Perception, 2000, volume 29, pages 1005 – 1008

DOI:10.1068/p2908no

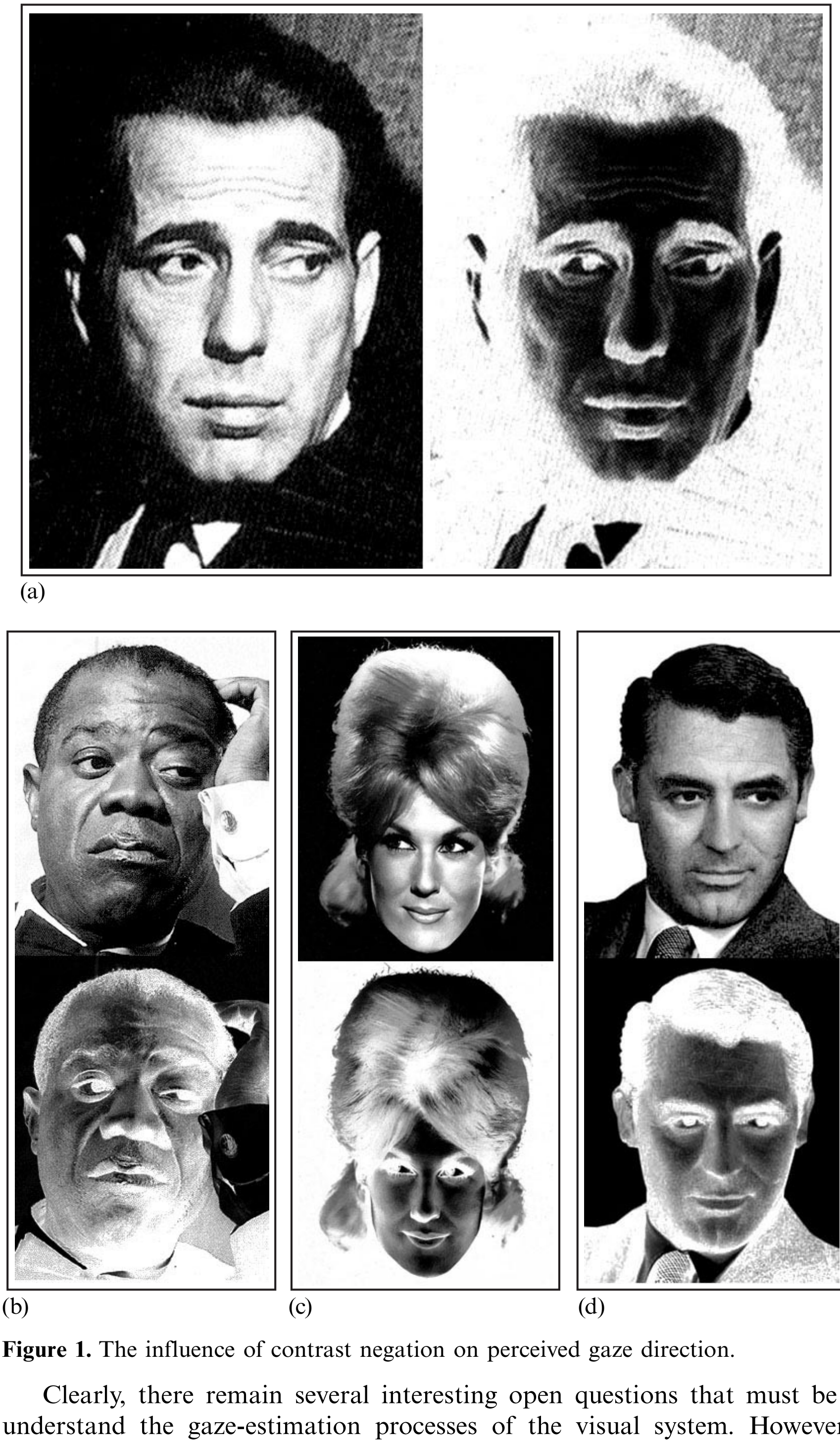
# Last but not least

## Here's looking at you, kid

One of the key aspects of face processing in primates is the estimation of gaze direction (Hinde and Rowell 1962; Kleinke 1986). Studies of how our visual systems achieve their remarkable levels of accuracy at this task have revealed that besides the overall orientation of the stimulus head, the stimulus eyes appear to be crucially important (Perrett et al 1985; Baron-Cohen et al 1995; von Grünau and Anston 1995). However, the question of what characteristics of the eye stimuli the visual system uses to estimate gaze direction is still open. Here I present a simple visual effect based on image contrast negation that provides some clues about the answer.

The left panel of figure 1a shows Humphrey Bogart looking to his left. Consider what happens to his gaze direction when we invert the contrast of the image (figure 1a, right panel). Instead of continuing to look left, the negated Bogart's gaze reverses direction. [This effect is obtained with non-Bogarts as well (as shown in figures 1b – 1d), but it is difficult to find as catchy a title.] To test the veracity of this informal observation, I collected data from ten subjects. Each of the subjects was shown the images in figure 1, one at a time and in random order, on a computer monitor placed 60 cm away. The images subtended 6 deg of visual angle at this distance. The subject's task was to indicate whether the individual depicted in the image appeared to be looking to the (subject's) left or right. Figure 2 shows the results of this simple experiment. It is evident that contrast negation led to a reversal of the perceived gaze direction for the majority of the subjects. As for the exceptions, while I do not yet have a definitive explanation, post-experiment debriefing suggests that they might have been deliberately compensating for contrast negation and estimating the 'real' gaze direction by reversing the perceived one.

This phenomenon (which I refer to as the 'Bogart illusion') suggests that the gaze determination strategy used by the visual system may be based on some simple heuristics. The strong correlation of perceived gaze direction with contrast polarity in images indicates that iris position (and hence gaze direction) estimation may rely on an elementary rule of thumb—"which side is dark?". The perceptual power of this rule of thumb is evident in the observation that for most of our subjects, gaze direction reversal was obtained even though the subjects could tell that they were looking at negative images and thus 'knew' that the irises are the light regions in the eyes. In Pylyshyn's words, the gaze-estimation process appears to be "cognitively impenetrable" (Pylyshyn 1999), with the rule of thumb taking precedence over cognitive classifications of eye regions as iris and sclera. It is also interesting to note that gaze direction reversal is obtained even though the putative iris in the negative image is of an abnormal size relative to the rest of the eye (figure 1a) and/or is bounded by arcs that curve in the wrong direction (figures 1a – 1d). Apparently, an eye region can qualify to be treated as an iris by the gaze-estimation process, so long as it satisfies the darkness heuristic, even though its other structural attributes may be abnormal. However, further experiments are needed to systematically and more thoroughly assess the influence of iris size and curvature cues on gaze estimation. Another important condition that merits investigation is that of the nearly frontal gaze. In contrast-negated versions of such images, will the simultaneous presence of two dark regions (the sclera on either side of the iris) disqualify both of them from being considered as irises? Results from figure 1d, wherein sclera is visible on either side of the iris, suggest that the gaze direction reversal phenomenon is weakened, but not extinguished in this circumstance (figure 2d).



(a)

(b) (c) (d)

**Figure 1.** The influence of contrast negation on perceived gaze direction.

Clearly, there remain several interesting open questions that must be answered to understand the gaze-estimation processes of the visual system. However, within the scope of our experiments we can begin to discern the use of a simple rule of thumb for gaze estimation based on ordinal brightness relationships. Ecologically, the simplicity of this strategy makes sense. The rule of thumb is generally valid (most animal eye irises are darker than the sclera), and might allow for a simpler and faster neural implementation of this important perceptual ability. By limiting its reliance on fine

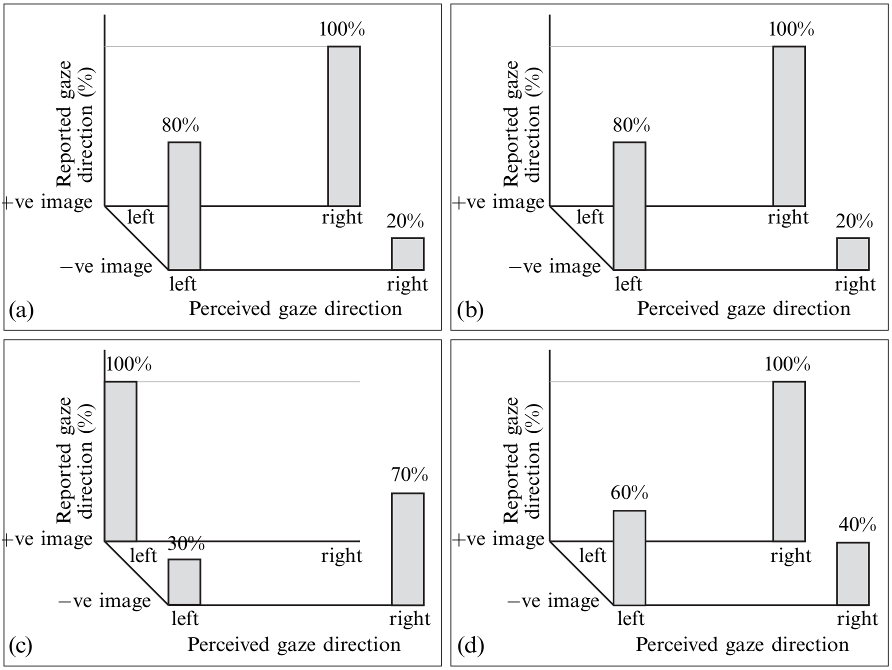



**Figure 2.** Gaze-estimation results from ten subjects tested with the face images shown in figure 1. Panels (a) through (d) display results for the positive and negative images of figures 1a through 1d, respectively. Contrast negation reverses perceived gaze direction for the majority of the subjects. The gaze direction reversal effect is weaker in (d) perhaps because the gaze direction is close to frontal.

structural cues (such as precise size and bounding contour curvature), the visual system may be able to estimate gaze direction even under degraded viewing conditions (say, due to problems in the optics of the viewer's eye) and especially at a distance. The use of this simple strategy may also account for an interesting illusion devised by Ando and Osaka (1998). Gaze direction of forward-looking eyes seems to be skewed to the side if one scleral region is strongly bloodshot. The explanation may lie in the visual system grouping both the iris and the darkened scleral region together into one 'composite' iris (since both of them now satisfy the darkness heuristic). The inclusion of the sclera makes the center of this composite iris shift to a side, thus leading to a change in the perceived gaze direction. Finally, this rule of thumb may also explain why it is so difficult to obtain desired gaze directions in drawings done on a blackboard with white chalk.

Pawan Sinha
E25-229, Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02142, USA; e-mail: sinha@ai.mit.edu
Received 20 June 1999, in revised form 12 April 2000

**References**

Ando S, Osaka N, 1998 "Bloodshot illusion: Luminance affects perceived gaze-direction" *Investigative Ophthalmology & Visual Science* **39**(4) S172

Baron-Cohen S, Campbell R, Karmiloff-Smith A, Grant J, Walker J, 1995 "Are children with autism blind to the mentalistic significance of the eyes?" *British Journal of Developmental Psychology* **13** 379 – 398

Grünau M von, Anston C, 1995 "The detection of gaze direction: A stare-in-the-crowd effect" *Perception* **24** 1297 – 1313

Hinde R A, Rowell T E, 1962 "Communication by posture and facial expression in the rhesus monkey" *Proceedings of the Zoological Society of London* **138** 1 – 21

Kleinke C L, 1986 "Gaze and eye-contact: A research review" *Psychological Review* **100** 78 – 100
Perrett D I, Smith P A J, Potter D D, Mistlin A J, Head A S, Milner A D, Jeeves M A, 1985 "Visual cells in the temporal cortex sensitive to face view and direction of gaze" *Proceedings of the Royal Society of London, Series B* **223** 293 – 317
Pylyshyn Z, 1999 "Is vision continuous with cognition?—The case for cognitive impenetrability of visual perception" *Behavioral and Brain Sciences* **22** 341 – 423