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ABSTRACT

Two experiments investigated the linear and nonlinear processes involved in a visual search of letter displays. The displays used in the experiments were well-illuminated 6 x 6 degree or 10 x 10 degree fields containing from 2 to 23 capital As, Bs, or Cs located randomly over the displays. The task of the subjects was to decide as rapidly as possible whether a predetermined target letter was present in the display. Reaction time functions had both linear and nonlinear components and varied from constant when targets were presented, to strongly curvilinear with one target, to strongly linear with a curvilinear aberration when there were no targets present. The results indicated that there are two separate processes that influence total response time in this type of visual search task--acquisition and decision. Acquisition is a perceptual process and is nonlinear, while decision follows acquisition and is a serial self-terminating search. The results demonstrate that the time to search a display of N letters for the presence or absence of a particular target letter is not always linear. (FL)

LINEAR AND NON-LINEAR PROCESSES IN VISUAL SEARCH OF LETTER DISPLAYS

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The display was a well-illuminated $6^o \times 6^o$ or $10^o \times 10^o$ square containing from 2 to 23 capital letters: A's, B's or C's. Either all of the letters were the same, or one letter was different from the rest. The letters were located randomly over the display. For each display the task was to decide as rapidly as possible whether a particular target letter: A, B, or C, was present in the display. The target letter remained the same for each observer throughout an experiment, which involved the presentation of 192 or 24 successive displays.

Using identical displays and an identical experimental arrangement, Donderi (1981) recorded decision latencies when the task was to decide as rapidly as possible whether all letters in each display were the same, or one letter on each display was different from the rest. The particular different letter varied randomly from display to display, and the sequence of same and different displays was random over the experiment. The conclusion was that for the same-different task, the mean correct decision latency for a single different letter ($\underline{D}$) was related to the latency to decide correctly that all letters were the same ($\underline{S}$) by the formula $\underline{D} = \underline{S}/2 + .4$. The search process was not necessarily linear in $\underline{N}$ (the number of letters displayed); under some experimental conditions decision latency was linear, under some conditions, monotonic increasing; and other others, almost constant (variability was over observers, not N).

Schneider and Schiffrin (1977) distinguish between visual decision tasks demanding constant mapping and variable mapping. The same-different task requires variable mapping, where serial decision processes, linear in N, were hypothesized to account for decision latency data. They call this process controlled search. The same-different results demonstrate that controlled search is not necessarily linear in N. The target search task, on the other hand, is a constant-mapping task. Schneider and Schiffrin postulate that this task is performed in parallel; they call the process automatic processing. The important theoretical question raised is: Are the results of the search experiments consistent with an automatic, parallel processing interpretation of constant-mapping search?

In experiment I, the observer started each display by releasing a central button, and stopped each display as soon as possible by pressing one of two lateral "yes" and "no" buttons to indicate whether or not the display contained the target letter and to record the decision latency. One group of 16 observers saw $10^{o} \times 10^{o}$ displays blocked into two groups of 96 displays each, one block with a screen luminance of 45 cd/m^2 and the other with a luminance of 7 cd/m^2. A second group of 16 observers saw $6^{o} \times 6^{o}$ displays blocked into two groups with luminances of 172 cd/m^2 and 27 cd/m^2. The number of letters per display varied randomly within observers from 2 to 23.

Figure 1 illustrates the results from this experiment, and compares them with the results of the previous same-different experiment. When all the letters were targets, the correct decision latency was constant. With one target letter, decision latency was non-monotonic, decreasing when as many as 19 or 22 other non-target background letters crowded the field. And when no target letters were present, decision latency was a linear function of the number of letters present, with an added constant increment if one of the background letters was different from the rest of the background letters, but was not the target letter. All of the effects mentioned were significant when assessed by analysis of orthogonal components of variance.

In experiment II, observers viewed and responded to 24 successive $10^{o} \times 10^{o}$ displays at 7 cd/m^2. For each observer, successive displays contained the same N, but the presence or absence of the constant target letter, and the location of individual letters in the display, was randomized across displays. Four groups of 10 observers were tested, with 2, 5, 11 and 20 letters per display. The results (Figure 2) are significantly non-monotonic. Decision latency was a quadratic function of N for all displays, with the non-monotonicity particularly evidence with the N-target displays. Maximum decision latency occurred to displays with 11 letters, and decreased for N=20.

The conclusion is that both linear and non-linear decision processes contribute to the decision latencies for correct responses in the visual search for randomly displayed letter targets. The linear component depends on decision processes, the non-linear component on perceptual acquisition processes. A two-stage separation of acquisition from decision is hypothesized in complex visual search.

References

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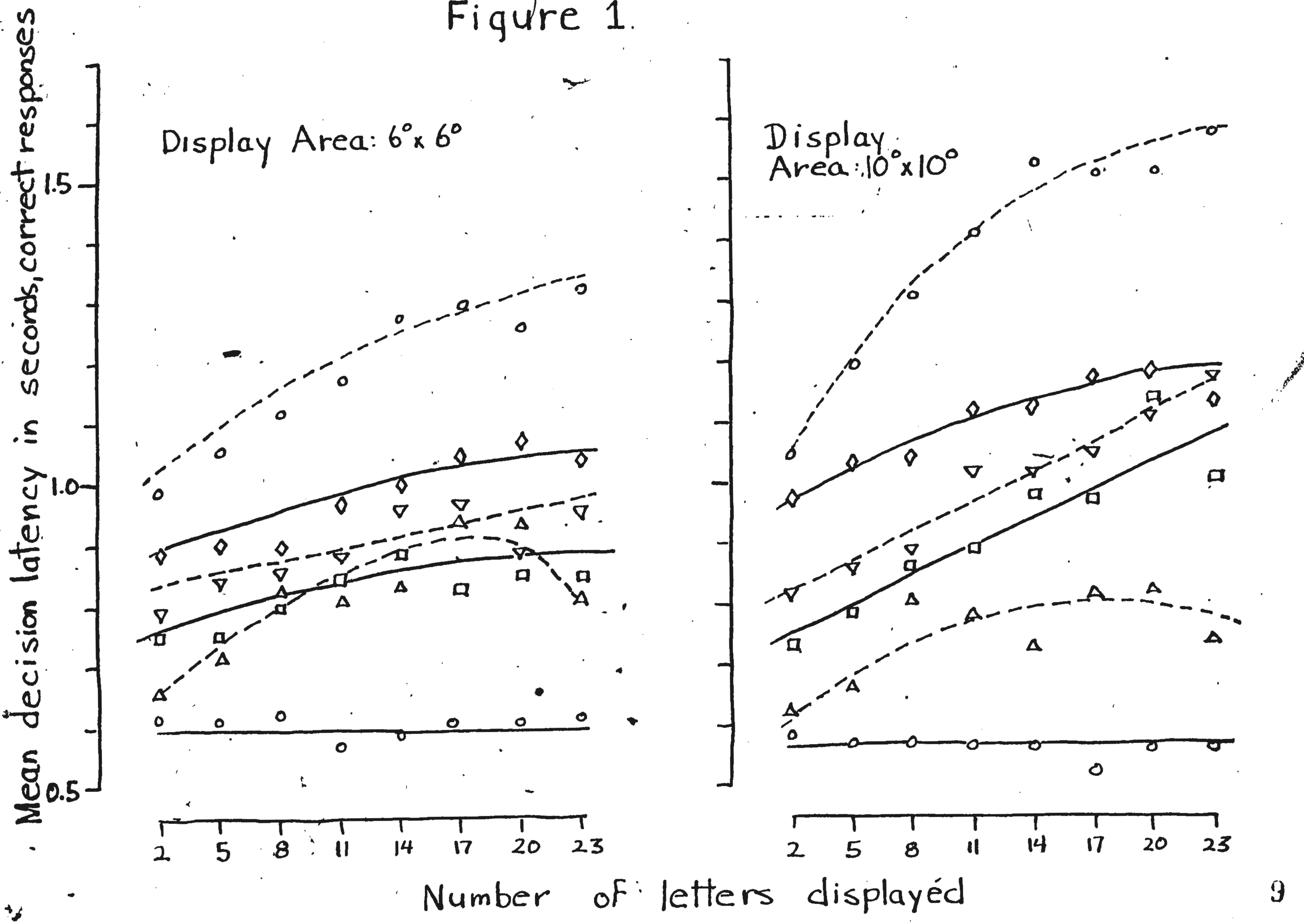
Schneider, W. & Schiffrin, R. M. Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review, 1977, 84, 1-66.

Fig. 1. Mean decision latency in seconds for correct responses in the same-different experiments (Donderi, 1981) and in Experiment I. The abcissa gives the number of letters displayed; the ordinate, the mean decision latency. Left hand graph: $6^{o} \times 6^{o}$ area displays, right hand graph: $10^{o} \times 10^{o}$ displays. On each graph from bottom to top: solid line and circles, N targets per display; dotted line and triangles, 1 target per display; solid line and squares, no targets, all letters the same; dotted line and inverted triangles, no targets, one letter different from the rest; solid line and diamonds, same-different experiments, 1 letter different; dotted line and circles, same-different experiments, all letters the same.

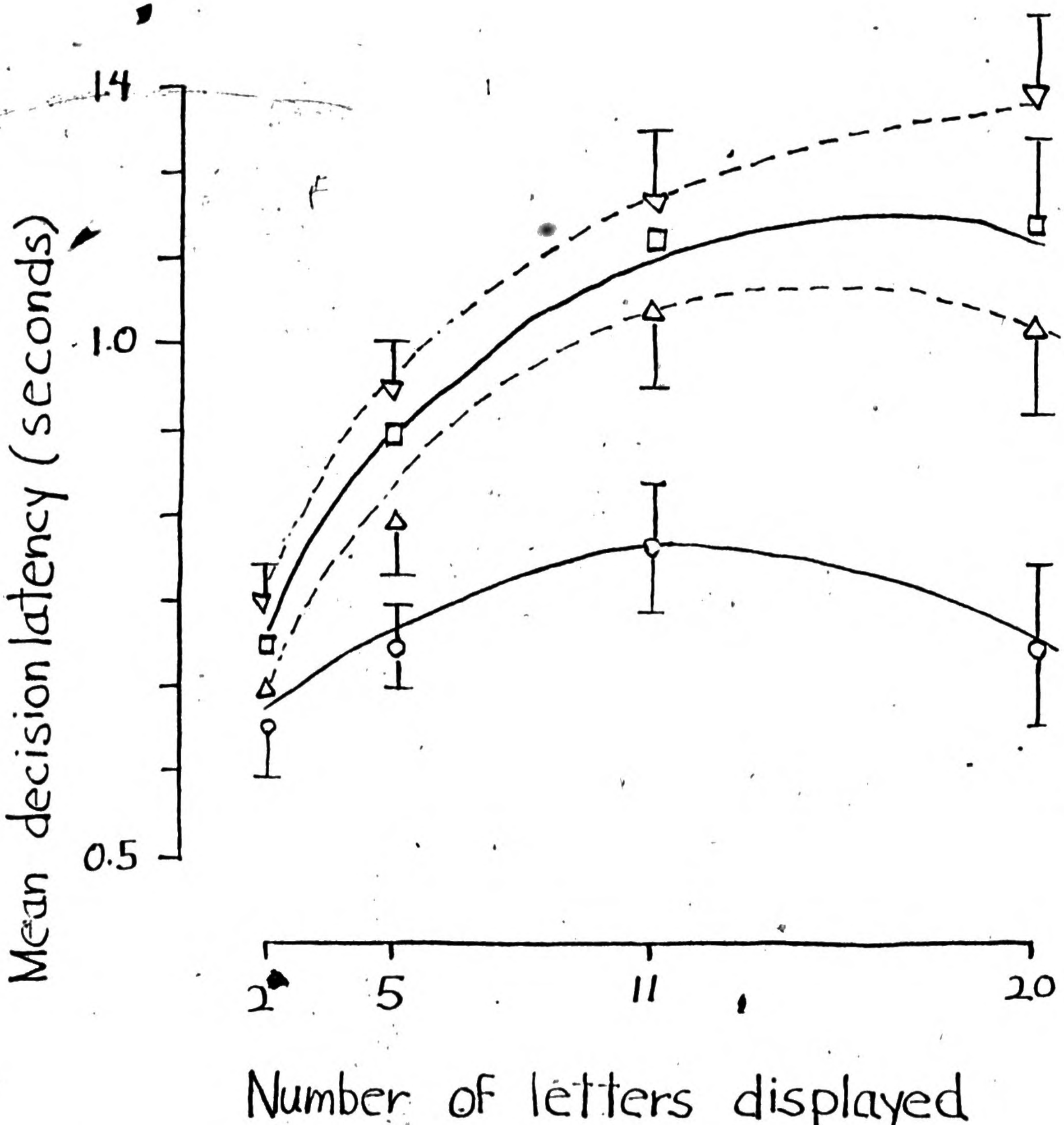
Fig. 2. Mean decision latency in seconds for correct responses when each subject sees displays with the same N (experiment II). Abcissa, number of letters displayed; ordinate, mean decision latency. Reading from bottom to top; solid line with circles, N targets per display; dotted line with triangles, 1 target per display, solid line and squares, no targets, all letters the same; dotted line with inverted triangles, no targets, one letter different from the rest.

Figure 1



Display Area: 6° x 6°
Display Area: 10° x 10°
Mean decision latency in seconds, correct responses
1.5
1.0
0.5
2
5
8
11
14
17
20
23
Number of letters displayed

Figure 2



1.4
1.0
0.5
Mean decision latency (seconds)
2
5
11
20
Number of letters displayed