Accuracy of delayed aiming responses[1]

DENNIS H. HOLDING, *DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF EXETER, England*

Stylus aiming responses were made in the dark after the brief illumination of a target, and during or before the target exposure. Response accuracy was measured as a function of length of delay and of the duration of target exposure. Error increases linearly with logarithmically increasing delay and, within the limits investigated, decreases with logarithmic increase of exposure duration.

Short-term retention of spatial information is conveniently studied by the measurement of motor response accuracy at varying delays. Initial target location may be visual or kinesthetic, the S attempting either to reach a previously seen position or to reproduce a prior movement. Münsterberg (1892) and Adams & Dijkstra (1966) have reported retention data for the blindfold reproduction of movements, showing progressive decrease in precision with time elapsing after an initial response. Posner (1967) has postulated a basic difference between visual and kinesthetic memory codes, finding substantial interference by an interpolated task but no effect of rest on the reproduction of a visually perceived movement length, with the reverse effect following kinesthetic length perception. However, it seems likely that this conclusion is dependent upon the particular circumstances of the experiment, in which all Ss were exposed to loss of kinesthetic set but the interpolated task was visual.

Earlier work with both modalities by Bowditch & Southard (1880) shows trends in aiming accuracy after visual target location which are comparable with those resulting from location by touch, both curves displaying tendencies to improvement at 2-4 sec delay preceding an overall deterioration. In the main version of the visual task the S observed a stationary target, closed his eyes and aimed a stylus point at the target after delays indicated by a metronome beat. The present experiment attempts a more systematic investigation of visual aiming, obviating voluntary eye closure by controlling target illumination and varying both delay and target exposure durations.

Method

Apparatus. Targets were 8 x 10 in. paper sheets, showing a black 1 cm diameter circle surrounded by concentric rings of 1, 2, 3, 4, and 5 cm radius. One at a time was mounted on a fibreboard backing at an angle of 45 deg, with the target center 6 in. above elbow height. Responses were made with a finely tapered stylus. The experiment was conducted in a completely darkened room, the target and surrounding equipment being diffusely illuminated when stimulus exposure was required. A low brightness level of approx. 0.05 mL was chosen to minimize the formation of afterimages. Timing equipment provided a repetitive 10 sec cycle of events during which the light-on time was followed by an adjustable delay period preceding the signal for response. The signal was a loud "pop" produced by the discharge of a capacitor across a loudspeaker.

Design. The 54 Ss, all college undergraduates, were used in 3 groups of 18 each at the target exposure times of 1/16, 1/4, and 1 sec. There were six response (delay) times, located at 1/4 sec before light offset, at light offset and thereafter at delays increasing by steps of 1/4, 1/2, 1 and 2 sec (i.e., at delays of -1/4 and 0 to 3-3/4 sec). Each S was tested at all delay times, each group of 18 Ss providing three replications of a 6 by 6 block in which delay times and order effects were counterbalanced.

Procedure. With the room lights on, seating position was adjusted, the sequence of operations demonstrated and Ss given an opportunity to respond with the stylus. The lights were then extinguished for the rest of the session lasting approx. 1/2 h. Ss were instructed to stab where the target had appeared immediately the signal was heard, making a ballistic movement without hesitation or correction. One practice shot was made at each delay time. Testing then proceeded with 20 shots at each delay time, in each case preceded by a demonstration of the appropriate delay with no response required. Sets of shots were separated by 1 min rest pauses.

Results

Mean deviation of stylus holes from the target center, irrespective of the direction of error, was measured at each delay time. The mean error for each stimulus exposure group is shown in Fig. 1. There are clear trends towards increasing error with length of delay and with brevity of stimulus exposure. An overall analysis of variance confirms that there is a highly significant difference between delays ($F = 9.6$, $df = 5/306$, $p < .001$) and between exposure times ($F = 30.4$, $df = 2/306$, $p < .001$). There is no significant interaction between delay and exposure times.

Omitting the response time at 1/4 sec before light offset, the delays are logarithmically ordered. A second analysis was therefore made, using only the data for the five later delays. Partitioning the delay time variance into linear, quadratic and higher order components shows the linear effect to be highly significant against this scale ($F = 30.7$, $df = 1/263$, $p < .001$), no appreciable

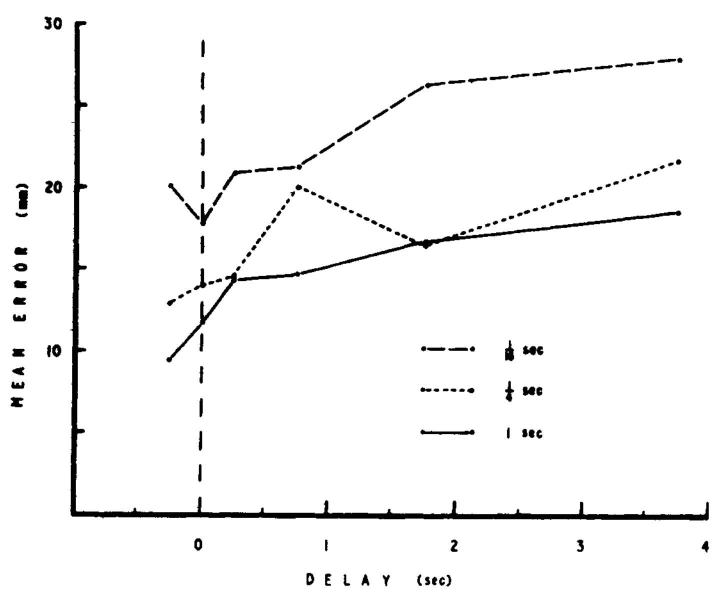

Fig. 1. Aiming error as a function of response delay and target exposure duration.

curvature effects being present. A similar analysis for exposure durations, which are also logarithmically spaced, again shows only the linear trend significant ($F = 38.5$, $df = 1/263$, $p < .001$).

Discussion

It is apparent that aiming error increases as a linear function of log delay time and of log exposure duration. The effect of delay parallels the steady deterioration found for longer time intervals by Adams & Dijkstra (1966) for kinesthetic retention. Since the data demonstrate a clear loss of accuracy during unfilled intervals, there is no confirmation of Posner's (1967) finding of zero loss after visual target exposure and thus no confirmation of the putative difference in function between visual and kinesthetic memory codes.

There is no evidence of the improvement shown at short delay intervals by Bowditch & Southard (1880). The curve for 1/4 sec exposure shows some apparent irregularity, but does not parallel the concave relationship of the earlier study. In any case no reliance should be placed upon the apparent anomaly, since the interaction between delay and exposure times was not significant. The Bowditch and Southard result was based upon only one S, who made many hundreds of responses, and may be due to individual difference or to several features of the experimental design.

The natural explanation of the steady loss during delay is in terms of a trace decay effect, which any rehearsal procedure is insufficient to overcome. It seems likely, nevertheless, that some form of sensorimotor rehearsal mechanism is a factor in delayed aiming behavior. Subjective reports suggest that during the delay period the S tends repeatedly to compare eye, limb and body sensations in order to preserve set. An iterative process of this kind would appear to be a continuation into the delay period of the normal preliminaries of "taking aim."

It is clear that some form of response preparation must be assumed necessary to the aiming activity. It is otherwise difficult to explain the increasing precision of aim with longer target exposure. What appears most probable is that the longer exposures permit the aim-taking process to be shifted forward into "light-on" time, with a consequent gain in accuracy. An effect of this kind would cease to obtain with exposure times greater than a few seconds, so that caution is needed in extrapolating from the exposure duration data.

REFERENCES

ADAMS, J. A., & DIJKSTRA, S. Short-term memory for motor responses. *J. exp. Psychol.*, 1966, 71, 314-318.

BOWDITCH, H. P., & SOUTHARD, W. F. A comparison of sight and touch *J. Physiol.*, 1880, 3, 232-245.

MÜNSTERBERG, H. *Beiträge zur Experimentellen Psychologie.* Freiburg: Siebeck, 1892, Heft 4, 81-88.

POSNER, M. I. Characteristics of visual and kinesthetic memory codes. *J. exp. Psychol.*, 1967, 75, 103-107.

NOTE

1. This work forms part of a project supported by the Science Research Council of Great Britain.