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EYE ORIENTATION DURING VISUAL DISCRIMINATION LEARNING BY MONKEYS

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Abstract—Motion pictures were taken of the eyes of monkeys as they learned simultaneous two-choice pattern discriminations. Discriminanda were projected onto the response keys. Each animal looked at and responded more to one of the keys, and as it learned the problem, looked more at the correct than at the incorrect stimulus. The preferred side for ocular, and hand responses was not correlated with the preferred eye or hand.

STUDIES of discrimination learning in animals have concentrated almost exclusively on such performance measures as rate, latency, or choice of response. In primates, eye movements are particularly important in perception and discrimination. Thus, we have undertaken to investigate eye movements during visual discrimination learning by monkeys. In the present study, we measured how many times and how long the monkeys looked at each stimulus during the acquisition of a simultaneous discrimination. Measures of ocular behavior were related to the animal's performance level, response latency, and eye and hand preferences.

One purpose of this study was to provide a more complete description of visual discrimination behavior. Analysis of eye movement may be a more direct way of determining response strategies than analysis of error patterns. A second purpose was to provide a normative baseline for investigations of the physiological mechanisms of visual discrimination. Several types of treatment (e.g. brain lesion, brain stimulation, drugs) can impair visual discrimination learning. Do such discrimination deficits involve changes in the behavior of the animal's eyes as well as in its learning scores? The technique and results described in the present study should help answer this question.

METHOD

Subjects

The *S*s were seven immature male rhesus monkeys (*Macaca mulatta*), weighing between 2·5 and 4 kg. All *S*s were experimentally naive at the start of this study.

Apparatus

The apparatus was similar to devices used for studying visual discrimination learning by split-brain monkeys [1]. It consisted of a box, 24 × 37 × 48·5 in., with an animal compartment and a discrimination panel (Fig. 1). The animal could view the panel through eye holes in a face mask, and could reach the

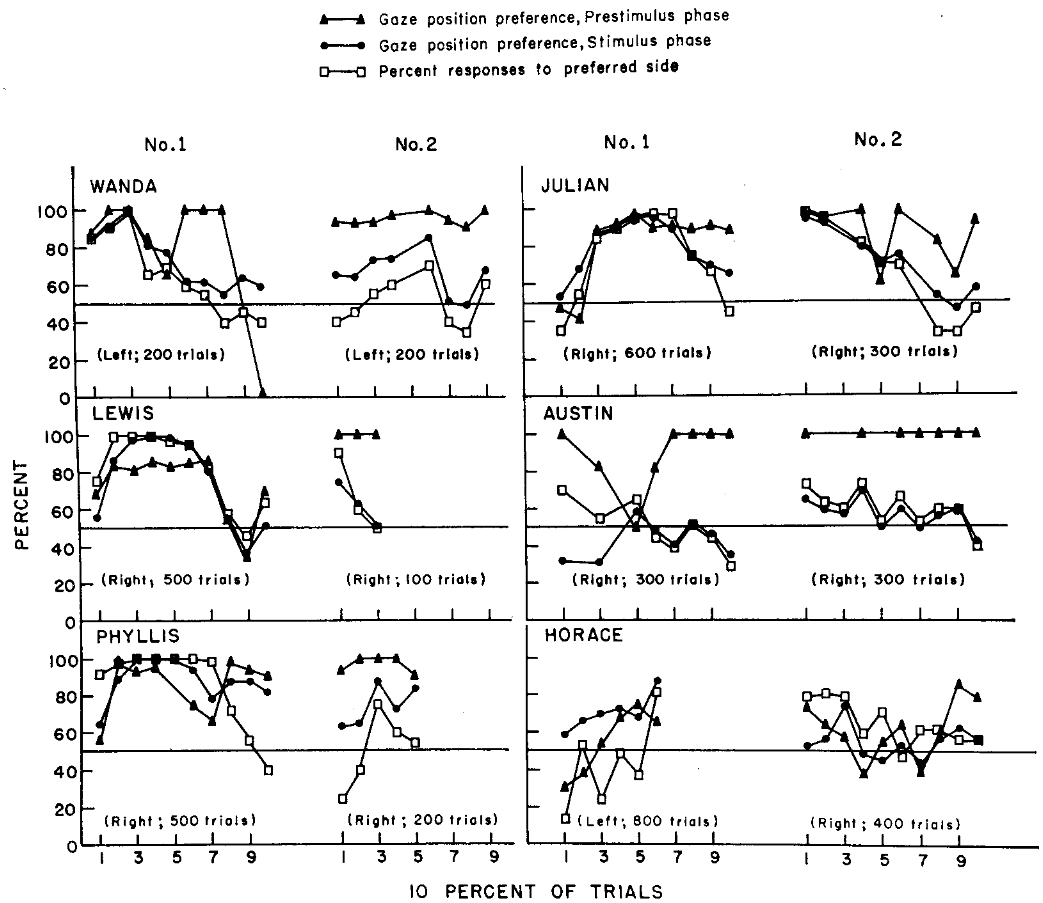

FIG. 2. Per cent responses to the preferred side and percent gaze position preferences, as a function of tenths of the total number of trials to criterion on pattern discrimination No. 1 and No. 2.

$$\% \text{ gaze position preference} = \frac{\text{Time } S \text{ looks at preferred side key}}{\text{Time } S \text{ looks at both keys}} \times 100.$$

The preferred side and the total number of trials are indicated beneath each set of curves.

range of from one every 2 sec to about three per sec. Sixty-nine per cent of all gaze shifts occurred during the stimulus phase.

Stare-time preference and gaze-shift preference for one animal (Julian) are compared with its gaze position preferences in Fig. 3. The close relation of the gaze position curve to the gaze shift curve (rather than to the stare-time curve) was typical. This suggests that the gaze position preference curve was made up principally of the sum of a number of separate gaze shifts to the preferred side rather than longer stares with fewer gaze shifts.

All *S*s looked more at the correct stimulus than at the incorrect stimulus as learning progressed. In fact, the curve representing the proportion of time *S* looked at the correct stimulus is nearly identical in form to the learning curve (Fig. 4).

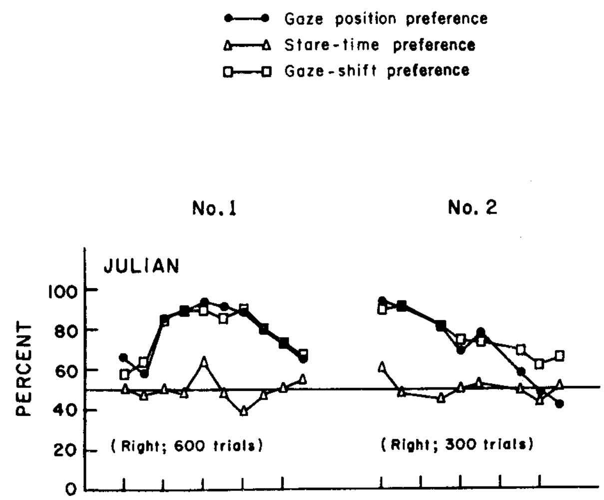

FIG. 3. Per cent stare time to the preferred side, percent gaze shifts toward the preferred side, and percent gaze position preferences for combined prestimulus phase and stimulus phase.

$$\%\text{ stare-time preference} = \frac{\text{Mean stare length at preferred side key}}{\text{Mean stare length at both side keys}} \times 100.$$

$$\%\text{ gaze-shift preference} = \frac{\text{Mean No. gaze shifts toward preferred side key}}{\text{Mean No. gaze shifts toward both side keys}} \times 100.$$

Response latency was measured as the time between side stimulus onset and a response. Latencies for correct responses were longer than for incorrect responses (t=2.85, df=11, p<0.02). Furthermore, latencies for responses to the preferred side were shorter than for responses to the nonpreferred side (t=5.19, df=13, p<0.01).

Table 1 shows that animals with a gaze position preference to one side did not necessarily prefer to use the ipsilateral eye or hand. Animals were consistent in their use of a particular hand for responding in the apparatus; however, they did not always use either hand exclusively for reaching in the home cage.

DISCUSSION

Throughout training each monkey had a strong preference for looking at one of the side keys. This ocular gaze-bias followed closely each subject's position bias in pressing the keys, thus confirming the common but previously unproved assertion that monkeys "look at what they touch" [2]. By contrast, the gaze and response side-preference was unrelated to either the animal's preferred eye or hand. It was interesting that, although as the animals learned each problem the position preference (both gaze and response) usually declined in the period when the stimulus was on, the gaze position preference remained strong in the pre-stimulus period.

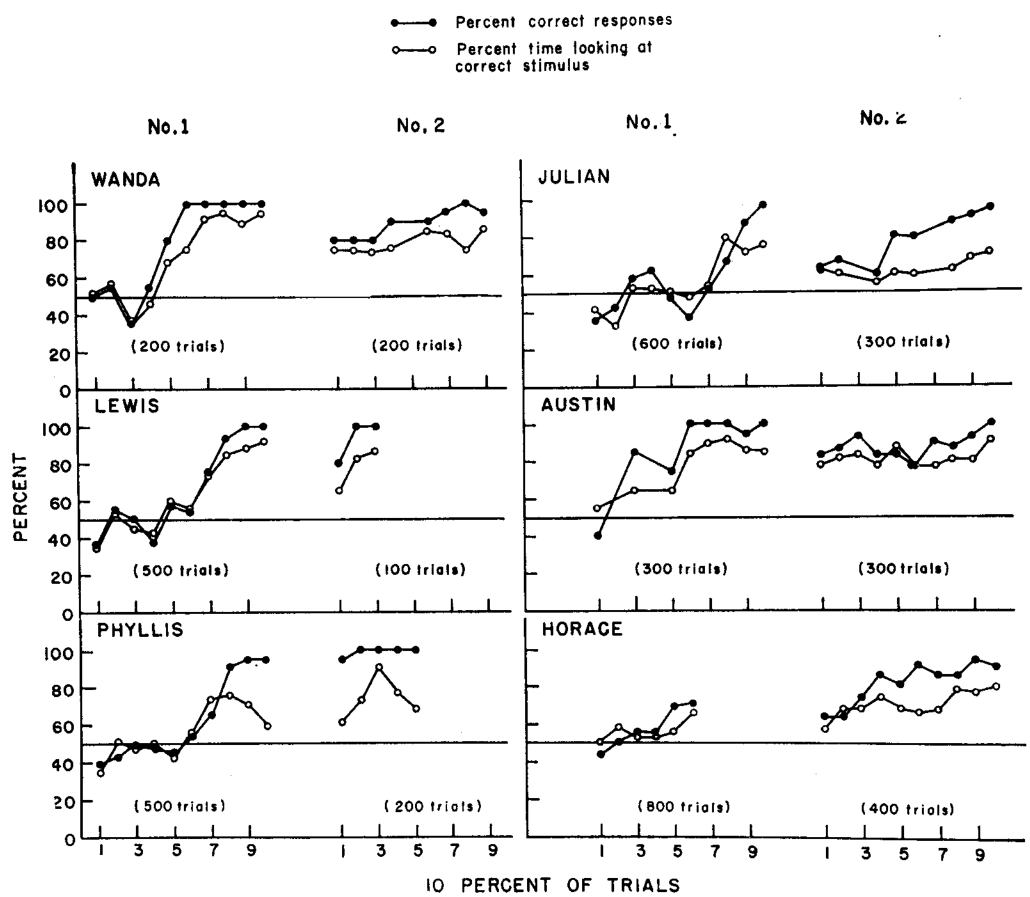

FIG. 4. Per cent correct responses and percent time spent looking at the correct stimulus. Total number of trials to criterion is indicated beneath each set of curves.

Table 1. Preferred eye, gaze position preference, response position preference, and preferred hand

	Eye preference	Gaze position preference (Prestimulus phase) Prob. No. 1	Prob. No. 2	Response position preference (Errors to preferred side) Prob. No. 1	Prob. No. 2	Hand preference Reaching	Responding*
Wanda	52% R	93%‡ L	95%‡ L	91%‡ L	33% L	58% L	R
Julian	76%† R	82%‡ R	86%‡ R	81%‡ R	87%‡ R	70%† L	R
Lewis	60% R	74%‡ R	100%‡ R	93%‡ R	100% R	88%‡ L	R
Austin	72%† R	78%‡ R	100%‡ R	76%‡ R	100%‡ R	78%‡ L	R
Serafino	92%‡ L	38% R	100%‡ R	74%‡ R	96%‡ R	84%‡ L	L
Phyllis	72%† R	92%‡ R	96%‡ R	96%‡ R	—	80%‡ R	L
Horace	88%‡ L	59%‡ L	61%‡ R	38% L	97%‡ R	100%‡ L	R

* Preference determined by observation of S in the apparatus.
† Significantly different from 50% ($p < 0.05$).
‡ Significantly different from 50% ($p < 0.01$).

The decline in the gaze position preference in the stimulus period as the animal learned the discrimination reflected an increased tendency to look longer and more often at the correct stimulus. Parallel to this increased proportion of time spent looking at the correct stimulus was a greater latency in responding to the correct stimulus. Previous studies measuring latency in discrimination learning, all with rats, have reported the opposite phenomenon, namely greater latency for incorrect than correct responses [3–5]. Here the latency differences between correct and incorrect responses appeared to be a result of the monkey's strong gaze position preferences in the pre-stimulus period. The latencies for response to the preferred side were less than those to the non-preferred side. In the pre-stimulus period, *S*s tended to look at their preferred side, and as they learned the problem, only looked to the other side when the stimulus came on if the correct stimulus was on the non-preferred side. Virtually all errors were made on the preferred side. Thus, the longer mean latencies for correct responses simply reflected the longer latencies on the non-preferred side.

In summary, the technique described in this report affords a relatively simple method of studying eye movements during discrimination learning by monkeys.* With it we demonstrated a close correlation between gaze and response position bias. Furthermore, we have shown how this gaze preference is modified in the stimulus period as the animal learns the problem so that it spends more time looking at the correct stimulus. We are currently applying this technique to two further problems: analysis of fixation changes within the borders of a single stimulus, and investigation of the effects of inferotemporal lesions on eye movements and eye orientation. Inferotemporal lesions are known to produce a severe impairment in visual discrimination performance. Preliminary data indicate that decreased rate of gaze shift and increased staring at the discriminanda are associated with this deficit.

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Résumé—On a filmé les yeux des singes tandis qu'ils apprenaient des discriminations de pattern à deux choix simultanés. Les discriminanda étaient projetés sur les touches de réponse. Chaque animal regardait et répondait d'avantage à l'une de ces touches et, tandis

* Recently SCHRIER [6] has developed a similar technique for the study of primate eye orientation.

qu'il apprenait le problème, regardait plus le stimulus correct que le stimulus incorrect. Il n'y avait pas de corrélation entre, le côté préféré pour les réponses oculaires et manuelles et l'oeil ou la main préférentielle.

Zusammenfassung—Während Affen Alternativwahlobjekte unterscheiden lernten, wurden ihnen gleichzeitig Filme vor Augen geführt. Das projizierte Material stimmte mit den zu unterscheidenden Wahlobjekten überein. Jedes Tier blickte hin und reagierte jeweils stärker auf eines der beiden projizierten Reizobjekte. Als die Tiere das Problem erfaßt hatten, bewegten sie die Augen mehr zum korrespondierenden als zum nicht entsprechenden Reizobjekt. Die bevorzugte Reaktionsseite für Auge und Hand korrelierte nicht mit Äugigkeit und Händigkeit.