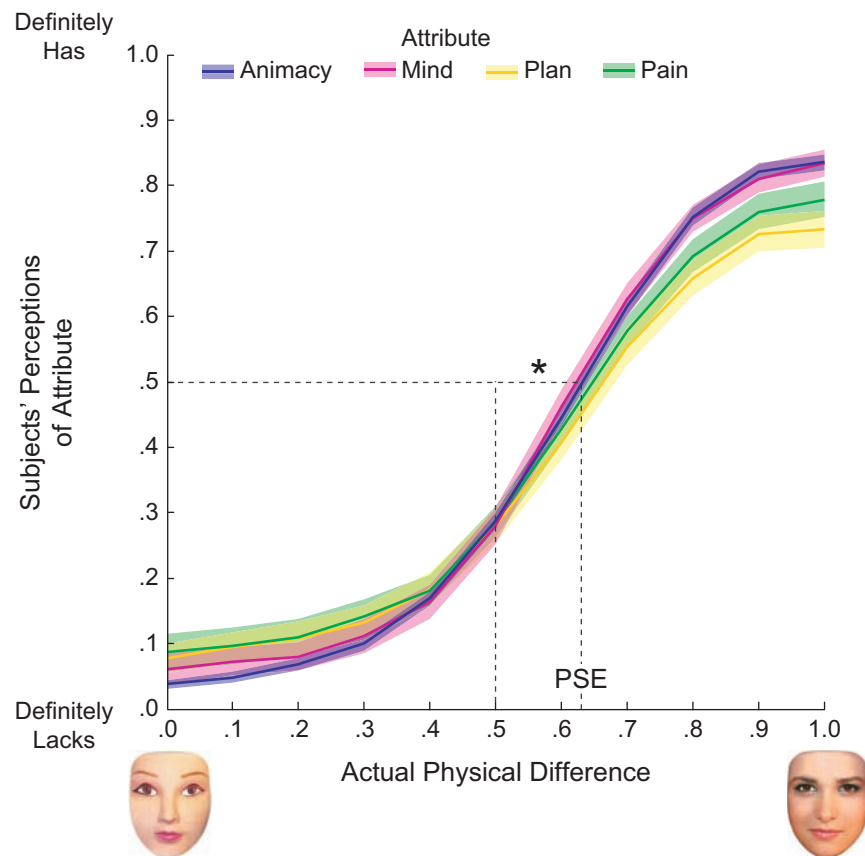
Results

Animacy ratings (Experiment 1a). Animacy ratings were linearly transformed to a scale from 0 to 1 (0 = inanimate, 1 = animate). Collapsing across morphs, we fit each participants' animacy data with a cumulative normal function in order to calculate the point of subjective equality (PSE)—the point at which a face was equally likely to be deemed animate or inanimate. If the perception of animacy tracked linearly with the percentage of the original animate face in the image, the PSE would be the image at the center of the morph continuum. However, the PSE for animacy was significantly shifted from the 50-50 image, $t(59) = 15.33$, $p < .001$, being significantly closer to the animate endpoint ($M = .64$, $SD = .07$; see Fig. 2).

JNA judgments (Experiment 1a). For each of the 20 morphs, a mean JNA judgment was computed by averaging across participants. The average of these mean JNA judgments was .67 ($SD = .07$). That is, the average JNA image was a face that was 67% animate and 33% inanimate. The proximity of the JNA point (67%) to the PSE (64%) indicates that the animacy boundary is robust to sampling resolution. That is, regardless of whether participants judged animacy at 2% increments

Fig. 1. Example of morphed stimuli used in the experiments.

Fig. 2. Experiment 1 results: participants' perception of animate attributes. The colored lines indicate the average rating for each attribute (animacy, having a mind, ability to plan, and ability to feel pain) at each point along the morph continuum. The lighter-colored region around each line corresponds to 1 *SEM*. The asterisk indicates the significant difference between the average point of subjective equality (PSE) and the center of the morph (*p* < .001).

(JNA) or 10% increments (PSE), perceptions of animacy first occurred around the same point along the morph continuum.

Pleasantness ratings (Experiment 1a). Participants' pleasantness ratings fit a linear, rather than a sigmoidal, function (r^2 = .96, *SD* = .04); pleasantness increased linearly with animacy. The image with the highest mean pleasantness rating was the image that was 90% human and 10% doll (*M* = 3.88, *SD* = 0.85). The image with the lowest mean pleasantness rating was the 100%-doll image (*M* = 2.14, *SD* = 1.09). This finding suggests that increased pleasantness may be informative for animacy judgments. However, the linear rather than sigmoidal pattern of ratings when plotted across the morphed continuum suggests that pleasantness is not sufficient to predict a categorical judgment of animacy.

Mind ratings (Experiment 1b). Four of the 29 returning participants were excluded for not performing the rating task in Experiment 1b correctly. To ensure that the remaining 25 participants were representative of the original data set, we compared the animacy PSEs for the returning participants (PSE = .63, *SD* = .06) with those for the nonreturning participants

(PSE = .65, *SD* = .08). An independent-samples *t* test confirmed that the original animacy ratings of these groups were not significantly different, *t*(58) = 1.24, *p* = .219.

Participants' ratings of whether a face could formulate a plan, could feel pain, and had a mind were strongly correlated with their earlier ratings of animacy (*r*s = .958, .953, and .922, respectively). Correspondingly, a one-way repeated measures analysis of variance (ANOVA) revealed no significant difference between the PSEs of animacy and these three judgments, *F*(2.17, 54.36) = 2.12, *p* = .13 (Greenhouse-Geisser corrected). Results were consistent with mind being a correlate of animacy, as all ratings were highly correlated and the PSEs for all judgments of mind were significantly shifted from the center of the morph toward the animate endpoint, all *t*s(24) > 7.84, all *p*s < .001 (see Fig. 2).

Realism ratings (Experiment 1c). Realism ratings for each inanimate-endpoint image were averaged across subjects and correlated with the mean JNA judgments for each morph. This analysis revealed a strong negative correlation: The animacy boundary shifted closer to the animate endpoint (human photograph) as the inanimate endpoint (doll photograph) appeared less realistic (*r* = –.6, *p* = .005).

Discussion

The results of Experiments 1a and 1b suggest that the region of the morph continuum in which participants attribute life and mind to a face is narrow and close to the human endpoint. Additionally, Experiment 1c revealed that the location of the animacy boundary is influenced by the realism of the inanimate image. Morphed images created with unrealistic inanimate images required a greater percentage of the original human image in order to be considered animate compared with morphed images created with realistic inanimate images. This suggests that people base animacy judgments of a face, at least in part, on how closely the structural proportions of the face fit a human prototype. Finally, the finding that the JNA and PSE points shared a close, physical proximity along the morph continuum suggests that people are highly tuned to the region of perceptual face space (Lee, Byatt, & Rhodes, 2000) that determines animacy. The narrow margin of animacy, together with the sigmoidal nature of the cumulative normal fits, suggests that the physical information within this particular region of the morph continuum provides the basis for the categorical judgment of life. Experiment 2 investigated this hypothesis.

Experiment 2: Categorical Perception

Method

Participants. Twenty-five participants who did not participate in Experiment 1 were recruited for Experiment 2.

Same/different task. Participants performed a same/different perceptual discrimination task in which they judged whether two paired images were identical or different. These pairs of images were taken from discrete locations along each of the morphed continua used in Experiment 1. Pairs were created from eight different images per morph continuum: 0%, 18%, 82%, and 100% human, as well as 9% above and below both the PSE and the PSE "mirror." Because the PSE images necessarily contained more visual distortion than either the animate or the inanimate endpoints, a PSE mirror point was calculated by subtracting the PSE from 100% for each morph. This resulted in an image with distortion equivalent to that of the PSE but an inverse animacy ratio.

Each pair included two images from the same continuum. The two images were either identical (*same* pairs) or different (*different* pairs). The *different* pairs included the following combinations: 0% and 18% (*inanimate pair*), 82% and 100% (*animate pair*), 9% above and 9% below the PSE (*animacy-boundary pair*), and 9% above and 9% below the PSE mirror (*mirror-boundary pair*). Each of the *different* pairs was repeated twice, counterbalanced for order of presentation, resulting in eight *different* trials per morph. The *same* pairs were identical images (the ones used to make up the *different* pairs) and were presented once, resulting in eight *same* trials per morph. All 20 morphs were used, for a total of 320 trials.

A trial consisted of the two images from a pair being presented for 500 ms each, separated by a 250-ms interstimulus interval. A phase-scrambled image was presented during the interstimulus interval, to avoid apparent motion between images. For *same* pairs, the phase-scrambled image was created from the image used in that pair. For *different* pairs, the phase-scrambled image was created from the midpoint between the images in that pair. After each trial, a response screen prompted participants to report whether the two faces were the same or different.
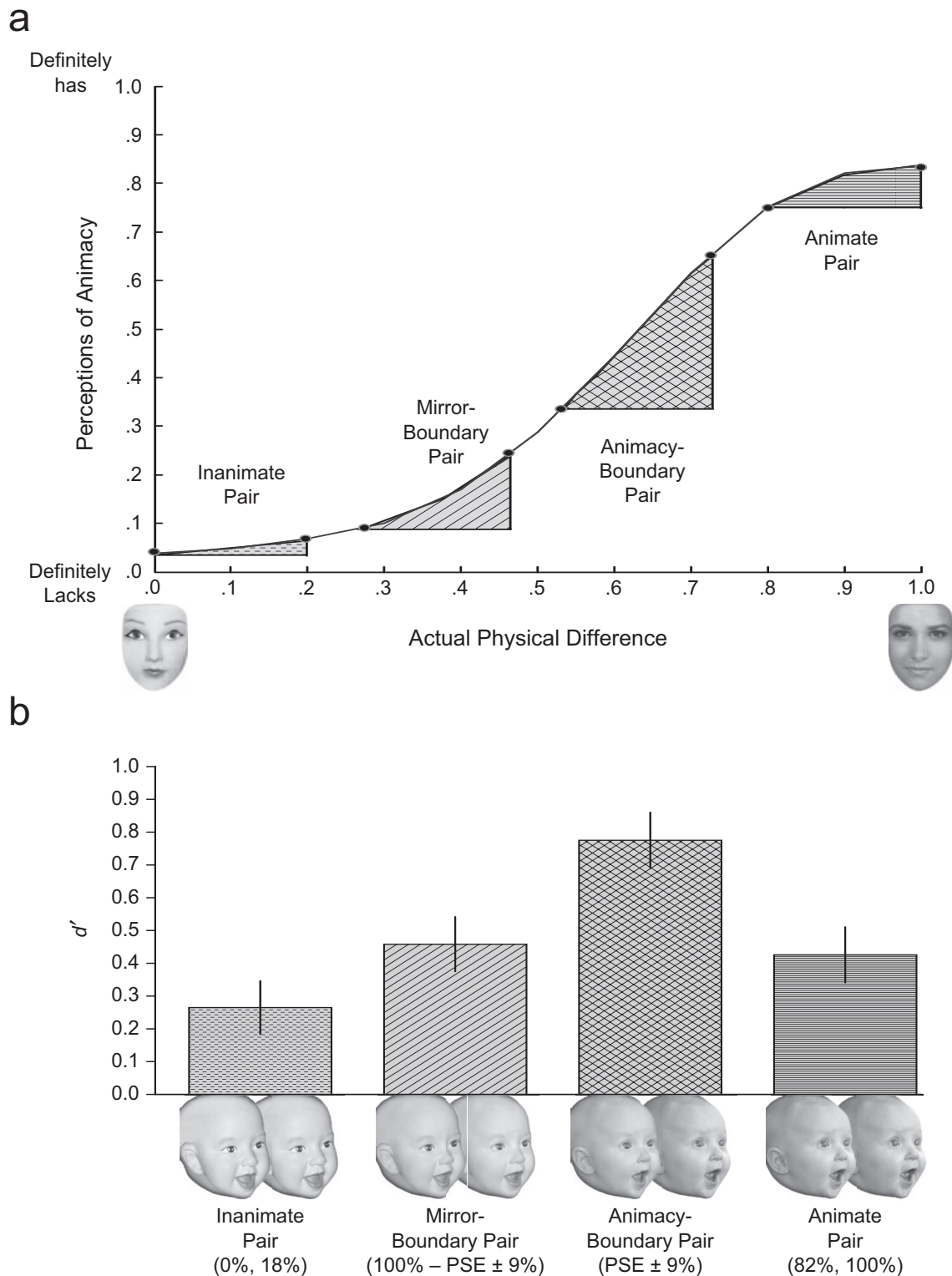
Results

Discrimination sensitivity (d') was calculated in order to determine accuracy on the same/different task while accounting for any potential response bias (β). To determine if sensitivity and bias differed across the four regions of the morph continua, we calculated d' and β for each participant at each location. These data were then submitted to a one-way repeated measures ANOVA with location as the within-participants factor.

Sensitivity to change. A repeated measures ANOVA revealed a significant difference in sensitivity across location, Wilks's $\lambda = .436$, $F(3, 22) = 9.49$, $p < .001$, $\eta_p^2 = .564$. Sensitivity to the animacy-boundary pair ($d' = 0.78$, $SD = 0.43$) was significantly greater than sensitivity to the animate pair ($d' = 0.43$, $SD = 0.42$), $t(24) = 3.57$, $p = .002$; the mirror-boundary pair ($d' = 0.46$, $SD = 0.42$), $t(24) = 4.17$, $p < .001$; and the inanimate pair ($d' = 0.27$, $SD = 0.41$), $t(24) = 5.44$, $p < .001$ (see Fig. 3).

Response bias (β). Response bias also differed across pair types, Wilks's $\lambda = .343$, $F(3, 22) = 14.04$, $p < .001$, $\eta_p^2 = .657$. The response bias was significantly lower for the inanimate pair ($\beta = -0.94$, $SD = 0.58$) than for all other pairs. Thus, participants had a greater tendency to respond "same" to doll faces than to respond "same" to animate pairs ($\beta = -0.57$, $SD = 0.46$), animacy-boundary pairs ($\beta = -0.58$, $SD = 0.49$), and mirror-boundary pairs ($\beta = -0.66$, $SD = 0.48$). Post hoc comparisons revealed that response bias did not differ across the latter three types of pairs (animacy-boundary, mirror-boundary, animate; all ps >.11).

Discussion

The finding that perceptual sensitivity was heightened for pairs straddling the PSE suggests these pairs contain psychological information that is not available for images from other regions of the continua, and this information creates a categorical shift between images. That is, images in *different* pairs that straddled the PSE not only were physically different but also appeared to belong to two separate, psychological categories (animate vs. inanimate). Subjects responded "same" more frequently to the inanimate faces than to all other pairs, regardless of the correct answer, which suggests that additional attention is allotted to stimuli that look more

a

b

Fig. 3. Experiment 2: stimuli and results. The graph in (a) shows the continuum location of the images in each of the four types of *different* pairs (inanimate, mirror boundary, animacy boundary, and animate). Shaded areas under the curve indicate the relative perceptual dissimilarity between images for each pair type. The graph in (b) shows sensitivity (*d'*) as a function of pair type. The numbers in parentheses are the percentages of the human image for the two images in the pair. Error bars represent 1 *SE*. PSE = point of subjective equality.

animate. However, calculations of sensitivity are not contaminated by response bias (Green & Swets, 1966); therefore, the difference in response strategy cannot account for the observed sensitivity across the animacy boundary.

Together, the first two experiments suggest that there is an animacy tipping point around which subtle, perceptual differences determine whether or not a face is perceived as alive. The use of whole-face stimuli precluded any conclusions about where information about animacy is carried in a face. Is animacy disproportionately carried in a person's skin tone, in a person's eyes, or in some other specific feature? Experiment 3 investigated the relative contribution of facial features to the perception of animacy.

Experiment 3: Where Life Appears in a Face
Method

Participants. Twenty-seven students who had not participated in Experiments 1 or 2 were recruited for Experiment 3.

Stimuli and procedure. The same 220 images described earlier were used. Each image was cropped elliptically four times, each time to reveal only one of the four features of interest: eye, mouth, nose, and skin. Because the morphs differed in the size and location of their features, a different cropping ellipse was used for each morph, and so the number of revealed pixels varied across morphs (mean = 10,663.7 pixels, SD = 3,604.1). However, the number was kept constant for all of the images and features within a morph. The largest feature (in all cases, the mouth) determined the size of the cropping ellipse for each morph. Participants rated the animacy of the cropped stimuli as well as the intact faces using the rating procedure described for Experiment 1. The order of stimuli was randomized for each participant.

Results

Each feature was analyzed separately using the analysis procedure from Experiment 1. As in that experiment, the cumulative normal function was found to be a good fit for the whole-face stimuli (r^2 = .98, SD = .02), and the PSE (mean PSE = .69, SD = .09) was significantly shifted from the midpoint of the morph, $t(26)$ = 40.16, $p < .001$.

As shown in Figure 4, participants' ability to judge animacy depended on the feature presented. The two features for which ratings were best fit by a cumulative normal function were the eye and mouth (both r^2s = .93); ratings for the nose (r^2 = .78)
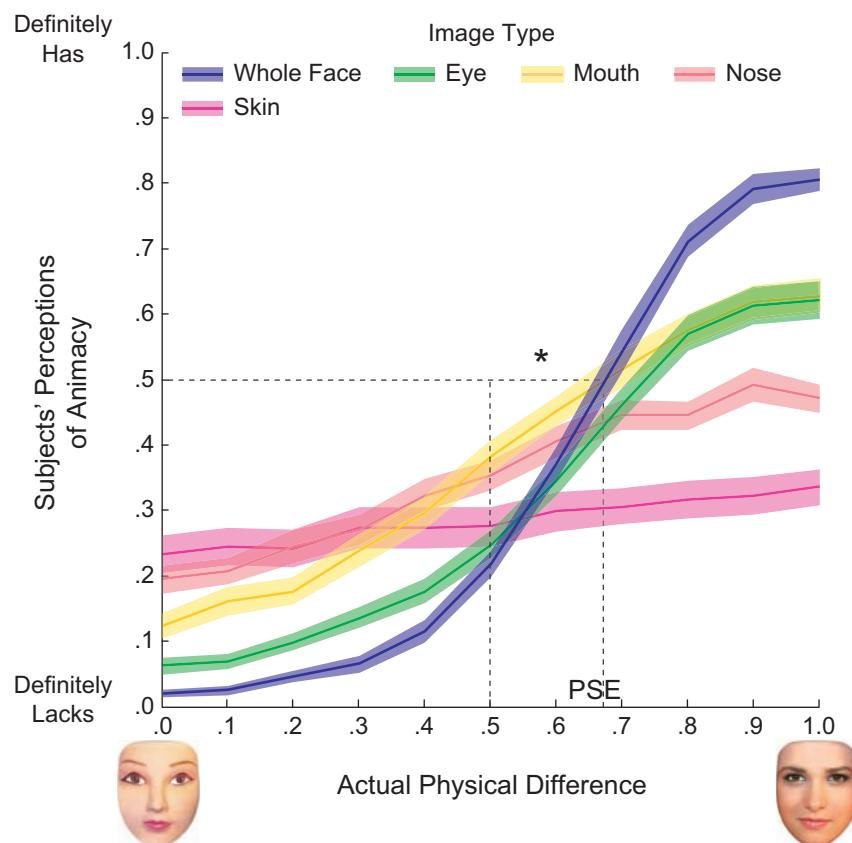
Fig. 4. Experiment 3 results: feature-dependent perceptions of animacy. The colored lines indicate the average animacy rating for each image type (whole face, eye, mouth, nose, and skin) as a function of position along the morph continuum. The lighter-colored region around each line corresponds to 1 *SEM*. The asterisk indicates the significant difference between the average whole-face point of subjective equality (PSE) and the center of the morph ($p < .001$).

and skin (r^2 = .46) fit to lesser degrees. Additionally, the animacy ratings of all features were correlated with animacy ratings of the whole face. The correlation was highest for the eye (r = .87), followed by the mouth (r = .81), nose (r = .60), and skin (r = .37). Although some features were more strongly correlated with whole-face ratings than other features, all correlations were significant (all ps < .001).

We used a stepwise regression analysis to examine how well each feature predicted animacy ratings of the whole face. This analysis revealed that the eye was particularly informative, accounting for 75.3% of the variance in whole-face animacy ratings, $F(1, 218)$ = 664.59, b = 1.14. Ratings of the mouth accounted for an additional 5.2% of the variance, $F(2, 217)$ = 447.04, b = 0.49, whereas the nose and skin did not account for a significant portion of the variance in whole-face ratings.

Unexpectedly, no isolated feature exceeded an animacy rating of 68%. That is, even when the feature was extracted from a 100%-human image, participants did not use the upper portion of the animacy scale. Participants were least likely to judge skin and a nose as alive, with neither feature exceeding a 50% perception of animacy. Indeed, a repeated measures ANOVA on the ratings of the animate endpoints (i.e., unmorphed human photographs) revealed a significant effect of image type, Wilks's λ = .945, $F(4, 23)$ = 99.36, p < .001, η_p^2 = .945. Subsequent t tests revealed that this effect emerged because whole-face images were rated as significantly more animate than any single feature, all ts(19) > 7.68, all ps < .001.

Discussion

Although animacy is carried disproportionately in the eyes, participants were reluctant to judge any isolated feature as having originated from a living face. It is possible that a combination of single features would result in ratings equivalent to those obtained for whole-face stimuli. Alternatively, a full perception of animacy may depend on the Gestalt of a face (Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987).

Conclusions

It is well established that people are highly attuned to faces and the meanings evoked by a vast array of facial configurations (e.g., Dimberg, Thunberg, & Elmehed, 2000; Ekman & Oster, 1979; Haxby, Hoffman, & Gobbini, 2002; M.L. Smith, Cottrell, Gosselin, & Schyns, 2005; Todorov, Mandisodza, Goren, & Hall, 2005). The experiments presented here suggest that this hyperacuity in perceiving meaning in subtle facial cues extends to the perceptual inference of animacy. It may be evolutionarily advantageous to overimpute animacy (better to have a false alarm regarding a rock than to miss a predator), and, accordingly, people have a strong proclivity to perceive faces in everyday objects (Guthrie, 1993). Yet, although face detection is rapid and indiscriminate, our results imply that mind perception is anything but indiscriminate.

This high bar may be one reason why realistic simulations of faces (e.g., humanoid robots, wax mannequins) are often met with a lukewarm reception, if not an aversive sensation described as the "uncanny valley" (Mori, 1970/2005). The theory of the uncanny valley posits that people experience a pleasurable sense of familiarity when objects possess lifelike features. For example, a pet rock with eyes is "cuter" than a plain rock. This pleasure increases as the features become more and more lifelike until the human likeness becomes too close, or the object becomes uncanny. At this point, pleasure is replaced by revulsion and eeriness. Though pleasantness did not decrease around the animacy category boundary, a number of participants anecdotally reported that they found some of the morphed images creepy or unsettling. Although these experiments were not designed to directly test these reactions, the morphing of animate and inanimate faces may provide a useful method for systematically probing whether the uncanny valley exists.

The present experiments suggest a few reasons why people are hypercritical of these human-form approximations. First, people appear to be highly sensitive to bottom-up, visual cues to animacy. In Experiment 1, the point of subjective equality was significantly shifted toward the human side of the morph. That is, a simulation must be highly realistic even to achieve 50:50 odds of being considered alive. Although depicting a face may be as easy as drawing two dots for eyes and a line for a nose (Goren, Sarty, & Wu, 1975), depicting life in a face is much more challenging. Whether this perceptual sensitivity for animacy extends to other living things (e.g., animals, insects, plants) remains a question for future research.

Second, unless the tipping point is reached, close and clumsy approximations are deemed equally inanimate. A wax mannequin may look more realistic than a drugstore doll, but realism is continuous; life is not. Instead, judgments of life and mind show categorical-perception effects. Categorical perception allows people to parse a monotonically changing continuum into discrete units, perceptually compressing differences on either side of a category boundary while amplifying differences across it. For example, in a rainbow, people perceive distinct colors that appear to abruptly shift, despite the fact that all wavelengths are continuously represented (Bornstein & Korda, 1984). Categorical-perception effects have been found for a number of facial attributes, including identity (Beale & Keil, 1995), emotion (Etcoff & Magee, 1992), race (Levin & Beale, 2000), and gender (Campanella, Chrysochoos, & Bruyer, 2001). In the research reported here, we extended this phenomenon to the perception of life.

Third, our results suggest that the eyes are disproportionately informative for decisions regarding animacy. This finding is consistent with work by Baron-Cohen and other researchers, who have demonstrated that a vast array of emotions and intentions can be communicated by subtle differences in the musculature in and around the eyes (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Emery, 2000; Langton, Watt, & Bruce, 2000). Much of this communication may be processed unconsciously (Williams, Morris, McGlone, Abbott,

& Mattingley, 2004); for example, participants who rated the attractiveness of photographed faces were unaware that their ratings correlated with the faces' pupil size, a physiological correlate of arousal (Demos, Kelley, Davis, Ryan, & Whalen, 2008). Eyes convey a wealth of information, from attention to emotion and intent; therefore, it is no wonder that eyes have been the Achilles heel of CGI, with recent renderings of eyes described as "unnervingly without soul" (C. Smith, 2007, para. 6). Although eyes were the most informative single feature in our study, participants were reluctant to rate any isolated feature as "definitely alive." This may suggest that animacy judgments rely, at least in part, on the holistic processing of a whole face (Tanaka & Farah, 1993; Young et al., 1987). Face-inversion paradigms may be particularly helpful in elucidating the role of holistic processing in these judgments.

Since at least the 1940s, perceptions of animacy have been well investigated in a different perceptual domain: biological motion. That work has powerfully demonstrated that cues such as self-propulsion and interactivity evoke the perception of animacy and a host of social inferences (Blakemore et al., 2003; Castelli, Frith, Happé, & Frith, 2002; Heberlein & Adolphs, 2004; Heider & Simmel, 1944; Martin & Weisberg, 2003; Scholl & Tremoulet, 2000; Wheatley, Milleville, & Martin, 2007). It is our hope that future research on face perception will similarly pin down the visual cues within faces that are critical for determining whether a face is animate and thus worthy of social inference.

Faces enjoy privileged processing for good reason. As its root word suggests, the human face is a facade—one controlled by a mind. Human survival depends on identifying beings with minds, and often mental states are telegraphed in the kinetics of facial and eye muscles: the upturned lips of amusement, the glower of anger. However, decoding these cues in terms of thoughts and feelings makes sense only in the context of a mind. A doll may look angry, but people know that the doll is not actually angry, and they do not waste time wondering what it will do next. Linking facial cues to the meaningful attributions that sustain social interactions and predict behavior requires more than detecting faces and recognizing their expressions. It requires perceiving animacy: understanding that the observable face is attached to an unobservable mind.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

References

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" Test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry*, *42*, 241–252.

Beale, J.M., & Keil, F.C. (1995). Categorical effects in the perception of faces. *Cognition*, *57*, 217–239.

Blakemore, S.-J., Boyer, P., Pachot-Clouard, M., Meltzoff, A., Segebarth, C., & Decety, J. (2003). The detection of contingency and animacy from simple animations in the human brain. *Cerebral Cortex*, *13*, 837–844.

Bornstein, M.H., & Korda, N.O. (1984). Discrimination and matching within and between hues measured by reaction times: Some implications for categorical perception and levels of information processing. *Psychological Research*, *46*, 207–222.

Breznican, A. (2007). Old 'Beowulf' takes digital filmmaking to new heights. *USA Today*. Retrieved September 23, 2010, from http://www.usatoday.com/life/movies/news/2007-11-08-beowulf-technology_N.htm

Campanella, S., Chrysochoos, A., & Bruyer, R. (2001). Categorical perception of facial gender information: Behavioural evidence and the face-space metaphor. *Visual Cognition*, *8*, 237–262.

Castelli, F., Frith, C., Happé, F., & Frith, U. (2002). Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*, *125*, 1839–1849.

Chang, J. (2007). Beowulf [Review of the motion picture Beowulf]. *Variety*. Retrieved September 23, 2010, from http://www.variety.com/review/VE1117935372.html?categoryid=31&cs=1

Darghis, M. (2007, November 16). Confronting the fabled monster, not to mention his naked mom [Review of the motion picture *Beowulf*]. *New York Times*. Retrieved September 23, 2010, from http://movies.nytimes.com/2007/11/16/movies/16beow.html

Demos, K.E., Kelley, W.M., Davis, F.C., Ryan, S.L., & Whalen, P.J. (2008). Human amygdala sensitivity to the pupil size of others. *Cerebral Cortex*, *18*, 2729–2734.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, *11*, 86–89.

Ekman, P., & Oster, H. (1979). Facial expressions of emotion. *Annual Review of Psychology*, *20*, 527–554.

Emery, N.J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience and Biobehavioral Reviews*, *24*, 581–604.

Etcoff, N.L., & Magee, J.J. (1992). Categorical perception of facial expressions. *Cognition*, *44*, 227–240.

Goren, C.C., Sarty, M., & Wu, P.Y.K. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, *56*, 544–549.

Gray, H., Gray, K., & Wegner, D.M. (2007). Dimensions of mind perception. *Science*, *315*, 619.

Green, D.M., & Swets, J.A. (1966). *Signal detection theory and psychophysics*. New York, NY: John Wiley and Sons.

Guthrie, S.E. (1993). *Faces in the clouds*. New York, NY: Oxford University Press.

Haxby, J.V., Hoffman, E.A., & Gobbini, M.I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, *51*, 59–67.

Heberlein, A.S., & Adolphs, R. (2004). Impaired spontaneous anthropomorphizing despite intact perception and social knowledge. *Proceedings of the National Academy of Sciences, USA*, *101*, 7487–7491.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, *57*, 243–259.

Langton, S.R.H., Law, A.S., Burton, A.M., & Schweinberger, S.R. (2008). Attention capture by faces. *Cognition*, *107*, 330–342.

Langton, S.R.H., Watt, R.J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences*, *4*, 50–59.

Lee, K.J., Byatt, G., & Rhodes, G. (2000). Caricature effects, distinctiveness, and identification: Testing the face-space framework. *Psychological Science*, *11*, 379–385.

Levin, D.T., & Beale, J.M. (2000). Categorical perception occurs in newly learned faces, other-race faces, and inverted faces. *Perception & Psychophysics*, *62*, 386–401.

Martin, A., & Weisberg, J. (2003). Neural foundations for understanding social and mechanical concepts. *Cognitive Neuropsychology*, *20*, 575–587.

Mori, M. (2005). The uncanny valley (K.F. MacDorman & T. Minato, Trans.). Retrieved September 29, 2010, from http://www.android science.com/theuncannyvalley/proceedings2005/uncannyvalley .html. (Original work published 1970)

New, J.J., Schultz, R.T., Wolf, J., Niehaus, J.L., Klin, A., German, T.C., & Scholl, B.J. (2010). The scope of social attention deficits in autism: Prioritized orienting to people and animals in static natural scenes. *Neuropsychologia*, *48*, 51–59.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science*, *12*, 94–99.

Sagiv, N., & Bentin, S. (2001). Structural encoding of human and schematic faces: Holistic and part-based processes. *Journal of Cognitive Neuroscience*, *13*, 937–951.

Scholl, B.J., & Tremoulet, P.D. (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences*, *4*, 299–309.

Smith, C. (2007, December 16). Beowulf [Review of the motion picture *Beowulf*]. *Week in Rewind*. Retrieved September 23, 2010, from http://www.weekinrewind.com/2007/12/beowulf-movie-review-2007.html

Smith, M.L., Cottrell, G.W., Gosselin, F., & Schyns, P.G. (2005). Transmitting and decoding facial expressions. *Psychological Science*, *16*, 184–189.

Tanaka, J.W., & Farah, M.J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology: Section A*, *46*, 225–245.

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition*, *13*, 657–665.

Todorov, A., Mandisodza, A.N., Goren, A., & Hall, C.C. (2005). Inferences of competence from faces predict election outcomes. *Science*, *308*, 1623–1626.

Tomalski, P., Csibra, G., & Johnson, M.H. (2009). Rapid orienting toward face-like stimuli with gaze-relevant contrast information. *Perception*, *38*, 569–578.

Wheatley, T., Milleville, S.C., & Martin, A. (2007). Understanding animate agents: Distinct roles for the social network and mirror system. *Psychological Science*, *18*, 469–474.

Williams, M.A., Morris, A.P., McGlone, F., Abbott, D.F., & Mattingley, J.B. (2004). Amygdala responses to fearful and happy facial expressions under conditions of binocular suppression. *The Journal of Neuroscience*, *24*, 2898–2904.

Young, A.W., Hellawell, D., & Hay, D.C. (1987). Configurational information in face perception. *Perception*, *16*, 747–759.