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Visual scan patterns of rhesus monkeys viewing faces

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Abstract. Two rhesus monkeys viewed black/white photographic slides depicting rhesus, human, chimpanzee, and schematic faces with direct gazes. Eye-track apparatus was used to assign visual fixations to one of four facial regions: the two eyes, nose, or mouth. Results showed that the eyes of stimulus faces received a disproportionate number of fixations from both observers across all stimulus face types. Stimulus faces depicting rhesus and human facial gestures shifted scan patterns somewhat, but did not disrupt the preoccupation with eyes. When the features of schematic faces were rearranged into non-facelike configurations, fixations directed to schematic stimuli were typically reduced in number.

1 Introduction

Social species of primates display an impressive array of facial expressions during gestural communication. In many Old World monkeys, for example, mouth position helps forecast impending interactions between sender and receiver (Hinde and Rowell 1962; van Hooff 1967). The manipulation of direct gaze and gaze avoidance is also an important channel of communication among monkeys and apes. Whether gaze serves as a threat (eg Hall and DeVore 1965), a bonding agent (eg Goodall 1967; Harlow and Mears 1979), or a window to the soul, most researchers agree that it is a striking feature of primate gestural communication.

Though ethologists have described primate facial gestures, the facial features to which these animals direct their gaze have yet to be measured directly with laboratory techniques. What laboratory studies have demonstrated is that monkeys respond differentially to photographic images of conspecifics. For example, Overman and Doty (1982) found that color-photographic slides depicting rhesus (and even human) faces elicited species-typical responses among rhesus-monkey observers whereas equally complex, non-facelike stimuli did not. Rhesus monkeys differentiated color and black/white photographic images of individual monkey faces (Rosenfeld and van Hoesen 1979). They also distinguished black/white televised images of conspecifics, using the gestures of other monkeys as cues for appropriate avoidance responses (Miller 1971).

Monkeys are discriminating about what they view. In a free-viewing primate 'peep show' squirrel monkeys spent more time viewing color and black/white slides of 'relevant' stimuli (conspecifics, predators, food items) than equally-complex 'irrelevant' stimuli (landscapes, random shapes, other species) (Marriott 1976). Rhesus monkeys permitted to activate presentation of color slides of other monkeys viewed certain expressive poses more than others (Sackett 1966; Redican et al 1971), and were more responsive to apparent differences among conspecifics than to those among members of other species (Humphrey 1974). Thus monkeys respond

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to photographic images of social stimuli the way we would expect them to respond in nature.

Our aim was to describe the visual scan patterns of rhesus monkeys viewing photographic images of their own and other species' faces. We wondered if rhesus scanning patterns would confirm the importance of eyes as a source of information/ communication. Would visual fixations disproportionately cluster around the eyes of stimulus faces? Would scanning patterns shift when gesturing faces were viewed?

2 Method

2.1 *Subjects*

The subjects were two feral adolescent rhesus monkeys (*Macaca mulatta*), one of each sex. The monkeys were housed in separate cages that partially restricted visual interaction with other animals in the same room. Both observer monkeys were trained to perform a visual-search task using the apparatus employed in the present study (Keating and Dineen 1982).

2.2 *Apparatus*

Eye position was recorded by means of the infrared corneal-reflection method (Bio Trac 200-Gulf & Western Labs). The observer animal, while sitting in a primate chair, was prevented from moving its head by a mount implanted in its skull. Light-emitting diodes positioned near the eyes flooded part of each cornea with invisible infrared light. Light reflected by the eyes was detected by photodiodes, transduced to a voltage, amplified, and then stored on tape. Changes in voltage thus translated to shifts in the position of eyes. When used to measure eye position over a 50 deg diameter field the infrared corneal-reflection method could distinguish eye positions to within 5 deg. Limitations of the method included its restricted precision and its partial obstruction of the view of one eye.

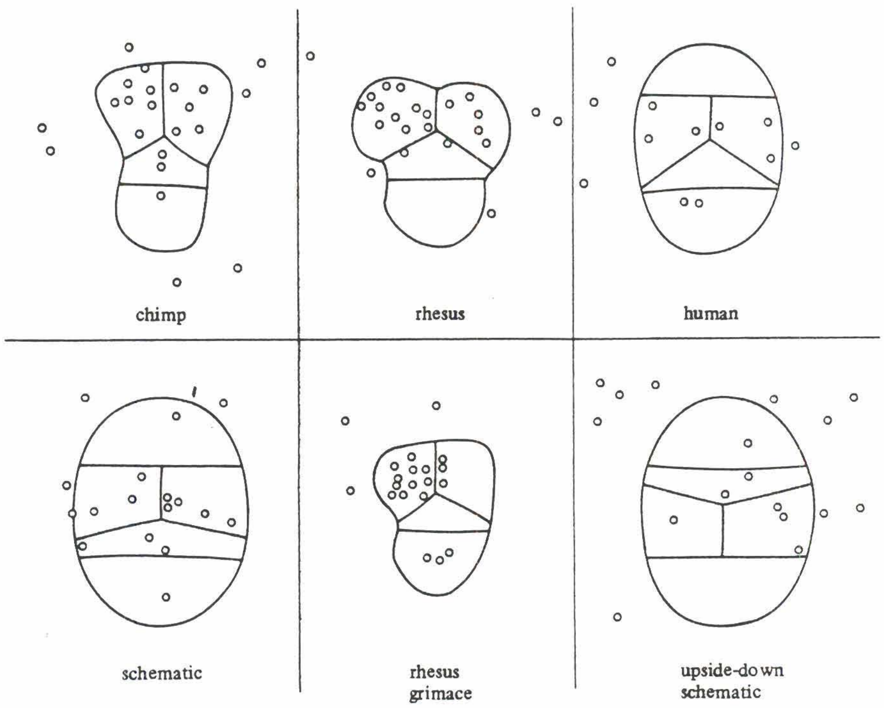


Figure 1. Representative scan patterns produced by different face types for monkey 1. Circles indicate fixations.

Photographic slide images of stimulus faces were projected from a 35 mm slide projector through a closed-circuit television system to a black/white television screen 20 cm from the observing monkey. The screen subtended a 32 deg x 40 deg visual angle. The infrared apparatus made it necessary to position the center of the television screen 16 deg above the primary position of gaze. The facial stimuli fell on various sectors of the viewing screen and subtended a visual field approximately 15 deg x 20 deg.

The limited resolution of the eye-track apparatus allowed us to confidently assign fixations to one of four regions of the face—the two eyes, nose, and mouth areas—but fixations were not necessarily accurately placed within each region. The boundaries for the four areas were determined individually for each stimulus face. Before testing sessions each face was projected to the experimenter's television monitor. An outline of each face was traced on a sheet of clear plastic acetate placed over the monitor. Lines were drawn separating areas around the two eyes, nose, and mouth (see figure 1). Thus, a priori subjective decisions were made as to what would constitute a look at (or near) each facial feature. The boundaries between features were contiguous and exhaustive. Therefore any fixation which fell on the viewing screen was judged to be either on or off the face (off-screen fixations were simply ignored). If on the face, a fixation was assigned to either an eye, the nose, or the mouth area. The relative sizes of feature areas varied among stimulus faces as their facial characteristics varied. To remedy some of the discrepancy human and schematic 'forehead' areas were not considered part of the face, as no primate counterpart could be adequately defined.

Four categories of stimuli were presented to the monkeys. A *menagerie of non-gesturing faces* constituted the first category. Included were three examples each of rhesus, human, chimpanzee, and schematic cartoon faces. These photographs depicted direct gazes (into the camera lens) with no obvious facial gesture. Elements of the second category of stimuli, *gesturing rhesus faces*, were interspersed among the elements of the first category. These three gesturing rhesus faces included one portraying a submissive averted gaze, another a direct gaze combined with a 'submissive grimace', and one with a direct gaze as part of an 'open-mouth threat' (van Hooff 1967). The third category was a set of *gesturing human faces*. Each of five human models was photographed first with lowered eyebrows, then again with raised eyebrows. Unlike the other stimulus faces, these human faces were carefully controlled so that the only difference between each model's two poses was brow position: screen position, overall face size, and feature area sizes were held constant. Lowered-brow poses were presumed to appear more threatening than raised-brow poses (Keating et al 1981). Finally, an upside-down schematic face and two schematic faces with rearranged features were inserted in the stimulus series as part of some *experimental controls* whose rationale will be explained with the aid of figures in the results section.

2.3 *Procedure*

The entire series of twenty-eight stimulus faces was presented in different order to observer monkeys. Each animal typically viewed two to three faces during a testing session and was given two to three testing sessions per week. Monkey 2 completed the sequence in six weeks whereas monkey 1 was tested somewhat more erratically for a period of eight weeks.

To reference the monkeys' eye-position signals to locations on stimulus faces the animals were trained to work for a juice reward by fixating on a point of light which appeared on a blank television screen (Wurtz 1969). Before face presentations the experimenter moved the light spot to various locations on the screen which corresponded to locations on the face previously outlined on the experimenter's monitor. By fixating successive points of light the monkey's eye position was 'calibrated' with respect to divisions drawn on the experimenter's outline of the stimulus face to be shown.

Immediately after calibration the light point was switched off and the appropriate stimulus face was presented for five seconds. The eye movements were registered on an FM recorder.

2.4 *Dependent measures*

Eye position was analyzed manually by playing the recorded data back through an *x*/*y* plotter at a quarter of the original speed. A fixation was defined as any hesitation or pause in eye movement. Fixations were counted if they fell anywhere on the television screen during the five-second exposure period for each face. The position and sequence of fixations were recorded by raters as dependent measures. Interrater reliability (number of agreements/number of agreements plus disagreements) was high for distinguishing fixations from nonfixations (0·92), as well as for determining their sequence (0·98).

3 Results

3.1 *Menagerie of non-gesturing faces*

The total number of fixations placed anywhere on the screen during the five-second presentation of a face varied between observer monkeys and across the four types of faces in this category. (Monkey 1 produced median total fixation frequencies of 16, 18, 12, and 22, while medians for monkey 2 were 15, 8, 16, and 17 for schematic, rhesus, human, and chimpanzee faces, respectively.) The proportion of these fixations directed to faces showed considerable interobserver and intraobserver variability, especially when rhesus and human faces were shown. For example, for each of three rhesus face stimuli the proportion of fixations on the face was 0·39, 0·78, 1·0 for monkey 1, but 0·0, 0·41, 0·70 for monkey 2. The most dramatic divergence evident from these figures resulted from the premier showing of a (different) rhesus face: monkey 1 directed all fixations to the face while monkey 2 fixated off the face entirely. Representative scan patterns for faces are found in figure 1.

For each type of face the median proportions of *on-face* fixations falling within eye, nose, or mouth regions are reported separately for each observer monkey in figure 2. Eyes received the greatest proportion of fixations from each animal. The attraction to eyes as opposed to other facial features occurred for all four types of faces: rhesus, human, chimpanzee, and schematic. Though both observer monkeys

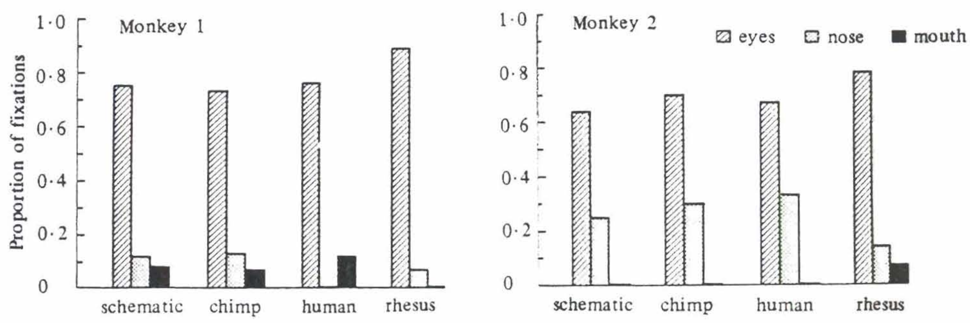


Figure 2. Median proportion of on-face fixations within eye, nose, and mouth regions for four face types.

predominantly fixated the eye area, figure 2 indicates that monkey 1 did so to a greater degree than monkey 2.

Considering the area they occupied, eyes received a disproportionate share of on-face fixations. Using a planimeter we calculated for each stimulus face the ratio of the area of the screen subtended by both eyes to that of the entire face, f. For each of the four face types mean ratios were used as expected values against which to assess the binomial probability of observed fixation frequencies for each observer separately. On-eye fixation frequencies exceeded expectations on all four stimulus face types for monkey 1 ($p < 0.01$) and for monkey 2 ($p < 0.05$) (Beyer 1968)[(1)].

Other studies have indicated that features viewed most often are also those viewed earliest (Loftus and Mackworth 1978). Did observer monkeys fixate eyes early or late during the five-second viewing period of each face? For each monkey we compared the average order of occurrence of on-eye versus off-eye fixations generated by each stimulus face. Fixations anywhere outside the eye area of faces were designated off-eye fixations, whether or not they fell on or off the face. No consistent sequencing pattern for fixating eyes was demonstrated for monkey 1. Monkey 2 showed a weak bias toward viewing the eyes early for nine faces and late for three others.

3.2 *Gesturing rhesus faces*

Observer monkeys also viewed faces of three gesturing rhesus monkeys. For monkey 1 the proportion of fixations falling on the face was 0·67, 0·85, and 0·87, while for monkey 2 the proportions were 0·30, 0·44, and 0·53 for the averted gaze, grin, and threat faces, respectively. Thus monkey 1 fixated gesturing faces more than monkey 2, a finding consistent with earlier observations for nongesturing rhesus faces. Both observer monkeys fixated on the rhesus face with an averted gaze *least* often and the rhesus threat face *most* often.

Figure 3 shows how on-face fixations were distributed with respect to eyes, nose, and mouth for the rhesus stimulus faces portraying different gestures. Comparable data for the nongesturing gaze-alone rhesus faces (presented earlier) are also included. Figure 3 shows that, compared to typical fixation distributions for rhesus gaze-alone faces, higher proportions of fixations occurred within the lower half of gesturing faces.

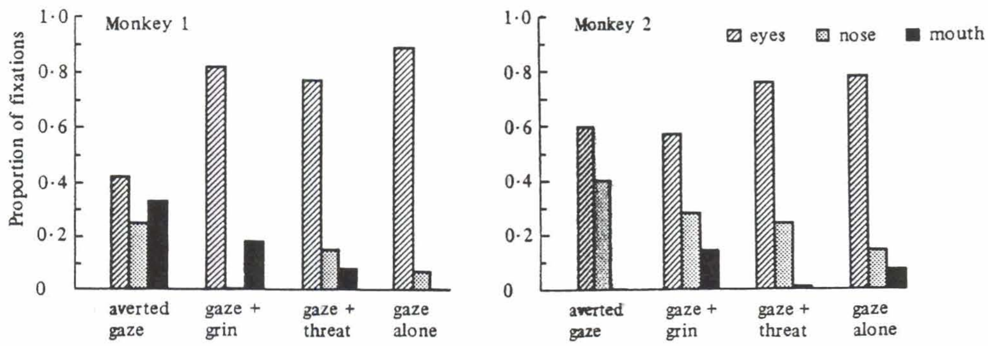


Figure 3. Proportion of on-face fixations within eye, nose, and mouth regions for rhesus gesture faces. Median proportions are displayed for the 'gaze-alone' type.

(1) Probabilities for rhesus, chimpanzee, human, and schematic faces in that order were ($x = 34/f = 0.47$; $n = 39$), ($x = 33/f = 0.42$; $n = 44$), ($x = 18/f = 0.41$; $n = 23$), ($x = 22/f = 0.5$; $n = 29$) for monkey 1 ($p < 0.01$) and ($x = 10/f = 0.45$; $n = 13$), ($x = 30/f = 0.45$; $n = 39$), ($x = 11/f = 0.43$; $n = 17$) and ($x = 20/f = 0.49$; $n = 30$) for monkey 2 ($p < 0.05$) where x = the number of on-eye fixations, n = the number of on-face fixations, and f = the average fraction of facial area occupied by eyes for all three faces of a type.

However, eyes remained the most fixated facial feature for these faces despite the presence of prominent mouth gestures. The eyes of stimulus faces captured a disproportionate number of fixations from observer 1 ($p < 0 \cdot 005$) and observer 2 ($p < 0 \cdot 05$) when the fraction of facial area eyes subsumed is taken into account[(2)].

As before, monkey 2 tended to fixate on the eyes of stimulus faces earlier and off the eyes later during each rhesus gesture-face presentation. No particular tendency for fixation sequencing could be discerned for monkey 1.

3.3 *Human facial gestures*

Five different human models were shown twice to each observer monkey: once with lowered and once with raised eyebrows. The order in which lowered-brow and raised-brow poses were presented was counterbalanced across models for each monkey. Table 1 presents the proportion of fixations directed toward models' varied brow poses. Human error resulted in the loss of data for one model. Therefore table 1 includes the responses of monkey 1 to only four models.

If brow gestures had no effect on scanning, any differences between the proportion of on-face fixations for lowered-brow and raised-brow poses should be inconsistent in direction. However, table 1 shows for monkey 1 differences in only one direction: in all four cases fewer on-face fixations occurred for brow frowns than for raised-brow expressions, $p < 0 \cdot 062$ (one-tailed binomial test). Table 1 shows that monkey 2 produced fewer on-face fixations when viewing lowered-brow poses for four of five models ($p < 0 \cdot 156$, one-tailed binomial test) though differences due to brow poses were much smaller than for monkey 1 and, in one case (model C), reversed direction.

The eyes attracted between 65 and 100% of on-face fixations across the eight human gesture faces for monkey 1: again, more than the expected number given the area subsumed by eyes ($p < 0 \cdot 001$)[(3)]. In general, fixations of monkey 2 also fell in disproportionately large numbers on the eyes of human gesture faces ($p < 0 \cdot 001$)[(3)]. However, monkey 2 displayed a particularly uncharacteristic avoidance of the eyes of model C when presented with lowered brows—only 20% fell on the eyes, compared with between 33 and 100% for the various poses of other models.

Neither monkey showed any obvious temporal pattern when scanning human gesture faces, there being about as many cases of early as late on-eye fixations.

Table 1. Percentage of on-face fixations for human faces with raised eyebrows (RE) and lowered eyebrows (LE).

Model	Monkey 1		Monkey 2	
	RE	LE	RE	LE
A	80	40	33	21
B	89	45	54	47
C	*	*	29	36
D	71	53	17	14
E	55	44	25	18

* Missing data.

(2) For observer 1, $p\ (x = 29/f = 0 \cdot 49;\ n = 42) < 0 \cdot 005$ while for observer 2, $p\ (x = 13/f = 0 \cdot 47;\ n = 20) < 0 \cdot 05$ where x = the number of on-eye fixations, n = the number of on-face fixations, and f = the average fraction of facial area occupied by eyes for all three rhesus gesture faces.

(3) For monkey 1, the $p\ (x = 72/f = 0 \cdot 37$ and $n = 90) < 0 \cdot 001$, while for monkey 2, the $p\ (x = 29/f = 0 \cdot 37$ and $n = 43) < 0 \cdot 001$, where x = the number of on-eye fixations, n = the number of on-face fixations, and f = the average fraction of facial area occupied by eyes across all human gesture faces.

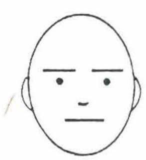
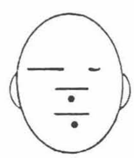
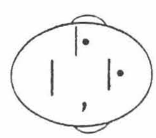
3.4 *Schematic controls*

Several factors might explain visual attentiveness to eyes and faces. Perhaps observer monkeys were merely attracted to visual contour provided by facial elements. The contours of the eyes were particularly salient. Alternatively, scan patterns might have been triggered not by isolated features but by 'faceness', the facelike configuration of individual features. To the extent that fixation patterns are attributable to 'faceness', non-facelike displays of identical features ought to shift such fixation patterns.

For each observer we compared fixation responses to each of three rearranged schematic 'faces' with the median responses produced by schematics having the same features arrayed in a facial configuration (see table 2). Medians were treated as expected values for binomial probabilities. Table 2 shows fixation patterns for each observer monkey in response to the three typical and the three rearranged schematic 'control' faces. As table 2 suggests, the on-face fixations for monkey 1 fall below the median for typical faces on two (a and b) of three control faces (each $p < 0{\cdot}01$). For monkey 2, fixations for each of the three control faces fall below the median for typical faces (all $p < 0{\cdot}05$). So, with one exception, less visual attention was paid to atypical faces, though they were comparable in detail as well as overall size. Thus it seems that at least part of the visual interest in schematic faces was owed to the facelike array of features.

Visual interest shifted away from eyes for only some of the rearranged schematics. Considering the fraction of the rearranged face subsumed by eyes, monkey 1 directed fewer on-face fixations to misplaced eyes than expected for schematic c (30%, $p < 0{\cdot}05$) and more than expected for b (83%, $p < 0{\cdot}06$) but not for a (57%, $p = 0{\cdot}26$). Monkey 2 produced more than the expected number of fixations in response to the misplaced eyes of b (87%, $p < 0{\cdot}02$), but not a (60%, $p = 0{\cdot}28$) or c (75%, $p = 0{\cdot}36$).

Table 2. Proportion of fixations occurring within facial outlines during presentation of schematic faces.

Monkey	Three typical faces (example)	Rearranged faces a	b	c
				
1	0·76(0·50–0·80)[a]	0·41	0·38	0·77
2	0·73(0·53–0·82)[a]	0·33	0·50	0·31

[a] Median (range).
Note: The total number of fixations for a, b, and c were, in that order, 17, 16, and 13 for monkey 1 and 15, 16, and 13 for monkey 2.

3.5 *Position effect*

We varied the location of stimulus faces on the viewing screen to control for a position influence on eye movements. However, position variation was restricted owing to certain features of the apparatus. So, although the exact location of the eyes of stimulus faces varied, eyes typically occupied areas in the upper half of the viewing screen and could have coincided with a position preference for the upper half of the screen. However, our observer monkeys showed no such position preference when searching the viewing screen for a target which appeared at unpredictable locations as part of a visual search study (see Keating and Dineen 1980).

4 Discussion

Fixation patterns for both observer monkeys revealed a striking preoccupation with the eyes of stimulus faces, regardless of facial expression. By about two months of age human scan patterns in response to human faces show a similar pattern (Haith et al 1977; Maurer and Salapatek 1976).

Though eyes were the main attraction of faces, the data hint at other factors which seemed to modulate the ability of the eyes to capture fixations. For instance, monkey 1 generally fixated the eyes of stimulus faces more than monkey 2, implicating individual differences in looking strategies. Such differences may relate to the social dominance of individuals (Hall 1968; Haude et al 1976). This possibility makes intuitive sense since interobserver differences in performance were most pronounced for the categories of faces which ought to be socially meaningful to laboratory monkeys (rhesus and human faces) and least obvious for fictitious (schematic) faces.

Another factor affecting scanning patterns, at least for schematic faces, involved facial configuration. An overall resemblance to faces apparently enhanced visual interest in schematic stimuli, since fixation frequencies were generally reduced for schematic drawings with rearranged non-facelike arrays of features. These results are consistent with findings for human infants which indicate the development of greater visual interest in facelike than non-facelike stimuli (Fagan 1972; Caron et al 1973; Haaf 1977).

Facial gestures may also influence fixation patterns. Perhaps our best test of gesture effects involved human faces, because, unlike the rhesus gesture faces, these stimuli were well controlled for overall size, feature-area size, screen position, and facial idiosyncrasies. For human models the proportion of on-face fixations were generally smaller for lowered-brow poses than for raised-brow poses. Did observer monkeys perceive the human brow frowns as threatening and respond submissively with their own averted gazes? This is an intriguing possibility since among rhesus monkeys lowered-brows frequently signal a confident threat (Hinde and Rowell 1962; van Hooff 1967). In contrast to results for human gestures, observer monkeys fixated *less* frequently on less threatening rhesus faces. When presented a rhesus displaying an averted gaze observer monkeys fixated the face less often than when shown rhesus faces which 'stared' at them.

Even for stimulus faces with dramatic mouth gestures eyes persisted in being the most fixated facial feature. Yet mouth gestures are known to play an important role in rhesus communication, and it is doubtful that such signals were ignored. There is reason to assume that visual fixations index attention (Mackworth and Morandi 1967), but do so imperfectly (Grindley and Townsend 1968). Observer monkeys may have fixated eyes while simultaneously attending to other facial features with their peripheral vision. Obvious mouth gestures could be readily monitored at the corner of one's vision. But shifts of the eyes may be fairly subtle, their detection requiring frequent sampling with direct foveal gaze. If eyes are the window to the soul and forecast intent, they may be critical to monitor in the initial five seconds of face-to-face contact.

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