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Relationship Between Shape Perception by Touch and Eye Movement: A Further Study

Shoji Itakura

Oita Prefectural College of Arts and Culture, 1-11 Uenogaoka-higashi, Oita 870 Japan

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Abstract.

Two experiments were conducted to explore the relationship between eye movement and perception of an object's shape by touch. In Experiment 1, subjects' eye movements were recorded during the exploration of object by touch. In Experiment 2, recognition of the shape of objects by touch was compared when eye movements were suppressed and when natural eye movements were allowed. Analysis shows that there is a specific pattern of eye movement in each subject during tactile exploration and these eye movements affect the perception of shape by touch.

In general, there are two types of studies of eye movement during problem-solving tasks. One type of study investigates the strategy of problem-solving by detecting where the subject is looking. The other type investigates the relationship between brain activity and eye movement during problem solving (Takeda, 1994). Both types of studies examine the relationship between information processing and eye movement.

Some researchers have found that the number of eye movements increases during problem-solving tasks (Stoy, 1930; Lorens & Darrow, 1962; Amadeo & Shagass, 1963); however, Nakamizo (1971) found that the number of eye movement did not increase during a mental arithmetic task, so results are inconsistent, although it is certain that there are relationships between eye movement and some psychological tasks (Koga, 1983; Yamada, 1983).

We were interested in the relationship between perception of an object's shape due to touch and eye movement. An object's shape can be perceived in both visual and tactile modalities. In other words, we are capable of recognizing the shape of objects by touch alone. If there are some relationships between eye movement and problem solving, may specific eye movements be observed during tactile exploration? What kinds of eye movement pattern appear during perceiving the shape of object by touch? Is the ability to perceive the shape of an object by touch affected if eye movement is controlled?

In Experiment 1, eye movement was recorded by an eye movement analyzer during the exploration of object's shape by touch. In Experiment 2, we investigated whether the suppression of eye movement affects the ability to perceive shape by touch by using a cross-modal matching task. Were there differences in performance on the matching task between the condition with suppressed eye movement and that with natural eye movement would suggest the possibility that eye movement plays a role as a cue in recognition of the shape of an object by touch.

EXPERIMENT 1

In Experiment 1, while subjects explored an object tactilely to determine its shape, their eye movement patterns were recorded using an eye movement analyzer.

Method

Subjects. The subjects were 9 female students, all of them were 19 years old, recruited from Oita Prefectural College of Arts and Culture. The subjects were divided into two groups arbitrary according to experimental conditions.

Apparatus. An eye movement analyzer (TALK EYE: TAKEI KIKI KOGYO CO.LTD.) was used to analyze and record eye movement during tactile exploration.

Stimuli. The stimuli consisted of "codon" which provide a complete basis for describing any wiggly curve and hence can be used to enumerate a class of silhouettes (Hoffman & Richards, 1982) . Codon quadruples were chosen as stimuli (Figure 1, see Richards, koendeeink, & Hoffmanet, 1988) . A codon was made of white plastic board, 0.7 cm thick and 6 cm in size. Each stimulus was stuck on a black paper panel (20×20cm) .

Procedure. With the subject wearing the eye-movement analyzer, the first stimulus on her lap and covered with 23×23×15cm enclosed box. So the subject could not see the stimulus. Then the subject's right hand was guided to the stimulus by the experimenter. The subject was asked to explore the stimulus for 20 sec by active touch (Gibson, 1962) and then to describe its shape. Subjects were instructed not to close their eyes and see the forward wall naturally, that was natural eye-movement. During the exploration, subjects' eye movements were recorded by the TALK EYE system. Half of the subjects were presented six codon, from No.1 to No.6, and the remainder were presented stimulus No.7 to No.12. Only six stimuli were presented because it was uncomfortable for the subject to wear the eye movement analyzer for more than 20 min.

Results and Discussion

Traces of the eye movements of each subject corresponding to each stimulus are shown in Figure 1. The eye movements of subject 1 for codon No.4 and subject 4 for codon No.6 were not recorded because of computer failure, so those parts of Figure 1 are left blank.

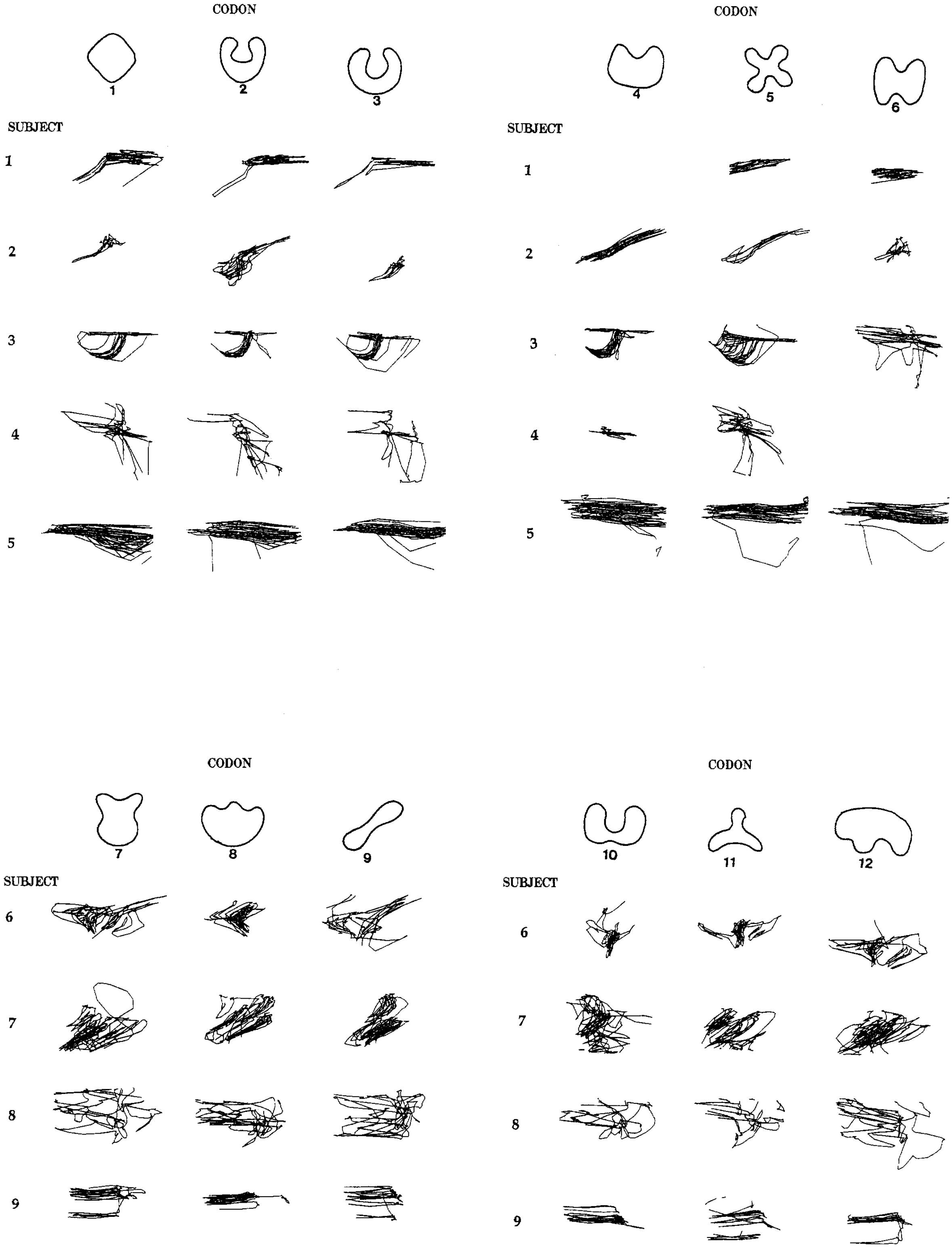

Figure 1. Traces of eye movements during the exploration by touch.

Traces of eye movements seem to suggest there is a pattern of eye movement for each subject during the tactile exploration of objects. Within each subject the traces of eye movement for each codon are similar to each other. However, although it seems that the outline of the eye movement was consistent for each subject, there are subtle differences within the trace for each codon. Those differences may reflect the differences among shapes of codons.

EXPERIMENT 2

In Experiment 1, we found that there was the same pattern of eye movement during the exploration of the shapes of objects for each subject. In Experiment 2, we investigated whether performance on the shape-perception task differed between the condition with eye movement suppressed and natural eye movement.

Method

Subjects. The subjects were 28 female students recruited from Oita Prefectural College of Arts and Culture. They were all 18- or 19-year-olds. The subjects were divided into two groups arbitrary according to the experimental conditions.

Apparatus. Data collection was controlled by NEC9801-FApersonal computer with a keyboard. The comparison stimuli were presented on the screen at a viewing distance of about 40 cm.

Stimuli. The sample stimuli were same as those used in the Experiment 1.

The comparison stimuli were presented on the CRT in a 3 x 4 matrix of blue line drawings.

Procedure. The task was a type of cross-modal matching to sample. The subject faced the CRT of the computer and the two experimenters sat on each side of the subject. One experimenter presented the sample stimulus, which were same stimuli as in Experiment 1, the same way as in Experiment 1. The other experimenter operated the computer. One experimenter presented the stimulus with a box put over the stimulus on the subject's lap and guided the subject's right hand to the stimulus. The subject was asked to explore the stimulus for 5-sec by active touch (Gibson, 1962) without seeing it. After 5 sec the stimulus was withdrawn and 12 stimuli (codon line drawings) were presented on the CRT. The subject had to choose the stimuli which corresponded to the one she has touched by typing the key corresponded to the stimulus position on the CRT simultaneously. The order of presentation of sample stimuli and the positions of comparison stimuli on the CRT were randomized on every trial.

Each subject was tested with 12 codons. It was possible to give 12 stimuli to the subjects, because they did not wear the eye-movement analyzer. There were two experimental conditions. Half of the subjects had to fixate a point on the center of the CRT during the exploration (suppressed eye movement) , The remainder of the subjects were allowed natural eye movement during the exploration, that is, instructed to look at the CRT naturally. Previously we tested whether subjects continued to fixate the center of CRT when instructed to fixate by using the eye-movement analyzer (TALK EYE). The results of this test suggested that we could control the subject's eye movement by instruction.

Results and Discussion

The results of Experiment 2 are shown in Figure 2 and Figure 3.

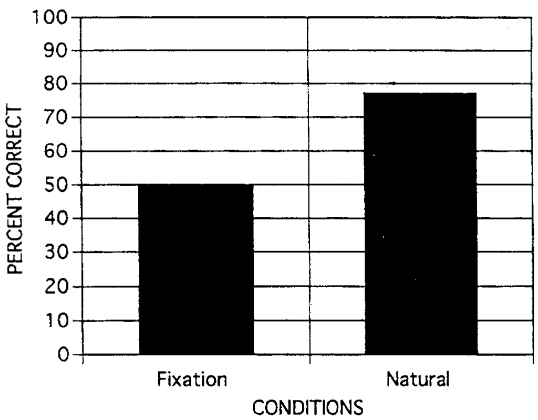

Figure 2. Percentage of correct responses in suppressed eye movement condition and natural eye movement condition.

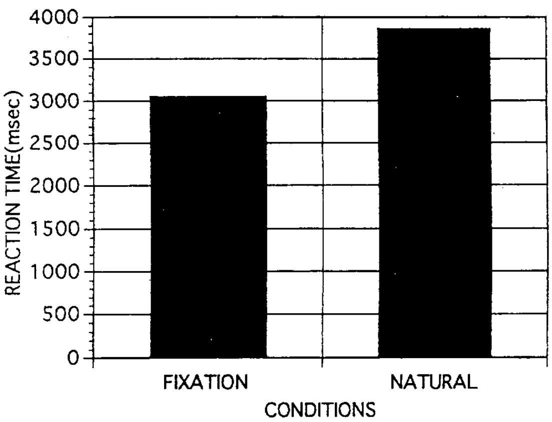

Figure 3. Mean reaction time in suppressed eye movement condition and natural eye movement condition.

Figure 2 shows the mean percentage of correct responses in the two conditions. A significant difference was found between success on the suppressed eve-movement and natural eve-movement ($t=3.55$, $df=24$, $p<0.01$). The percentage of correct responses in the condition with natural eye movement was higher than that with suppressed eye movement. Figure 3 shows the mean reaction time for responses, which was significantly longer in the natural eye-movement condition than in suppressed eye-movement condition ($t=2.59$, $df=24$, $p<0.02$).

GENERAL DISCUSSION

Tow main conclusions can be drawn from these studies. First, there are regular patterns of eye movement specific to each subject during the exploration of objects by touch (Experiment 1). Second, there is some relationship between eye movement and the ability to perceive an object's shape by touch (Experiment 2). Specifically, the percentage of correct responses in the task requiring perception of shape by touch was higher when eye movements were natural than when eye movements were suppressed.

There are many reports of relationships between cognitive tasks and eye movement, but not tactile tasks like as in our experiments. However, little is known about individual differences in the pattern of eye-movements during the tasks. According to Takeda (1994), the cognitive style of the subjects is reflected in the scanpaths elicited during a task required comparisons of figures.

The specific patterns of eye movement during the exploration of an object's shape suggest the possibility that the information processing involved in the perception of shape by touch produces movements of the eyes as a side effect. These movements would not influence the cource of the information processing but arise purely as a consequence of it, similar to the phenomena of lateral eye movement (Day, 1964; Duke, 1968; Weiten & Etaugh, 1973). However, some of the eye movements recorded in our studies were not mere movements to the right or left. Suggesting a need to explore the relationship between each pattern of eye-movement and the shape of the codon presented. This may answer why suppressive eye-movement makes this kind of cross-modal matching task difficult.

One possible reason for lowered performance in the condition with suppressed eye-movement concerns attention. Some level of attention may be necessary to fixate a point on the screen, leaving less attentional resources for the task of perceiving shape. Such dispersion of attention might result in decreasing the percentage of correct responses. However, we seem to be able to fixate a target without attention. If so, the subjects recognize the shape of objects in suppressed eye movement condition. The subject might have used eye movement as a cue for the recognition of the shape without consciousness. In the suppressed eye-movement condition, however, they could not use eye movement as a cue. For this reason, performance in the natural eye movement condition was superior to that in the suppressed eye movement condition. We may be able to speculate that the differences in subjects' confidence were reflected in the different mean reaction times in the two conditions. In brief, because subjects had high confidence in their ability to discriminate the shape of the object in the natural eye movement condition, they tended to search until they found the exact target. In contrast, in the suppressed eye movement condition subjects had low confidence in their ability to discriminate the shape and were therefore more influenced by the request to respond as soon as possible.

In conclusion, eye-movement affects performance in this cross-modal matching task matching between perceptions of the shape of an object shape by touch and by vision. These eye movements are subject-specific and may be systematically related to the shape of the perceived object. However, these are only exploratory experiments. We are currently engaged in more sophisticated experimental work which aims to specify these relationships in detail.

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REFERENCES

Amadeo, M.,. & Shagass, C. 1963 Eye movements, attention and hypnosis. *Journal of Nervous & Mental Disease,* 136, 139-145.

Day, M.E. 1964 An eye movement phenomenon relating to attention, thought and anxiety. *Perceptual & Motor Skills,* 19, 443-446.

Duke, J. D. 1968 Lateral eye movement behavior. *Journal of General Psychology,* 78, 189-195.

Hoffman, D. D., & Richards, W. A. 1982 Representing smooth plane curves for recognition: implications for figure-ground reversal. *Prc. AAAI* 5-8.

Koga, K. 1983 Visual perception. *Advances in child psychology* 25-52(in Japanese) .

Lorens, S. A., & Darrow, C. W. 1962 Eye movements, EEG, GSR, and EKG during mental multiplication.
Electroencephalography and Clinical Neurophysiology, 14, 739-746.

Nakamizo, S. 1971 A psychophysiological study on eye movement: Some observations of eye movement during waking state with closed eyes by electrooculograph.
Kyusyu Daigaku Bungakubu Tetsugaku Nenpo, 30, 55-68.

Richards, W., Koendeeink, J. J., & Hoffman, D. D. 1987 Inferring 3D shapes from 2D silhouettes. *Science,* 224, 1260-1262.

Stoy, E. G. 1930 A preliminary study of ocular attitudes in thinking of spatial relations. *Journal of General Psychology,* 4, 379-385.

Takeda, M. 1994 Eye movements and problem solving.
in (Eds) R. Osaka, S., Nakamizo, K., & Koga *Experimental Psychology of eye, movements.* (Nagoya Daigaku Syuppankai. [in Japanese]

Weiten. W., Etaugh, C. F. 1973 Lateral eye movement as related verbal and perceptual-motor skills and values.
Perceptual & Motor Skills, 36, 423-428.

Yamada, K. 1983 Problem solving. *Advances in child Psychology.* [in Japanese]