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Monsters are people too

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Animals, including dogs, dolphins, monkeys and man, follow gaze. What mediates this bias towards the eyes? One hypothesis is that primates possess a distinct neural module that is uniquely tuned for the eyes of others. An alternative explanation is that configural face processing drives fixations to the middle of peoples' faces, which is where the eyes happen to be located. We distinguish between these two accounts. Observers were presented with images of people, non-human creatures with eyes in the middle of their faces ('humanoids') or creatures with eyes positioned elsewhere ('monsters'). There was a profound and significant bias towards looking early and often at the eyes of humans and humanoids and also, critically, at the eyes of monsters. These findings demonstrate that the eyes, and not the middle of the head, are being targeted by the oculomotor system.

1. Introduction

Animals attend to social stimuli beyond what would be predicted based on physiology and sensory processing alone [1–3]. For example, monkeys and humans look more often towards higher-ranking animals than lower-ranking animals, and look more towards the head than the body [4,5].

Looking towards the head is especially important because it provides gaze information. Friesen & Kingstone [6] first reported that humans will attend automatically in the direction gazed at by a conspecific. Deaner & Platt [7] demonstrated with macaques that gaze following occurs across species, implicating neural substrates that are shared across primates. Other animals have also been found to follow gaze, including apes, birds, dogs, seals, goats and dolphins [8], indicative of a widespread biological process.

Gaze following in diverse species poses an important biological question: what neural mechanisms drive gaze selection and following? For primates there are two viable proposals: (i) a cortical neural system in the temporal lobe, the superior temporal sulcus (STS), is preferentially biased towards processing eye information [9], or (ii) the nearby fusiform face area (FFA), directs fixations to the middle of peoples' faces, which is where the eyes are located [10,11]. Resolving this issue will reveal not only the neural systems mediating social attention within primates, but also the computational and evolutionary links between social attention in different species. It will also inform why a subset of people may fail to select the eyes of others, and what brain mechanisms may be compromised, as in the case of autism. It has been argued, however, that distinguishing between these two accounts may be impossible because human eyes *are* in the centre of the face [12].

The present study resolves the issue. Observers were presented with images selected from the popular fantasy game Dungeons and Dragons (D&D; figure 1*a*). The images could be of humans, creatures with eyes in the centre of the face (humanoids), and creatures with eyes that are not on the face but broadly distributed on other parts of the bodies, such as the hands or the tail (monsters). The question is straightforward: will there be a preferential bias to select the eyes of monsters despite the fact that their eyes are not in the centre of their face? If people select the eyes early, and frequently, for monsters as well as humans and humanoids, it will show that eyes are selected and not just the centre of the
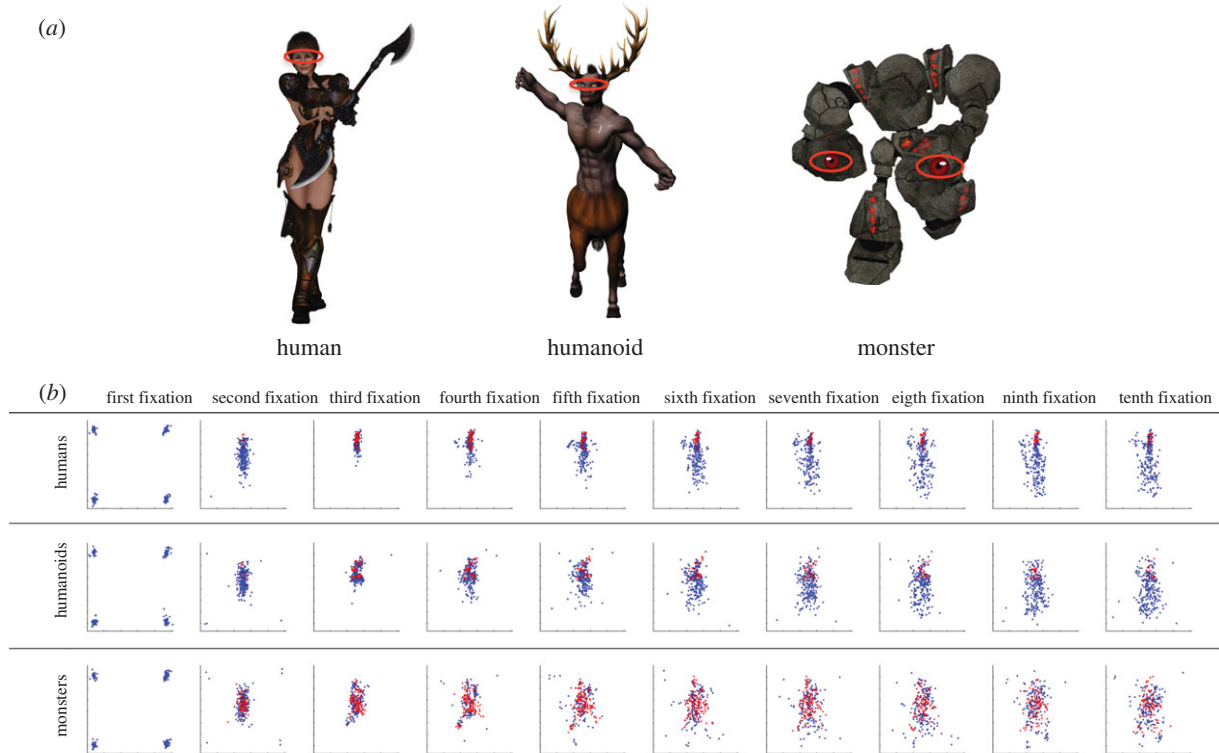
Figure 1. (a) Example of each image type: human, humanoid and monster. Red ovals (which were not present on the image) mark the location of the eyes for each image type. (b) Illustration of how each image type was fixated over the first 10 eye fixations. Dots mark the location of all participants' fixations on all images, with red dots indicating fixations to the eyes in the image. First fixations always begin in one of the corners of the display.

face; if the bias to the eyes is manifested only for humans and humanoids, then selection is targeting the centre of the face.

2. Material and methods

Twenty-two naive student volunteers were instructed to simply look naturally at the images (1024×768 pixels). Eye movements were calibrated and monitored using an Eyelink 1000 system. At the beginning of each trial, a fixation point was displayed randomly in one of the four corners of the screen. Participants were told to fixate on this point and then press the spacebar to start a trial. This had the effect of constraining the initial fixation to one of the corners of the screen, correcting the eye tracker for any drift, and removing any central bias from the initial fixation. One of 36 pictures was then shown in the centre of the screen. Each image was chosen at random, without replacement, and remained visible until 5 s had passed. This process repeated until all pictures had been viewed. Data deposited in the Dryad repository: doi:10.5061/dryad.4rk06. While D&D images were used in the study, due to copyright, figure 1 presents exemplars.

3. Results

For each image, an outline was drawn around the region of interest. The eye region varied in size from $0.25°$ to $4.5°$, with the average in each image category ranging from $1.7°$ to $1.9°$. We also computed the relative visual saliency of the eyes to other regions in the scene [13] and replicated the finding [12] that the eyes in the images were not especially salient and that visual saliency did not predict fixations to the eyes. Figure 1b presents a scatterplot of the first 10 fixations, with red dots indicating fixations that landed on the eyes. Data are for all participants and images, with the first fixation on the peripheral fixation point at the start of the trial, through

to the 10th fixation. What is immediately apparent is that for all images people first make a saccade that moves from the periphery to the centre of the image. This provides a compelling demonstration that there is a marked tendency to land in the middle of images. Note also that because monster eyes are oddly positioned, many of the initial saccades to the centre of the image landed on the eyes.

Figure 1b also shows that the second and subsequent fixations resulted in observers demonstrating a preferential bias to look at the eyes. This was manifested differently for the different image types. Fixations moved vertically up to the eyes of humans and humanoids. In sharp contrast, they remained centralized and distributed for monsters. This was confirmed statistically by comparing the average vertical fixation position in a repeated-measures ANOVA. The starting peripheral fixation was excluded. There was a main effect of image type, $F_{2,42} = 83.0$, $p < 0.001$, showing that fixations were closer to the top of the image in humans (mean position $= 3.4°$ above centre; s.e.m. $= 0.25$) than in humanoids ($M = 1.5°$; s.e.m. $= 0.18$) or monsters ($M = 1.3°$; s.e.m. $= 0.19$). This interacted with fixation number, $F_{16,336} = 12.5$, $p < 0.001$, and Bonferroni-adjusted paired comparisons confirmed that fixations on humans were higher than those on monsters as early as the first saccade and that they remained spatially distinct for eight of the first nine saccades (with the exception of the eighth saccade; all other $p < 0.01$). This vertical shift was mirrored for humanoids but lagged by a single fixation, with the second and subsequent three saccades for humanoid fixations being consistently further up the image, indistinguishable from humans and reliably different from monsters (all $p < 0.01$). Thus fixations to humans and humanoids went first to the centre of the image and then immediately shifted vertically to their eyes; fixations on monsters went to the centre of the image and then moved in any
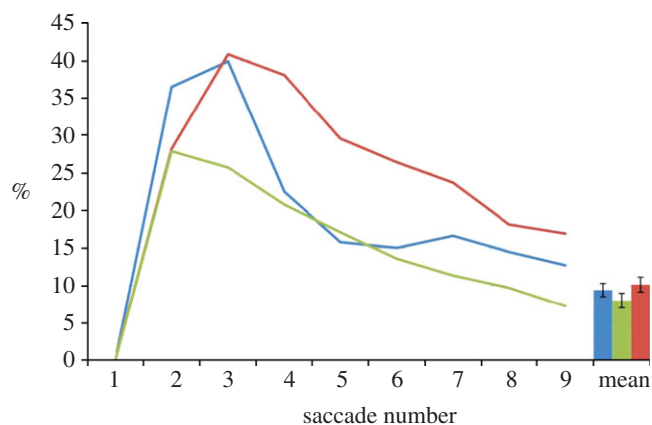
Figure 2. A line graph illustrating the proportion of fixations on eyes for humans, humanoids and monsters. Histogram on the right shows the overall mean fixations on the eyes for each image type, across the whole trial (with standard error bars). Blue, humans; green, humanoids; red, monsters.

number of possible directions as monster eyes were broadly distributed. To test whether the eyes were fixated more often than chance, we also compared the uncorrected proportion of fixations on the eyes to the area of the image that they took up. Across all images and fixations, the eyes were fixated much more often than their tiny area would suggest (one-sampled t-tests, all $t_{21} > 4.5$, $p < 0.001$).

These data indicate that *where* people looked was different for humans and humanoids versus monsters, but *what* they looked at—the eyes—was the same. This was confirmed statistically. We calculated the proportion of each participant's fixations that landed on the eyes, splitting the data over time by looking at the first fixation, the second fixation, and so on. Because some initial saccades to monster images landed on the eyes, as a conservative test and to ensure equity we examined only those trials where the initial central saccade was *not* on the eyes. Figure 2 shows the proportion of fixations on the eyes across the first nine fixations (initial corner fixation is excluded).

Across the whole trial, there was a significant effect of condition ($F_{2,42} = 5.8$, $p < 0.01$). Humans and monsters did not differ significantly (while humanoid eyes were looked at slightly less ($p < 0.05$)). Figure 2 shows a similar trend over time in all three conditions. There was also an interaction between image type and saccade number ($F_{16,336} = 4.7$, $p < 0.001$). Simple main effects showed that image types were different on the second and third saccade ($p < 0.005$, because humanoids were lower than humans and monsters) but *not* on subsequent saccades where there was no significant difference between image types.

4. Discussion

Participants' initial saccade targeted the centre of the image. This confirms that there is a bias towards looking at the geometric centre of objects [11]. For images of humans and humanoids, subsequent fixations quickly moved vertically to the eyes. Similarly, fixations to the eyes also occurred rapidly for monsters, but critically they were manifested in a very different spatial manner. As monster's eyes were unusually positioned, fixations to the monsters' eyes did not yield a vertical shift. Nevertheless, and despite this difference in the spatial allocation of fixations, the target of their fixations was the same as with the humans and humanoids—the eyes. Moreover, the time-course for the selection of monster eyes (e.g. peaking at the third fixation and declining thereafter) closely mirrored the time-course for the selection of human and humanoid eyes. These data cannot be explained in terms of mechanisms within the primate brain that guide selection based on simple visual saliency [13]. Nor can they be accounted for by computational models of eye movements that assume a face-selective mechanism that orients early fixations to the geometric centre-of-faces, e.g. the nose or cheek region depending on head orientation [11,14]. Rather the fact that participants select the eyes early, and frequently, even when they are not positioned in the centre of a face, provides strong and converging evidence that the neural substrate driving the selection of eyes is the STS.

The present study strongly supports the idea that the primate brain is specialized for acquiring social, behaviourally relevant information from others. As gaze selection is the key precursor to gaze following, which is common to both humans and non-human primates, and present in other animals as well, it is reasonable to speculate that this behaviour is subserved by a neural system that is shared within and across species, possibly the phylogenetically old subcortical system that is shared across all terrestrial vertebrates and processes coarse information regarding biological primitives (e.g. prey, predator, conspecific). In primates, the subcortical pathway passes information directly to 'higher' cortical systems such as the STS [15].

Our conclusion that human gaze selection is mediated by a specialized brain mechanism, sensitive to the eyes rather than only the head, sheds light on individuals with autism who often fail to select the eyes of others. Naturalistic studies of autism do not distinguish between gaze direction and head position, making it unclear whether individuals with autism are deficient at selecting and targeting the head, or eyes, or both. The present study indicates that typically developing individuals select gaze information, and therefore efforts to train individuals with autism to look at others in a typical manner should focus on the selection of the eyes of others rather than targeting the head alone.

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