Face animacy is not all in the eyes: Evidence from contrast chimeras

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Abstract. Observers are capable of distinguishing real faces from artificial faces of various types (eg dolls, computer-generated faces) relatively easily. While a number of diagnostic cues are potentially available to observers to accomplish this task, the appearance of the eyes has been shown to be critically important. However, eye appearance appears to interact with other cues, like the appearance of the skin, in some settings. The ‘uncanny’ appearance of some artificial faces appears to result from multiple visual features and their departure from typical face norms, for example, and recent results investigating how real and artificial features are perceived in chimeric faces also suggest that observers use multiple cues to measure face animacy. Presently, we examined the cues that support real–artificial face discrimination by using contrast negation and so-called ‘contrast chimeras’ to selectively disrupt the appearance of the eyes and the remainder of the face pattern. First, we demonstrate that, like other aspects of face perception, perceived animacy is significantly impacted by contrast negation. Second, by selectively manipulating the contrast of the eyes relative to the rest of the face, we demonstrate that these face regions are of approximately equal use to observers for animacy discrimination.

Keywords: face perception, animacy, contrast negation

1 Introduction
Computer-generated (CG) faces have become frequent components of movies, video games, and other interactive experiences. Over the past decade, advances in computer graphics and motion capture technology have substantially improved the quality of CG faces and made it possible to accurately render the 3-D shape of human faces, nonrigid movements of the face, and the interaction of light with human skin (Krishnaswamy & Baronoski, 2004).

The perceived status of a face as real or artificial affects a range of perceptual, cognitive, and neural processes. The perceived animacy of a face determines the extent to which a mind, the ability to feel pain, or the ability to have intentions are attributed to a face (Gray & Wegner, 2012; Looser & Wheatley, 2010). The social categorization of faces is also impacted by the perceived ‘life’ in a face, and vice versa. Artificial faces tend to look more female, for example, and female faces also tend to be rated as looking more artificial (Balas, 2013). Membership in a social out-group, such as those defined by race, also interacts with perceived animacy such that out-group members are subject to a stricter criterion for being labeled as ‘real’ faces (Hackel, Looser, & Van Bavel, in press). Perceptually, animacy appears to be a basic dimension of facial appearance, as evidenced by high-level aftereffects following adaptation to real and artificial faces (Koldewyn, Hanus, & Balas, in press). Indeed, a range of neural markers exhibit sensitivity to real versus artificial appearance. The N170, though it is not significantly modulated by real versus artificial human facial appearance, is affected by artificial face appearance such that other category distinctions between faces (eg effects of species category) are not evident when artificial faces are used—real faces must be shown to participants for category effects to obtain (Balas & Koldewyn, 2013). Later event-related-potential components are directly sensitive to real versus artificial appearance, however, suggesting that processing animacy may be to some extent part of a second stage.
of face recognition (Wheatley, Weinberg, Looser, Moran, & Hajcak, 2011). Functional MRI data provide some preliminary support for this conclusion as well, since components of the extended face perception network (Haxby, Hoffman, & Gobbini, 2000) exhibit sensitivity to artificial face appearance, and multivoxel patterns obtained across the network distinguish between real and artificial faces (Looser, Guntupalli, & Wheatley, 2013). Biological motion patterns enacted by real actors also elicit a larger BOLD response in the superior temporal sulcus than matched motion patterns enacted by animated agents (Mar, Kelley, Heatherton, & Macrae, 2007), suggesting that real versus artificial appearance has broad effects on visual processing at multiple loci. Real versus artificial face appearance is thus not solely a problem domain of interest for graphics artists and animators. The human visual system is sensitive to the differences between real and artificial faces, and the distinctions drawn between faces based on perceived animacy have important sequelae at social, perceptual, and neural levels.

Given that labeling a face as real or artificial has a range of important consequences, how do typical observers distinguish between real and artificial faces? To date, there have been relatively few studies addressing the critical information observers use to assess the animacy or ‘life’ in a face, or to discriminate between real faces and artificial faces. Farid and Bravo (2012) demonstrated that observers are generally very accurate at making the distinction between real and artificial faces and that their ability to distinguish between these categories is largely robust to a range of image transformations. While labeling faces accurately as being real was substantially affected by image resolution, removing color information from images, turning images upside down, or subjecting images to JPEG compression had relatively modest impact on performance. To our knowledge, this is the only study to examine the discrimination of real faces from artificial faces that were matched closely for similarity, and the results reveal that animacy discrimination is a process that functions consistently even when several properties of typical face appearance are altered. We note, however, that the small but significant effect of face inversion in this study suggests that observers are potentially making use of some high-level mechanisms to accomplish animacy discrimination.

Other relevant data that speak to the issue of critical features for animacy discrimination come largely from studies designed to explore various aspects of the category boundary between real faces and artificial faces. For example, Looser and Wheatley (2010) demonstrated both that ratings of animacy are categorical across a continuum spanned by morphed images of real faces and doll faces and also that the ratings assigned to the eye region alone were the best predictor of the ratings assigned to the entire face. That is, subjective ratings of whether faces looked real or artificial were largely driven by how the eyes looked, and other regions of the face made little to no contribution. A similar study by Balas and Horski (2012), however, demonstrated via ‘eye transplants’ performed on real and artificial faces that the remaining face pattern does appear to make a significant contribution to the perceived animacy of a face, suggesting that the real versus artificial distinction may depend on a range of cues. Multiple studies examining the nature of the so-called ‘uncanny valley’, which refers to the sometimes grotesque appearance of some artificial faces (MacDorman, 2006; Mori, 1970), have also identified a range of cues that appear to determine whether or not an artificial face looks ‘uncanny’ or disturbing. The arrangement of facial features within a face, often referred to as the configural properties of the face, impact the perceived eeriness or uncanniness of faces (Green, MacDorman, Ho, & Vasudevan, 2008), and the size of the eyes appears to have a disproportionate effect on uncanny appearance (Seyama & Nagayama, 2009). However, the spacing and size of the eyes is not the sole determiner for whether or not an artificial face looks disturbing: the combination of large eyes and photorealistic texture leads to the most unsettling appearance, suggesting that skin texture and eye appearance
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interact (cf Balas & Horski, 2012) to determine the overall uncanniness of the face. Indeed, direct manipulation of the level of detail used to render the face and the textural properties of the skin confirm that these surface properties, along with eye appearance and configuration, influence how eerie artificial faces look (MacDorman, Green, Ho, & Koch, 2009).

The literature thus suggests to date that, in a range of tasks that may be useful proxies for animacy discrimination, eye appearance appears to make a substantial contribution to the perceived animacy of a face [and is a useful index of face processing for real and artificial faces (Seyama & Nagayama, 2009)], but many other facial features may also contribute to observers’ assessments of the properties of real and artificial faces, and their discrimination of real faces from artificial ones.

In the current study our goal was to determine the relative contributions of the eye region and the remaining face pattern to observers’ ability to distinguish between real faces and artificial faces in a true discrimination task. Compared with prior work, we used a proprietary model of 3-D facial appearance to create CG faces with the same identity as the real individuals depicted in photographs. This allowed us to present observers with identity-matched real and artificial face stimuli and also provide a uniform set of artificial face stimuli with appearance variability roughly the same as the original photographs of faces. In two experiments we presented observers with these faces in a two-alternative forced-choice real–artificial discrimination paradigm that required participants to identify which of two identity-matched faces was real. To examine the contribution of the eye region relative to the rest of the face, we used contrast negation as a tool to manipulate local and global face appearance in an attempt to disrupt animacy discrimination performance. Contrast negation has long been known to substantially impair face processing (Galper, 1970), but not the processing of other objects in general (Nederhouser, Yue, Mangini, & Biederman, 2007). Negation appears to impact the perception of surface properties of the face (e.g., pigmentation/albedo) in particular (Russell & Sinha, 2007; Russell, Sinha, Biederman, & Nederhouser, 2006). The contrast polarity of the eyes, however, is also known to play a critical role in face processing, and negation also disrupts the typical polarity relationship between the pupil and the sclera (Sinha, 2000). Indeed, the typical polarity of the eye region is a critical cue for face detection (Paras & Webster, 2013) and the holistic processing of faces (Sormaz, Andrews, & Young, 2013). Moreover, recent results obtained via ‘contrast chimeras’ (images in which the polarity of the eye region has been manipulated independently from the remainder of the face) demonstrate that the contrast polarity of the eyes plays a critically important role in the recognition of real faces (Gilad, Meng, & Sinha, 2009). Specifically, faces composed of positive-contrast eyes in an otherwise contrast-negated face tend to be effectively recognized, suggesting that negating the majority of the face pattern incurs little cost to recognition, and that the negation of the eyes is the basis of the overall negative impact of contrast reversal on recognition performance.

We suggest that contrast negation, and contrast chimeras in particular, are a highly useful tool for examining the relative contributions of the eye region and the remainder of the face to the task of discriminating real from artificial faces. In two experiments we applied these transformations to real and artificial faces to determine whether or not contrast negation affected animacy discrimination at all (experiment 1) and whether the eyes make a disproportionate contribution to animacy discrimination relative to the rest of the face (experiment 2). Given prior results describing the critical features for various tasks related to animacy discrimination, we predicted that negating the entire face pattern should impair animacy discrimination, since negation disrupts many of the cues previously identified as being relevant to animacy perception. Selective negation of the face via contrast chimeras, however, could lead to a range of outcomes depending on how the eyes and the rest of the
face combine (or not) when animacy is being determined. Specifically, if the eyes dominate animacy perception (as suggested by Looser & Wheatley, 2010), then selective negation of the eyes should impact performance regardless of the contrast polarity of the remaining pattern. If, however, both the eyes and the remaining face area make independent contributions to perceived animacy (cf Balas & Horski, 2012), then negating each feature singly should have a measurable effect on performance. Finally, if the joint appearance of the eyes within the face is of critical importance (as suggested by McDorman et al., 2009), then it may be that selectively negating either the eyes or the remaining face will have little impact, but negating the entire pattern will lead to less accurate performance.

2 Experiment 1
In our first experiment we wished to determine whether or not global contrast negation of face patterns would disrupt animacy discrimination performance. We predicted that, like other tasks (eg identification, detecting configural changes), animacy perception would be significantly worse when faces were negated.

2.1 Methods
2.1.1 Subjects. We recruited a total of sixteen observers (eleven female) to take part in this task. All participants were between the ages of 19 and 22 years old and reported normal or corrected-to-normal vision.

2.1.2 Stimuli. We selected photos of sixty undergraduates (thirty female) from a large database for use in both experiment 1 and experiment 2. The original images were 480 × 640 pixels in size and were full-color photographs. We chose images of Caucasian faces with no piercings, visible tattoos, or conspicuous facial blemishes, since these features tend to be poorly rendered in the software we used to generate CG faces from these stimuli.

We generated images of artificial faces using these photographs by importing each original image into FaceGen Modeler 3.1, which is a commercial application that supports 3-D modeling of faces based on a morphable model of facial appearance (Blanz & Vetter, 1999). FaceGen’s ‘PhotoFit’ procedure allows the user to identify several fiducial points on photographs depicting frontal and profile views of an individual, which the application then uses to create a least-squares fit to the estimated 3-D shape data and the surface reflectance of the original face. The result is a 3-D model of the target individual’s face and head that can be manipulated within the application or exported as an image file. We generated a frontal image of each target individual’s estimated FaceGen model using front and profile view photographs. FaceGen models did not include hair (though eyebrows were included), and all 3-D models were rendered with uniform lighting to match the illumination conditions of the original photographs. The FaceGen images were 400 × 400 pixels in size, and we reduced the size of our original photographs to match this. Since our original images did include hair and the FaceGen models did not, we cropped all of our images (original photographs and CG images) to exclude the top of the head. The jawline was retained in each image, though we also removed the ears in all cases, since these were not reliably rendered in the CG images (figure 1). Finally, to minimize the potential for observers to use low-level image properties (mean luminance or spatial frequency variation across categories), we used the SHINE toolbox (Willenbockel et al., 2010) to equalize luminance histograms and spatial frequency across our full set of images. We converted all stimuli to grayscale prior to this step. The resulting images were then contrast negated by inverting pixel values across the entire image. Note that luminance and spatial frequency are thus not matched across our contrast-negated stimuli and the original images, but that within each contrast condition real and artificial faces are matched for these properties.
2.1.3 Procedure. We asked observers to complete an animacy discrimination task using the original photographs we selected and their CG counterparts presented with positive and negative contrast polarity. On each trial we presented observers with two sequentially presented images: one image depicted a real individual, and the other depicted the same individual rendered using CG. We asked participants to identify which image (the first or second) depicted a real individual. Participants were asked to respond as quickly and accurately as possible. Each image was presented for 500 ms, with a 750 ms interstimulus interval between the first and second image within a trial (see figure 2). The order of the images within each trial was randomized, and each image within a trial was also randomly and independently rescaled to 80%, 90%, 100%, 110%, or 120% size. We included this manipulation to ensure that our participants could not reliably use any size differences between the original faces and their CG counterparts as a cue to animacy category.

We presented positive-contrast and negative-contrast images in separate blocks. Thus, both images presented on an individual trial were always of the same contrast, and contrast polarity did not change trial to trial. Each block was composed of 120 trials (2 repetitions of each unique identity in our stimulus set), and participants typically completed the task in approximately 10–15 min. Block order was counterbalanced across participants.

2.2 Results
For each participant we calculated the proportion of correct responses in both the positive-contrast and negative-contrast conditions. In addition, we also computed the median response time for correct trials in each condition. In each case we assessed the impact of contrast negation by applying a paired-samples $t$-test to the data, using a one-tailed test to reflect our a priori hypothesis that contrast negation should negatively impact performance. In the case of accuracy, we predicted that contrast-negated faces should be categorized according to animacy category less accurately. For response times, we predicted that participants would be slower to correctly identify which face was real.

Figure 1. Examples of original and CG faces in positive or negative contrast. These images have not been processed using the SHINE toolbox, and so differences in luminance and spatial frequency between real and artificial faces may be apparent.
Considering the accuracy data first, we found that, indeed, participants were less able to accurately identify which face was real when images were presented in negative contrast. Performance with positive-contrast images was approximately 94% on average (SD = 0.04%), while performance with negative contrast images was approximately 78% (SD = 0.20%), and this difference reached significance ($t_{15} = 3.08, p = 0.004$, one-tailed paired-samples $t$-test). As we predicted, response times were also significantly slower ($t_{15} = -2.48, p = 0.012$, one-tailed paired-samples $t$-test) when participants viewed negated faces ($M = 960$ ms, SD = 300 ms) compared with positive faces ($M = 790$ ms, SD = 247 ms). The combination of lower accuracy and slower response times when negative faces were viewed also precludes a simple speed–accuracy trade-off, suggesting that observers really are simply worse at animacy discrimination when images are globally contrast negated.

2.3 Discussion

In our first experiment we confirmed that contrast negation disrupts participants’ ability to accurately identify which face was real when images were presented in negative contrast. Like other aspects of face perception and recognition, face animacy thus must depend critically on the polarity relationships in positive-contrast images. We note, however, that there are multiple properties of face images that are disrupted by negation, leaving open a range of potential features that may play a critical role in observers’ judgments in this task. For example, contrast negation appears to disrupt the perception of second-order relationships between facial features (e.g., the distance between the two eyes, or the distance between the nose and mouth) (Kemp, McManus, & Pigott, 1990). The utility of these geometric features in our own stimulus set is likely to be relatively low, however, since our CG faces were created using an algorithm that attempts to preserve 3-D shape as much as possible when interpolating a surface from the fiducial points identified by the user. Alternatively, contrast negation is also known to disrupt face pigmentation substantially (Russell et al., 2006), and the difference between real skin and CG skin tone is both an area of active research in graphics (Krishnaswamy & Baronoski, 2004) and a source of perceived ‘uncanniness’ for observers viewing a range of artificial faces (MacDorman et al., 2009).
In general, contrast negation disrupts material perception (Fleming & Bülthoff, 2005) and texture discrimination (Balas, 2012), both of which may contribute to animacy perception. Finally, contrast negation as applied in our first experiment also reverses the contrast polarity of the pupil and sclera. The robustness of this ordinal relationship in natural images appears to make the direction of contrast in the eye region a strong cue for gaze perception (Sinha, 2000), and in photographic faces the contrast polarity of the eye region appears to determine recognition performance to a large extent (Gilad et al., 2009). In order to disentangle the contribution of (1) the appearance of the eyes and (2) the accurate perception of the material properties of the skin to our task, we continued by using contrast chimeras (Gilad et al., 2009) to examine how selective manipulation of the contrast polarity of the eyes relative to the rest of the face impacted animacy discrimination. To the extent that the eyes are a disproportionately important cue for animacy perception, we conjectured that performance would largely be driven by whether or not the eyes were presented in positive contrast regardless of the appearance of the rest of the face. Alternatively, if the material properties of the skin (or pigmentation more generally) makes a substantial contribution to animacy perception, we hypothesized that negating the remainder of the face pattern would negatively impact performance even in the presence of positive-contrast eyes.

3 Experiment 2
In experiment 2 we extended the design we employed in our first task to include contrast chimeras of the photographic and CG faces we used previously.

3.1 Method
3.1.1 Subjects. We recruited an additional twenty-one observers (fifteen female) to take part in experiment 2. None of these individuals had taken part in experiment 1, and all reported normal or corrected-to-normal vision.

3.1.2 Stimuli. We used the same photographic and CG faces described above in experiment 1 for this task. Additionally, we created contrast chimeras of these images by selectively negating the eye region of each face using Adobe Photoshop. Briefly, in each image we selected the eyes with the ‘Lasso’ tool and applied the negation transformation within the selected regions. We note that we excluded the eyebrow region from this manipulation and altered the contrast of the orbit only, which differs from the contrast chimeras made by Gilad et al. (2009). In our stimulus set we found that eyebrow appearance in artificial faces was not always well rendered, and eyebrows were difficult to segment cleanly. Thus, we selectively changed the polarity within the eye itself rather than in the eye–eyebrow complex. We raise this issue again in section 4 to properly contextualize our data in relation to prior results. The result of our manipulation is a face with that is composed of both positive and negative contrast, which we refer to here as a contrast chimera. Chimeric images with positive-contrast eyes and negative skin tone are easily created by negating the entire image after the eye region has been selectively negated—this effectively reverses the contrast of the negated eye region back to positive and negates the remainder of the face pattern (see figure 3). Our stimulus set for experiment 2 was thus composed of eight unique face categories: real and artificial faces that could have either positive-contrast or negative-contrast eyes and either positive-contrast or negative-contrast skin tone (and remaining facial features). As in experiment 1, the faces within each contrast category were matched for luminance and spatial frequency using the SHINE toolbox so that low-level properties were matched closely. Again, this matching does not extend across categories defined by image contrast, but does ensure that real–artificial discrimination is not easily accomplished by basic comparisons of luminance or contrast.
3.1.3 Procedure. The testing procedure for experiment 2 was nearly identical to that described above in experiment 1. The only substantive difference between the two tasks is that participants in experiment 2 completed the additional contrast chimera conditions. As described above, we varied contrast condition in separate blocks and presented these blocks in a counterbalanced order across participants. Participants completed 120 trials in each block for a grand total of 480 trials, typically completing the task in approximately 45 min.

3.2 Results
As in experiment 1, we calculated each observer’s proportion of correct responses in each contrast condition, as well as the median response time for correct responses. In each case we analyzed the data using a $2 \times 2$ repeated-measures ANOVA, with the contrast of the eyes (positive or negative) and the contrast of the remaining face pattern (positive or negative) as within-subjects factors.

3.2.1 Accuracy. Our analysis of observers’ accuracy as a function of contrast revealed a main effect of negating the contrast polarity of the larger face pattern ($F_{1,20} = 5.71, p = 0.027, \eta^2 = 0.22$), but no significant main effect of negating the eye region ($F_{1,20} = 2.37, p = 0.14, \eta^2 = 0.11$). The interaction between these terms also did not reach significance ($F_{1,20} = 0.33, p = 0.57, \eta^2 = 0.016$). We note, however, that, when we consider the mean accuracy values for each condition (figure 4), the average performance when just the eye region is negated is numerically very close to the average performance when the remaining face pattern is negated. Nonetheless, this analysis suggests that the contrast polarity of the eye region has a weaker influence on animacy discrimination than the polarity of the remaining face pattern. We note also that the average performance in the full positive ($M = 0.89\%, SD = 0.09$) and full negative conditions ($M = 0.79\%, SD = 0.18$) agrees well with the results we obtained in experiment 1.

3.2.2 Response time. Our analysis of the median response times as a function of eye and skin contrast revealed neither a main effect of eye contrast ($F_{1,20} = 0.19, p = 0.67$) nor a main effect of negating the remainder of the face pattern ($F_{1,20} = 2.52, p = 0.13$). The interaction between these factors also did not reach significance ($F_{1,20} = 1.97, p = 0.18$).

Figure 3. Examples of the contrast chimeras used in experiment 2. (a) Positive eyes chimera; (b) negative eyes chimera. These images were created by selectively manipulating the contrast of the eye region relative to the rest of the face pattern.
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4 General discussion

We have found in two experiments that contrast negation impairs observers’ ability to distinguish between real faces and artificial faces. Specifically, and in contrast to previous studies, we used identity-matched images of real faces and their CG counterparts to measure observers’ sensitivity to real face appearance. Our results demonstrate, first of all, that observers can tell the difference between rapidly presented real and artificial faces when the sex, age, race, and identity of the individual are matched across test images. To our knowledge, this is the first report of real–artificial face discrimination to make use of identity-matched faces, which we suggest is a useful strategy for further research. Matching categories like sex and race across real–artificial test stimuli is an important means of avoiding spurious effects resulting from appearance covariation between distinct categories—race, for example, appears to be ‘gendered’ (Johnson, Freeman, & Pauker, 2012), as is animacy to some extent (Balas, 2013). Second, and more importantly, our results also demonstrate that the eye region and the appearance of the remaining face pattern each contribute to animacy discrimination such that performance can be negatively impacted by selective polarity reversal of each region. Our results suggest, in line with recent reports that both the eyes and the larger face pattern contribute to animacy judgments (Balas & Horski, 2012; McDorman et al., 2009), that negation of each feature lowers performance. Animacy judgments thus appear to be not solely driven by the appearance of the eyes. We point out, however, that our exclusion of the eyebrows from the eye region we used to create contrast chimeras means we cannot directly compare our results with those of Gilad et al. (2009), who used the eye and eyebrow region to make chimeric faces. Our results speak directly to the contribution of the orbit in our task, not a larger region including the eyebrow. With regard to Looser and Wheatley’s (2010) report describing the nature of category boundary between real and artificial faces as a function of the distinct facial features available to observers, they do not explicitly state whether or not the eyebrows were included when they presented observers with the eye region only. If the eyebrows were not included, then our results would suggest that, unlike in their task, real–artificial discrimination does not depend so heavily on the isolated orbits. Indeed, in experiment 2, the effect of negated eyes did not reach significance, suggesting that the appearance of the other facial features is potentially of more importance to animacy discrimination. If, however,
they did include the eyebrow region in their segmented stimuli, then our results are not necessarily discrepant in the context of their report. Instead, the exclusion of the eyebrow region in our case may suggest that this specific feature may carry a great deal of important information for discriminating real and artificial faces. When included in a contrast chimera (cf Gilad et al., 2009) or in a segmented face (as may have been the case in Looser & Wheatley, 2010), the eyebrows may disproportionately contribute to face recognition processes that support discrimination between real and artificial faces. When grouped together with the remaining face pattern (as in the current study), the eyebrows may lead to the overall face pattern, making a significant contribution to performance. The notion that the eyebrows may be making a large contribution to perceived animacy is concordant with prior work demonstrating that they do substantially impact recognition (Sadr, Jarudi, & Sinha, 2003), and so presently we simply offer the conclusion that the eye itself does not appear to impact perceived animacy more than the rest of the face pattern. We note, however, that in either case (that is, the role of the eyebrow notwithstanding) the impact of negating the eyes and negating the rest of the face on the average discrimination performance was numerically very similar in our study, which suggests that caution is needed in treating our data as an outright rejection of the role of eye appearance in this task. Instead, we interpret our data as evidence that animacy discrimination, and by extension the categorization of animacy, is multiply determined by several diagnostic features. Similar to sex categorization (Bruce et al., 1993), which appears to rely upon a number of cues including 3-D shape differences between the sexes (Burton, Bruce, & Dench, 1993) and sexual dimorphisms in pigmentation (Bruce & Langton, 1994), the perceived life in a face appears to be a function of a number of different features.

The design of our study precludes the examination of several particularly interesting features that may make varying contributions to animacy discrimination or categorization, and further investigation of how these various cues contribute to animacy judgments would be very interesting. In particular, owing to technical limitations of the software we used to generate CG faces, we chose to use cropped faces that included the jawline, but not the entire external contour of the head. These external features are known to play a dominant role in face recognition (Sinha & Poggio, 1996) and may also make a substantial contribution to animacy discrimination. We have also rather crudely divided the face up into two regions: the eyes and everything else. Obviously, the nose, mouth, and skin may make differential contributions to animacy discrimination and categorization that may or may not reflect the differential role they play in recognition. A more thorough examination of how feature hierarchies for individuation and categorization interact with the real or artificial appearance of the face would be an interesting way to investigate the ‘tuning’ of face recognition as a function of experience, and to characterize animacy discrimination in terms of a more complete library of facial features. Similarly, investigating animacy discrimination in terms of low-level features that reflect early visual processing (eg spatial frequencies or orientation) would be an important complement to the current results. Face recognition depends critically on intermediate spatial frequencies (Costen, Parker, & Craw, 1996; Näsänen, 1999) and horizontal orientations (Dakin & Watt, 2009), for example, and the dependence of animacy judgments on these same features will not necessarily be the same.

Establishing the neural sensitivity of face-sensitive responses to real versus artificial faces as a function of the features considered here is also an intriguing direction for future research. As described previously, multiple neural responses generated by the extended face network appear to encode the difference between real and artificial face appearance, but the extent to which individual loci are sensitive to holistic differences between these types of faces as opposed to more local features (eg the eyes alone) is unknown. The N170 appears
to be highly sensitive to eyes, for example (Itier, Latinus, & Taylor, 2006), and may be further
tuned to be sensitive to the difference between real versus artificial eyes regardless of the
appearance of the rest of the face. Later ERP components like the P200, which may reflect
holistic processing of the face, may respond in a manner that is more consistent with joint
encoding of multiple cues to animacy category.

Finally, there are a range of practical questions that remain unanswered regarding
how critical features for animacy discrimination may vary as a function of other parameters
that define facial appearance. For example, does the emotion expressed by a face determine
how diagnostic various features are for distinguishing between real and CG images? Emotion
recognition from the face does not always exhibit the same dependence on spatial frequencies
(Kumar & Srinivasan, 2011) and orientations (Huynh & Balas, in press) as individuation,
which may mean that the diagnostic features for telling real faces apart from artificial ones
may also change if the face is expressing an emotion. Likewise, how invariant to changes
in illumination or viewpoint is animacy discrimination and the features that it depends on?
To the extent that artificial agents need to be perceived as being capable of agency and
experience (MacDorman & Ishiguro, 2006) to be useful in specific domains, determining
how various elements of facial appearance contribute to animacy discrimination as a function
of task, emotional expression, race, age, or other task and stimulus parameters is critically
important. Presently, we have taken a small step in this direction by developing a stimulus
set and a straightforward task that allows us to ask a range of questions about how faces are
discriminated according to real or CG appearance when other category variables are matched.

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