MONTAGUE. W. E., HILLIX, W. A., KIESS, H. O., & HARRIS, R. Variation in reports of covert rehearsal and in STM produced by differential payoff. Journal of Experimental Psychology, 1970, 83, 249-254.

PETERSON, L. R., & PETERSON, M. J. Short-term retention of individual verbal items. Journal of Experimental Psychology, 1959, 58, 193-198.

POSNER, M. I., & ROSSMAN, E. Effect of size and location of informational transforms upon short-term retention. Journal of Experimental Psychology, 1965, 70, 496-505.

PYLYSHYN, Z. W. The effect of a brief interpolated task on short-term retention. Canadian Journal of Psychology, 1965, 19, 280-287.

SCOTT, D., & BADDELEY, A. D. Acoustic confusability values for 1172 CCC trigrams. Psychonomic Science, 1969, 14, 189-192.

WICKENS, D. D., BORN, D. G., & ALLEN, C. K. Proactive inhibition and item similarity in short-term memory. Journal of Verbal Learning & Verbal Behavior, 1963, 2, 440-445.

## NOTES

1. Data were run on Temple University CDC 6400 computer.

2. Our data meets the assumption of symmetry and equality of the covariance matrices associated with repeated measures (Greenhouse-Geisser method, Winer, 1962).

# Scanning strategies and differential sensitivity in a visual signal detection task: Intrasubject reliability

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Four Ss (two of each sex) were run on 960 trials of a 16-alternative forced-choice visual signal detection task. Analysis of variance of d' values indicated the usual practice effects, as well as differential sensitivity to different target locations, and three significant interactions. Despite the significant changes in magnitude of d', each S demonstrated consistency in the ordering of sensitivity as a function of target location across blocks of 320 trials (W = .51, .76, .85, and .81). The data imply extremely strong scanning biases which existed prior to the experimental task and further suggest that less than 400-500 trials is quite sufficient for reliable estimation of differential sensitivity among all 16 target locations in a 16-AFC task.

Normal visual perception requires selective processing of the information available at any given time. An analysis of the selection process may be approached in the laboratory by presenting a visual display with more elements than can be processed during the presentation duration. Subsequent hypotheses are generated which attempt to describe the characteristics of those elements which will be processed. As the elements attended to on any trial are not randomly drawn from the display (Taylor, 1970), any consistency in relative sensitivity to parts of the display increases the information concerning the processing rules and/or scanning strategies used by a given S.

One measure of relative sensitivity to visual stimuli is d', the sensitivity index of signal detection theory. If a number of elements occur in a visual display, for example, and the S is required to specify the location of a particular target element, d' values for different locations could be most descriptive of the scanning or processing strategy in use by the S.

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Unfortunately, stable estimates of d' in a two-alternative forced-choice (2-AFC) task require from 500 to 2,500 observations (Green & Swets, 1966; Swets, 1964). For larger numbers of alternatives, the number of trials required for stable estimates of sensitivity to each alternative could become staggering. One of the major reasons for such high numbers of trials is a well-documented practice or learning effect, which may continue for as long as 10-12 h in a visual detection task (Blackwell, 1953). If, however, there is stability in the ordinal sensitivity to different target locations during the learning or practice effect, and if this differential sensitivity is of primary importance, it should be possible to obtain reliable estimates of differential sensitivity in fewer trials than would be necessary to obtain reliable estimates of the absolute magnitude of the sensitivity. Estes & Taylor (1966) have shown that test-retest reliability is high for the elements sampled by a S from a particular display, and this would suggest stability in relative sensitivity to parts of a display.

This study was preliminary to a series of studies concerning the factors influencing scanning strategies in a visual signal detection task. In this context, scanning refers to the method of processing a single visual image displayed for an interval too brief for actual physical scanning (no multiple fixations). A 16-AFC task was used, and the intent was to determine if a rather small number of trials might provide reasonable estimates of differential sensitivity for the 16 possible target locations.

## METHOD

Each stimulus contained 16 circles, in a 4 by 4 array, with 15 of the circles having an inscribed "upright" equilateral triangle (base down), and the 16th circle containing an "inverted" triangle (base up). For purposes of analysis (but not during the experiment), the circles were numbered consecutively, beginning with the upper left corner and progressing from left to right in each row. The data in Tables 1 and 2 are presented in a spatial arrangement similar to that of the original target locations. Stimuli were on 35-mm slides and were projected by means of a Lafayette two-field projection tachistoscope, with a blank frame identical in size to the stimulus frame projected at all times other than during stimulus presentation. Ss were seated approximately 3.4 m from the projection screen, and the projected stimulus frame measured 30.5 cm on a side. Each projected circle measured 4.6 cm in diam and contained a centered equilateral triangle, 2 cm on a side. The visual angle subtended by the 16 circles was approximately 4 deg, with each circle subtending an angle of about 48 min and each triangle subtending an angle of about 20 min.

Four Ss (two male, two female) were used in the experiment, each run individually for a total of 960 trials. Each trial consisted of presentation of a stimulus slide for 200 msec, with about 6 sec between trials. During the intertrial interval, Ss recorded the location of the target (inverted triangle) on a schematic drawing of the stimulus, together with a confidence rating concerning the judgment. Confidence ratings were made by means of a check mark on a horizontal line with the statements "sure" and "???" at opposite ends. For purposes of analysis, the line was divided into three equal segments, and all confidence ratings were coded as one of three values (1 = not sure, 2 = moderately certain, 3 = highly certain). The experiment was run in one 2½-h session, with brief rest periods after blocks of 40 trials and longer rest periods after blocks of 240 trials. Stimuli were presented in a pseudorandom order, with the target occurring in each location five times in

consecutive series of 80 trials, and thus 60 times in the experiment. Ss were instructed to "try to pay attention to all 16 possible target locations," were told that the target was placed in a random fashion, and were given a brief description of the meaning of random ordering. Five practice trials were run prior to the experiment to assure appropriate interpretation of the instructions by the Ss. There was no feedback given to the Ss during the experiment.

## RESULTS

Proportion correct (Pc) was obtained for each S over all trials and over consecutive blocks of 320 trials for each target location and for all target locations combined. Table 1 contains Pc values for each S for each target location across all trials. Proportion of hits (correct identifications of target location) and proportion of false alarms (trials on which a target location was specified when in fact that location was not correct) were calculated for each S for each target location, both for all trials and within each block of 320 trials. These data were used to obtain d' values for the specific target locations, using conversion tables in Swets (1964).

Pc ranged from .34 to .69 across Ss for all trials and for each block of 320 trials. Table 2 contains d' values for each S for each target location across all trials. An analysis of variance was run on d' values for each S for each target location for each consecutive block of 320 trials. All effects were significant at the .05 level. The blocks effect, $F(2,91) = 9.56$, reflected improved detection with additional trials, while the Blocks by S interaction, $F(6,91) = 3.27$, described different effects of practice across Ss. The location effect, $F(15,91) = 7.16$, demonstrated differential sensitivity to specific locations across Ss, while the Blocks by Location interaction, $F(30,91) = 3.02$, and the S by Location interaction, $F(45,91) = 5.22$, showed that the magnitude of the differential sensitivity varied as a function of practice and specific S. Examining d' values in each cell, it appeared that Ss were differentially sensitive to different target locations, and although there was general improvement with practice the magnitude of the improvement typically was greater for those targets with higher d' than for those with lower d' values. Similar results were obtained with $d_s$ values calculated by using confidence ratings (i.e., from a Type II ROC curve), although zero frequencies of high confidence ratings for some locations for given Ss and blocks of trials prevented calculation of $d_s$ for all cells.

### Table 1
Proportion Correct (Pc) for Each S for Each Target Location

| | Location | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| S1 | .45 | .43 | .47 | .13 |
| S2 | .15 | .33 | .48 | .10 |
| S3 | .55 | .35 | .35 | .22 |
| S4 | .35 | .68 | .62 | .12 |
| | 5 | 6 | 7 | 8 |
| S1 | .53 | .72 | .85 | .42 |
| S2 | .40 | .82 | .87 | .38 |
| S3 | .83 | .88 | .87 | .97 |
| S4 | .43 | .97 | .97 | .72 |
| | 9 | 10 | 11 | 12 |
| S1 | .40 | .33 | .67 | .20 |
| S2 | .70 | .72 | .93 | .68 |
| S3 | .90 | .85 | .85 | .83 |
| S4 | .67 | .90 | .95 | .78 |
| | 13 | 14 | 15 | 16 |
| S1 | .13 | .13 | .12 | .07 |
| S2 | .08 | .28 | .27 | .57 |
| S3 | .25 | .13 | .10 | .08 |
| S4 | .12 | .77 | .53 | .62 |

As the prime interest was in the ordinal stability of the differential sensitivity across locations, ordinal values were attached to d' values for each target location within each block of 320 trials for each S. A coefficient of concordance (W) was calculated for each S among the rank orders of target location sensitivity for the three blocks of 320 trials. Values of W for the four Ss were .51, .76, .85, and .81, indicating reasonably high stability of the ordinal sensitivity to target locations within Ss across trials.

### Table 2
Sensitivity (d') for Each S for Each Target Location

| | Location | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| S1 | 1.42 | 1.37 | 1.68 | 1.20 |
| S2 | 1.28 | 1.88 | 1.70 | 1.04 |
| S3 | 1.26 | 1.26 | 1.50 | .98 |
| S4 | 1.36 | 1.87 | 2.18 | 1.14 |
| | 5 | 6 | 7 | 8 |
| S1 | 1.42 | 1.98 | 2.51 | 2.12 |
| S2 | 1.80 | 2.66 | 2.68 | 1.74 |
| S3 | 2.83 | 3.50 | 3.45 | 4.20 |
| S4 | 1.70 | 3.76 | 4.20 | 2.90 |
| | 9 | 10 | 11 | 12 |
| S1 | 1.38 | .96 | 1.99 | 1.48 |
| S2 | 2.58 | 2.33 | 2.60 | 2.02 |
| S3 | 3.16 | 3.36 | 3.40 | 3.00 |
| S4 | 2.49 | 3.33 | 3.69 | 2.65 |
| | 13 | 14 | 15 | 16 |
| S1 | .92 | 1.19 | 1.14 | .90 |
| S2 | 1.00 | 1.74 | 1.14 | 1.93 |
| S3 | .72 | 1.19 | 1.04 | .92 |
| S4 | .88 | 2.62 | 2.40 | 2.36 |

Postexperimental interviews with the Ss indicated that three Ss specifically tried to be equally sensitive to all target locations, while the fourth S claimed to have focused on different sets of locations for consecutive blocks of 240 trials. Apparently, his intended strategy did not affect his performance, as he had the highest value of W (.85), indicating exceptional ordinal stability of differential sensitivity across trials.

## DISCUSSION

Differential sensitivity to target locations proved reasonably stable across blocks of 320 trials for each S. The analysis of variance of the d' values verified the existence of a practice effect as well as differential sensitivity as a function of target location, and the significant interaction terms suggested that these effects differ in magnitude across Ss. However, these significant differences in magnitude did not affect the consistency of the ordinal relations among target location sensitivities within Ss. The Blocks by Location interaction indicated that ordinal relations were stabilized in part by greater increases in d' for initially higher values of d'.

Although Ss tried to follow the instructions in giving equal attention to all target locations, their responses exhibited consistent biases reflecting particular scanning strategies. Considering that the 320 trials in each block of the analysis contained only 20 presentations of each target location, the stability of the ordinal values for d' is remarkable. These data imply extremely strong scanning biases which existed prior to the experimental task.

In summary, the data suggest that less than 400-500 trials is quite sufficient for reliable estimation of differential sensitivity among all 16 target locations in a 16-AFC visual signal detection task.

## REFERENCES

BLACKWELL, H. R. Psychophysical thresholds: Experimental studies of methods of measurement. Bulletin of the Engineering Research Institute, No. 36, University of Michigan, 1953.

ESTES, W. K., & TAYLOR, H. A. Visual detection in relation to display size and redundancy of critical elements. Perception & Psychophysics, 1966, 1, 9-16.

GREEN, D. M., & SWETS, J. A. Signal detection theory and psychophysics. New York: Wiley, 1966.

SWETS, J. A. (Ed.), Signal detection and recognition by human observers: Contemporary readings. New York: Wiley, 1964.

TAYLOR, H. A. Context and learning in the processing of information from brief visual displays. Perception & Psychophysics, 1970, 7, 15-18.