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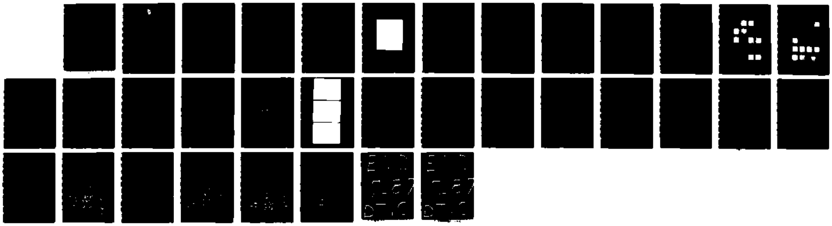

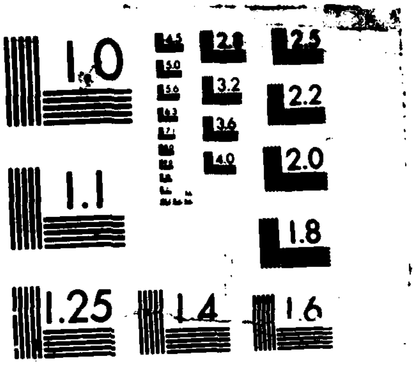

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Changes in the internal representation of a visual display during the first second after presentation are among the earliest phases of human cognition where memory mechanisms may be investigated. The effect of array size (2-6 digits) on the latency to name a visually marked element in a brief display increases rapidly with marker delay, revealing such a change in representation. For early markers the effect is negligible, indicating direct access (and spatially-selective attention); for late markers the effect is a linear increase, indicating a failure of selective attention and suggesting search. In other words, the transformation changes the representation from a random-access memory ~~(RAM)~~ to a sequential-access memory ~~(SAM)~~. Two alternatives to direct access (marker makes element visually distinctive; marker automatically attracts visual attention) are rejected, as tactile spatial markers produce similar effects.

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Direct Access by Spatial Position in Visual Memory: 1. Synopsis of Principal Findings

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ABSTRACT

Changes in the internal representation of a visual display during the first second after presentation are among the earliest phases of human cognition where memory mechanisms may be investigated. The effect of array size (2-6 digits) on the latency to name a visually marked element in a brief display increases rapidly with marker delay, revealing such a change in representation. For early markers the effect is negligible, indicating direct access (and spatially-selective attention); for late markers the effect is a linear increase, indicating a failure of selective attention and suggesting search. Two alternatives to direct access (marker makes element visually distinctive; marker automatically attracts visual attention) are rejected, as tactile spatial markers produce similar effects.

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January 20, 1986

Direct Access by Spatial Position in Visual Memory:
1. Synopsis of Principal Findings[1]

1. Introduction

In recent years the traditional account of the dynamics of short-term visual memory -- or iconic memory -- has come under attack. For example, Coltheart (1980, 1984) suggested that there may be two different representations concurrently present after a display, one that is phenomenally visible, and a different one from which information is extracted.[2]

What are the initial properties of the memory-representation of a display, and how do they change over time? Given Coltheart's suggestion, the question may even be raised whether the earliest representation from which information is extracted is a visual (or spatial) one. Indeed, what properties *ought* a representation have to be called visual (or spatial), given that it may not be phenomenally visible?

Direct access by spatial position is one candidate. We would argue that this property was implicitly assumed in the classic spatially-cued partial-report experiments of Sperling (1960) and of Averbach and Coriell (1961). Suppose this property obtains, and suppose further that we know how to specify, or address, a location in the memory. Then information about the element in the specified location should become available with approximately the same delay, regardless of the number of other filled locations. In the terms of Kahneman, Treisman & Burkell (1983), the "cost of visual filtering"[3] should be negligible. On the other hand, if (for example) the representation of the display took the form of covert sequential verbalization, there seems less reason to expect direct access by spatial position.

---

[1] This memorandum approximates the verbatim text of a paper presented at the annual meeting of the Psychonomic Society, Boston, November 1985. The first series of experiments reported could not have been done without the expert hardware and software support of A. S. Coriell and W. J. Kropfl. The remaining experiments depended on the Parasite-FS real-time operating system developed by C. E. Wright and M. A. Derr in Bell Laboratories' Human Information-Processing Research Department. The work reported was supported in part by Contract N00014-85-K-0643 between the Office of Naval Research and the University of Pennsylvania.

[2] Earlier, Turvey (1978, pp. 108-111) had reviewed several studies that indicated the existence of "nonvisible visual representations," and suggested that whereas the visible representation was referred to retinal coordinates, the longer-lasting nonvisible one was not.

[3] The "cost of visual filtering" is the additional time required to select and respond to a specified display element that results from the process of rejecting or ignoring other display elements.

2. Experimental Method

We chose to address locations in memory in the same way that Averbach & Coriell did, with a *visual* marker that designated a *single* element. Indeed, our experiments were similar to theirs, but with several critical differences, mentioned below. A sample display from our first series of experiments is shown in Figure 1. It contains three constituents, which could appear and disappear at different times. One is the array of digits, here of size four. Another is a pair of dots for each digit ("registration dots"). And the third is the marker (or probe), two vertical line segments, one above and one below the target digit. The subject's task was to name the target digit as fast as possible; we measured vocal reaction time (RT). Subjects were paid for speed and penalized for errors. We varied array size from trial to trial, and probe delay from block to block.[4]

Three of the possible time sequences of array, registration dots, and marker are described in Figure 2. In all three examples, the correct response is to pronounce the word "eight." In the first example, probe delay is zero. The 50 msec probe and the 150 msec array turn on simultaneously. In the second example the probe immediately follows the array, so the probe delay is 150 msec. The final example shows a long delay. Here the dots are especially useful in reducing difficulties of registration of array and marker. The dots stayed on until the response.

There are three important differences between our experiments and those of Averbach and Coriell (1961). First, rather than overloading the memory we used small arrays, so that subjects were almost always correct. The average error rate was about 3%.[5] Second, we applied time pressure, and the primary measure was reaction time. Finally, we varied the number of elements in the array, since our main interest is in the effect of array size on mean reaction time.

Some of the details of design and procedure are best considered in the context of Figure 3. The display area contained six potential element locations *(absolute positions)*. At the start of a trial, subjects fixated in the center of this area.[6] To avoid confounding number of elements *(array size)* with their separation, we placed elements in *contiguous* locations. To reduce the confounding of array size with retinal eccentricity, we placed the arrays at all possible positions within

---

[4] In the first series of experiments (Experiments 1-5, Section 3) array size was $s=3,4,5$, or 6, and probe delay (in msec) was -50, 0, 150, 350, 650, 950, 1650, or 3450.

[5] The effects of array size and probe delay on error rate were similar to their effects on RT; details will be included in a subsequent report.

[6] A change with delay in the effect of absolute position suggests that at long probe delays subjects may have shifted their fixation from the center of the display area to the center of the array.

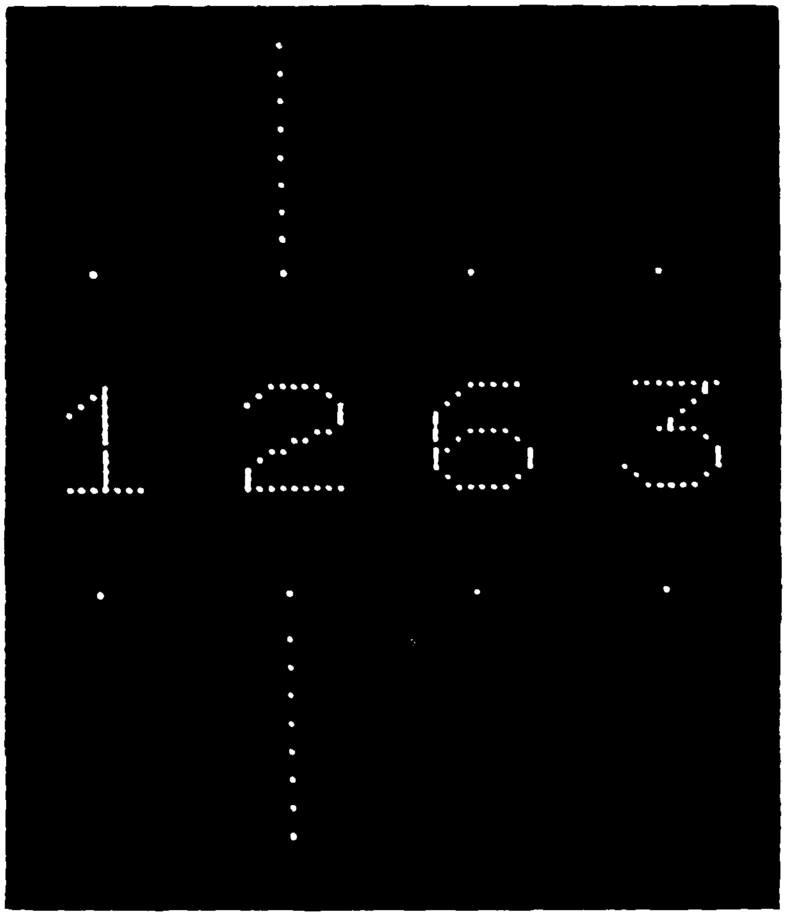

Figure 1

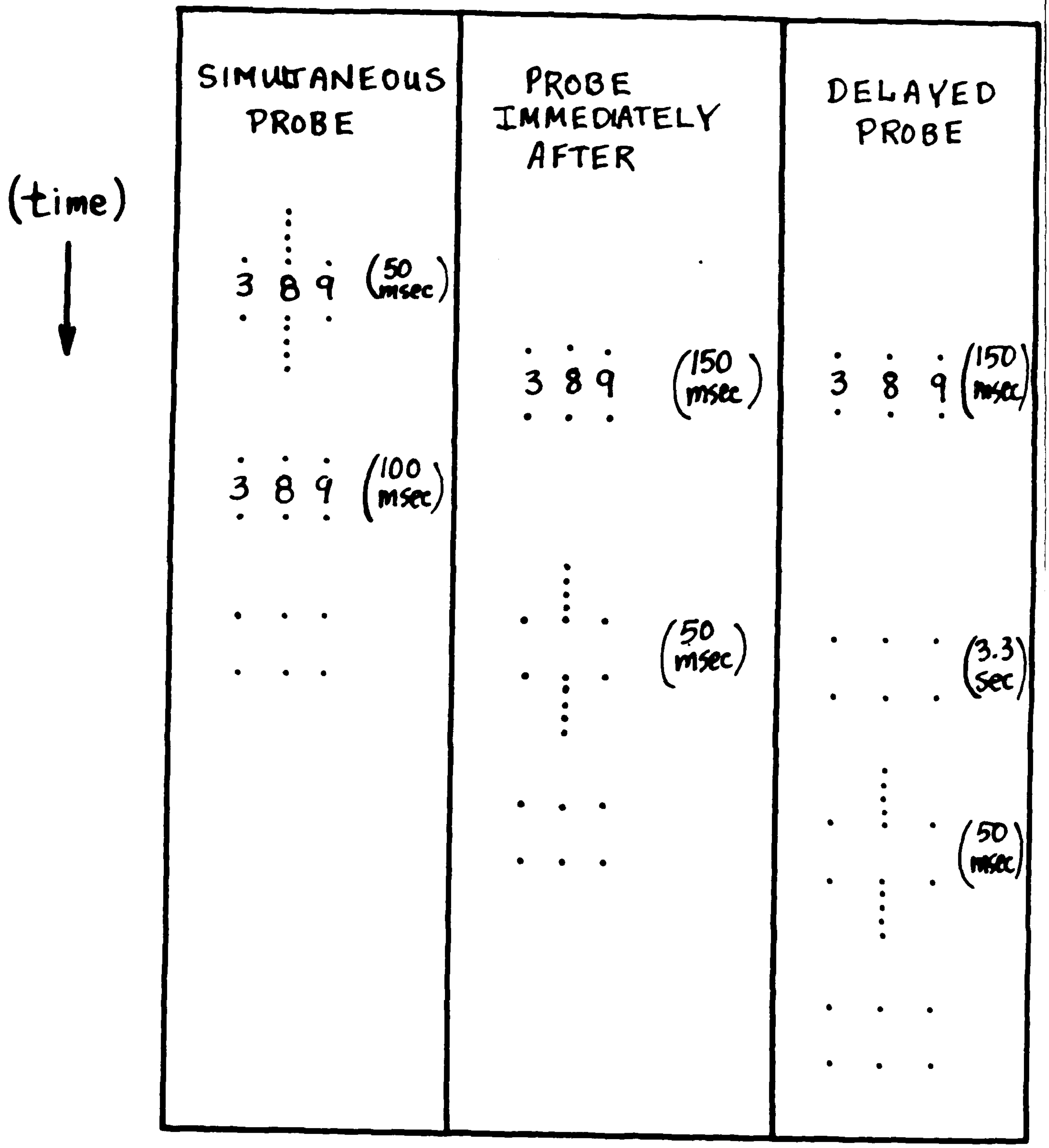
(time)
SIMULTANEOUS PROBE
3 8 9
(50 msec)
3 8 9
(100 msec)
PROBE IMMEDIATELY AFTER
3 8 9
(150 msec)
(50 msec)
DELAYED PROBE
3 8 9
(150 msec)
(3.3 sec)
(50 msec)

Figure 2

the display area.[7]

There are of course several factors other than array size that might influence reaction time: for example, absolute positions of array and of marker (and target element) within the display area, and serial (relative) position of the target element within the array. It is not possible to arrange for all these factors, together with array size, to be mutually orthogonal. The obvious simple averaging we performed is biased, and happens to favor the smaller arrays.[8] As shown below, however, a more sophisticated multiple regression analysis, in which the position effects are estimated and removed, suggests that the simple analysis is not far off. At this writing, however, only some of the data have been treated this way.[9]

3. Results with Visual Markers

Data from our first series of experiments, averaged over the four subjects, are shown in Figures 4 (shorter delays) and 5 (longer delays). Before starting this series, each subject had served for 28 hours in a related task.[10] The new series included about 26 hours of testing. Each plot shows mean reaction time as a function of array size. In each of Experiments 1-5 we tested several probe delays in a balanced order. The time lines at the top of both figures show that probe delays start at -.05 sec (or -50 msec) on the left, and become positive on the right. Each experiment is represented by the plots in one row, and each probe delay is shown in a different column.

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[7] The leftmost element in an array of size $s=4$, for example, could occupy absolute positions 1, 2, or 3.

[8] For an array of size s, each of the $7-s$ possible array positions occurred equally often, as did each of the s possible serial positions of the target element. An equally-weighted mean over the $(7-s)s$ resulting combinations produces a distribution of absolute positions that varies with array size. (The frequencies of markers over the six possible absolute positions are in proportion to (1:2:3:3:2:1) for $s = 3$ and 4, to (1:2:2:2:2:1) for $s = 5$, and to (1:1:1:1:1:1) for $s = 6$. The resulting mean distance from fixation point to marker (mean eccentricity), measured in absolute-position units, was 1.17, 1.17, 1.30, and 1.50 for $s = 3, 4, 5,$ and 6, respectively. Because RT tends to be longer with greater eccentricity, smaller arrays are favored. Unless these effects are removed, mean RT might then artifactually appear to increase with array size.

The smaller arrays are also favored by the distribution of serial positions, because end positions tend to produce shorter RTs, and the proportion of end positions ($2/s$) decreases with s. Whether this last effect should be removed, however, in estimating a "pure" effect of array size, may depend on whether it is interpreted as an effect of lateral masking on acuity, or an effect of the order of a self-terminating search, for example.

[9] In the multiple linear regression analysis we separately fitted an additive model to the data for each probe delay and each subject. We incorporated effects of array size, response digit, and serial position, as well as two separate effects of absolute position, one for end elements (serial positions 1, s), and the other for interior elements.

[10] See Sternberg, Knoll, & Leuin, 1975.

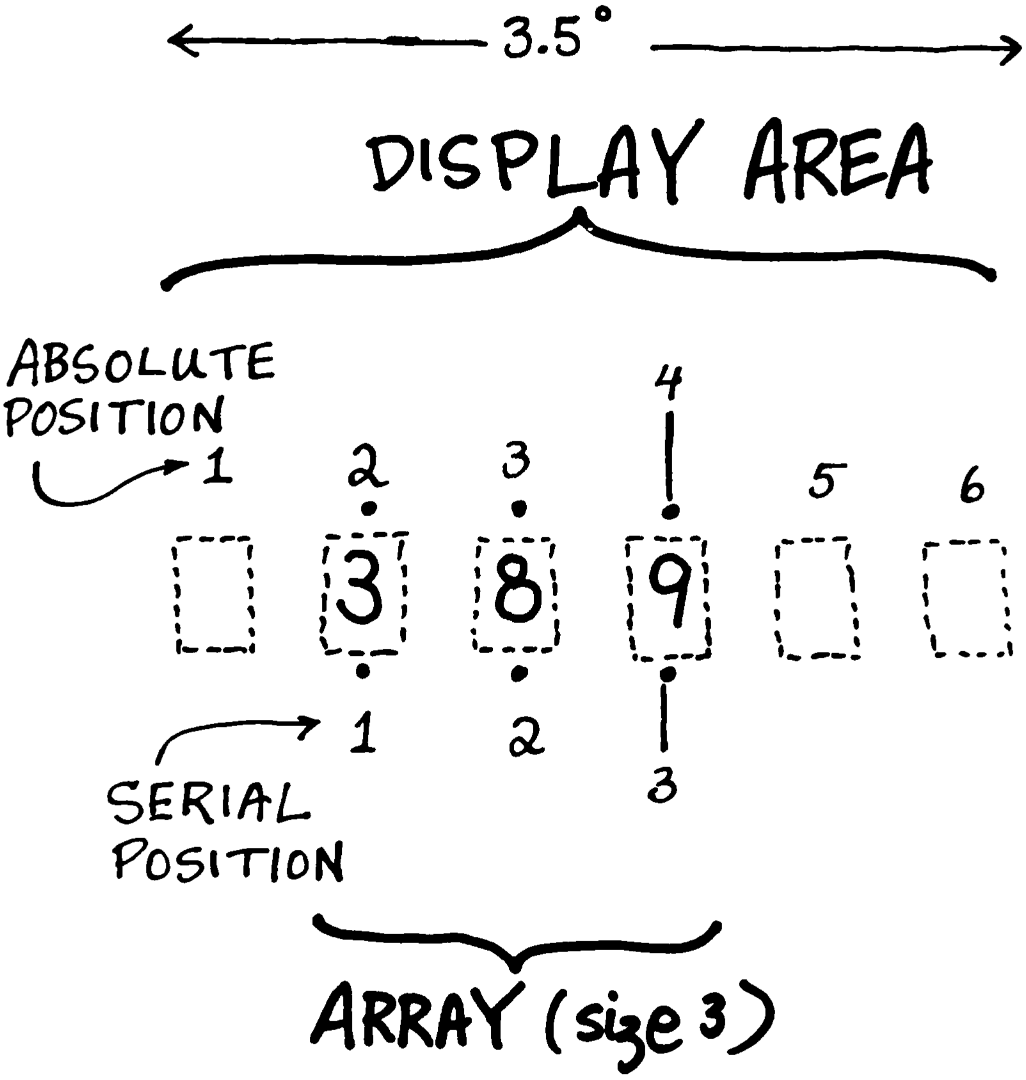
3.5°
DISPLAY AREA
ABSOLUTE POSITION
1
2
3
4
5
6
3
8
9
1
2
3
SERIAL POSITION
ARRAY (size 3)

Figure 3

At all delays the lines fit well, justifying a description of the data in terms of slope and intercept. Functions from the same probe delay in different experiments show good agreement, especially in their slopes.[11] Consider first the data in Figure 4. For the earliest probes the effect of array size is negligible. This is evidence for the direct-access property. Even after a short delay an effect emerges, however. That is, the direct-access property appears to be rapidly lost. Put another way, the cost of visual filtering (Kahneman, et al., 1983) is highly sensitive to timing.[12]

The plots for longer delays (Figure 5) show that by about 2/3 second the effect of array size has reached an asymptote: There is little further change, even out to 3.5 seconds. We shall argue that the dramatic change with delay in the pattern of retrieval times reflects a qualitative transformation of the memory representation of the array -- a change that is completed in less than one second. One approach to testing its completeness is to see whether the pattern after 2/3 second shows any evidence of the display having been visual. This was the purpose of Experiment 6. We displayed the registration dots on an otherwise blank screen, while the subject *heard* the digits as a spoken sequence. The subject had been told to use the natural correspondence between serial-order (of the spoken digits) and left-to-right position (of the registration dots). After about two seconds the visual marker appeared. Results are shown in the lower right corner of Figure 5. The data are similar to those for a visual array after less than a second.

Figure 6 shows the slopes of the fitted lines separately for the six experiments, as a function of probe delay.[13] The agreement across experiments is good, with the effect of array size growing from close to zero to about 80 msec per digit in less than a second.

In Figure 7, slope values have been combined across experiments, and are shown along with the corresponding intercepts, as functions of probe delay. The bars indicate estimates of two standard errors, based on differences among subjects. While the slope rises, the intercept falls, and with a similar time course. We mentioned (Section 2) that a more sophisticated analysis using multiple

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[11] The heights of the functions (reflected by the intercepts) decrease slightly with experiment number, as the subjects become increasingly practiced.

[12] Because the dependence of "cost" on timing is so great, it is not useful to make statements about cost without also stating the effective time-point in the life of the display memory at which the location of the target is specified. Furthermore, this time point is not necessarily zero just because marker and array are displayed simultaneously, and is likely to be greater than zero, given simultaneity, when some visual or categorical aspect of the display elements that must be discriminated informs the subject about target location.

[13] Note that for Experiment 6, where no array was displayed and the sequence of spoken digit names was presented at a rate of 510 msec/digit, we cannot define an equivalent probe delay.

regression produces a better measure of the array-size effect. The slope bias in our simpler analysis seems to be only about 5 msec, however. For example, the improved slope estimate for the -50 msec probe delay is 0.7 ± 1.0 msec/digit, whereas the value given by the simple analysis (and shown in Figure 7) is 4.7 ± 1.6 msec/digit.

4. Interpretation: Rapid Transformation of Visual Memory

It is tempting to argue from these data that there is no persistence of the direct-access property. But note that this argument depends on making the unwarranted assumption that the *effective* probe delay is equal to the *physical* probe delay.[14]

The slope reflects operations that are influenced by array size, whereas the intercept reflects operations that are not so influenced. Figure 7 shows that probe delay affects both sets of operations, and with a similar time course. This similarity suggests a common mechanism.

One interpretation is as follows: The initial representation of the array, which has the direct-access property, is transformed into something else in less than a second, with rapid loss of direct access. At any delay, once the representation of the probed element is found, (either directly, or by search) it is converted into its spoken name. The intercept drops because the duration of this conversion operation is shortened with delay. The similarity in time course follows from the fact that the same transformation that destroys the direct-access property also brings the array elements closer to their spoken names.[15]

---

[14] It seems likely that the effective probe delay is greater than the physical delay, because the time to transmit information about the marker from the retina to the relevant place(s) in the visual system plus the time to discriminate its location is greater than the time to transmit information about the array from the retina to relevant place(s) in the visual system. If so, then the delay of -50 msec may effectively be greater than zero. One potential complication is that if a difference between effective and physical delays existed, it might vary with physical delay, so that to provide a function relating slope to effective delay, the delay axis would have to be more than merely translated.

[15] For other evidence that indicates such a transformation, derived from three other experimental approaches using reaction-time measurements with small arrays, see Sternberg, Knoll, & Leuin, 1975; Sternberg & Knoll, 1985, and Turock, 1985.

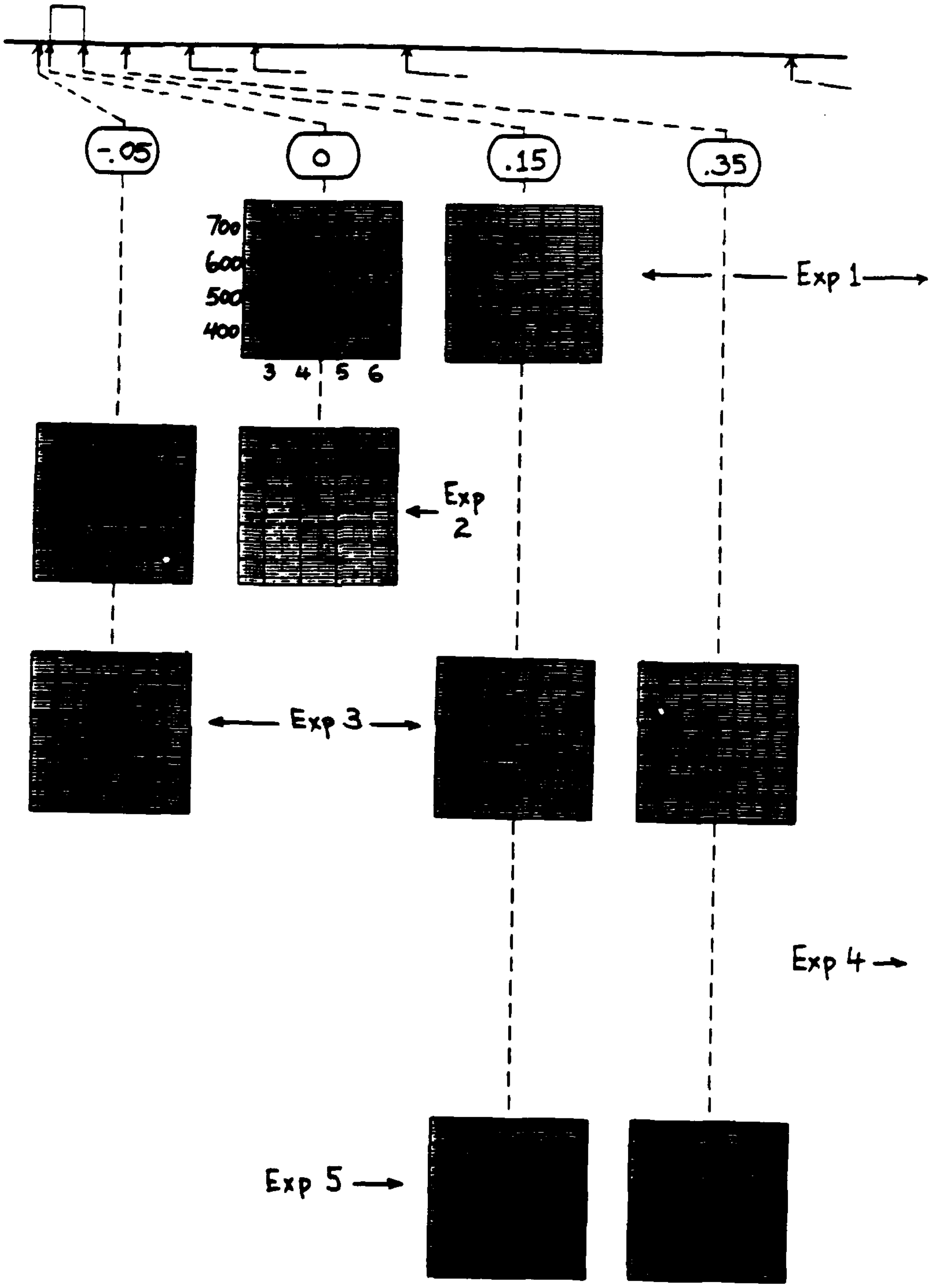

Figure 4

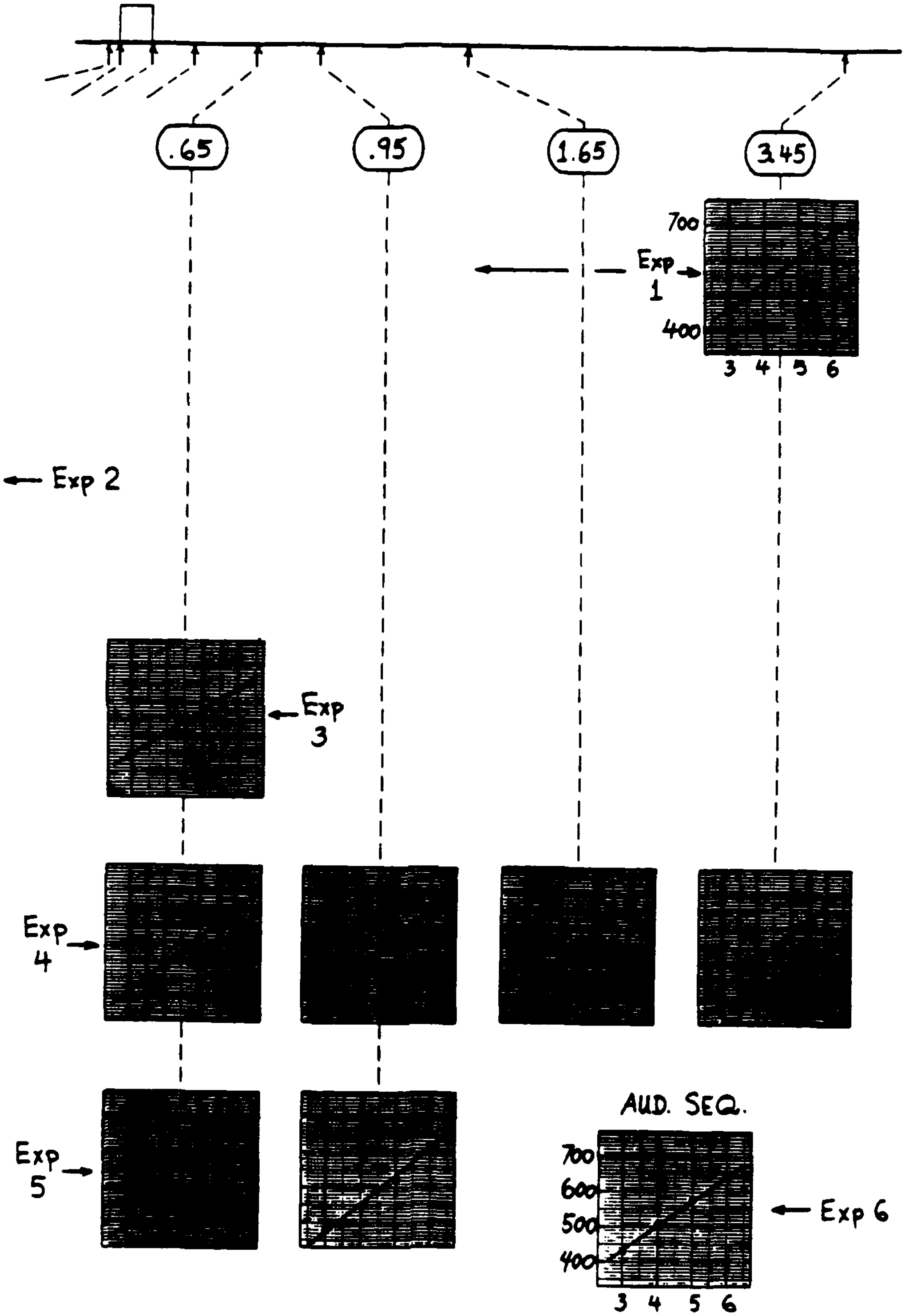
.65
.95
1.65
3.45
700
Exp 1
400
3
4
5
6
Exp 2
Exp 3
Exp 4
Exp 5
AUD. SEQ.
700
600
500
400
3
4
5
6
Exp 6

Figure 5

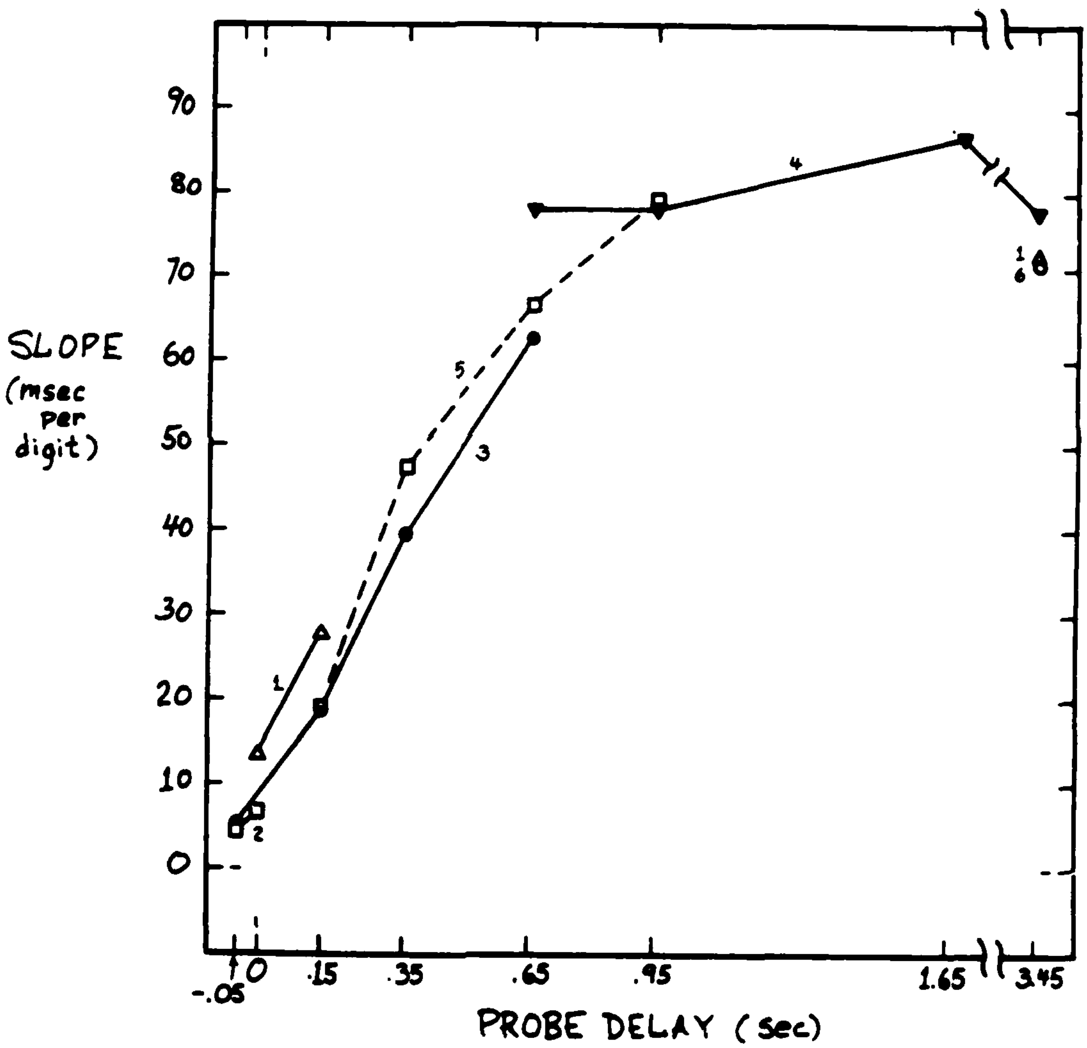
SLOPE (msec per digit)
90
80
70
60
50
40
30
20
10
0
PROBE DELAY (sec)
-.05
0
.15
.35
.65
.95
1.65
3.45
1
2
3
4
5
1
6

Figure 6

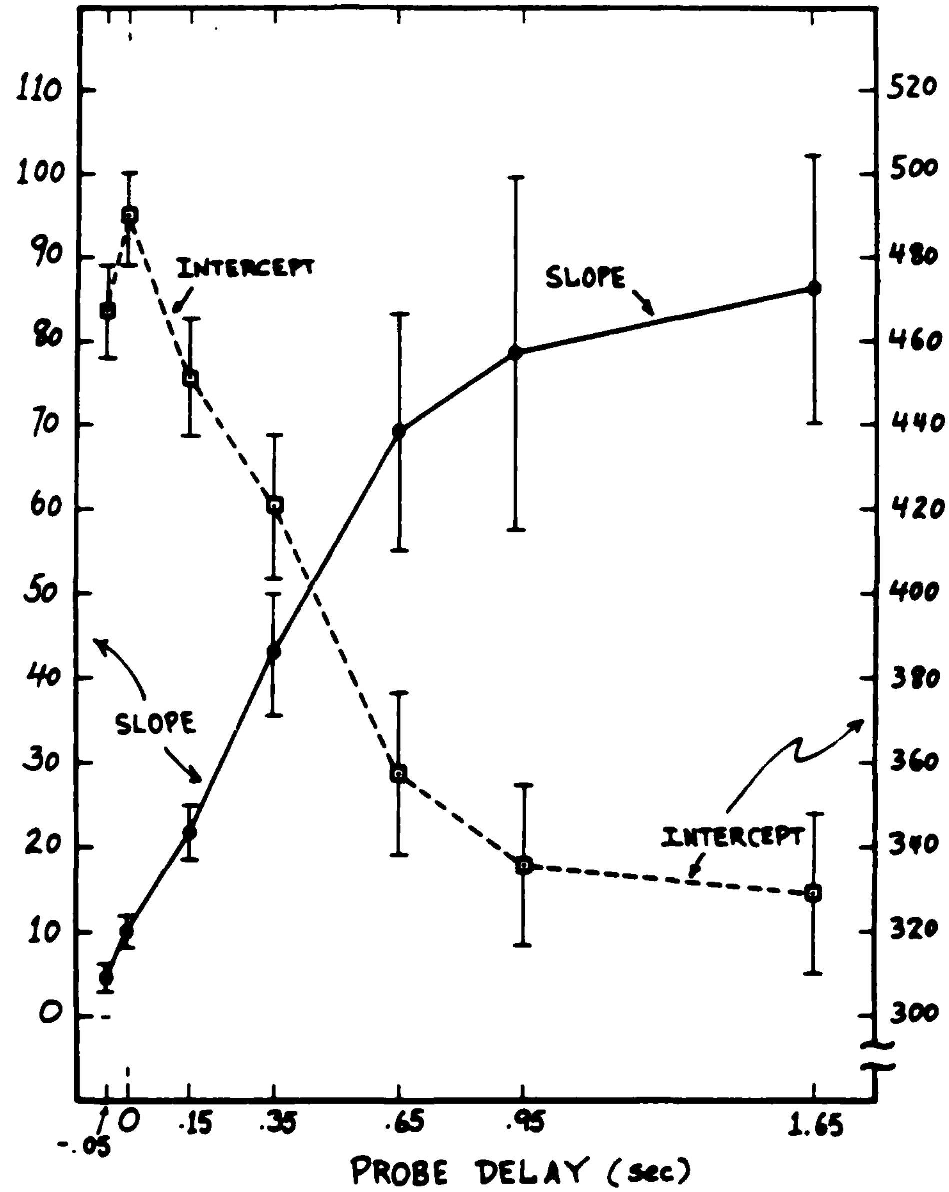
110
100
90
80
70
60
50
40
30
20
10
0
520
500
480
460
440
420
400
380
360
340
320
300
INTERCEPT
SLOPE
SLOPE
INTERCEPT
-.05
0
.15
.35
.65
.95
1.65
PROBE DELAY (sec)

Figure 7

5. Alternative Explanations for the Absence of an Array-Size Effect at Short Probe Delays

We have discussed two principal findings about the effect of array size. First, the effect is absent for early probes. And second, the effect is present for delayed probes. We have already mentioned one interpretation (direct access), but there are others. Consider first the finding for early probes. Figure 8 lists the three alternative explanations we have considered.

The first was suggested by Julian Hochberg.[16] Given approximate synchrony of probe and array, the marker is visually integrated with the target digit. This produces a highly distinctive pattern, easily found by a search process. Thus we find no array-size effect, not because search is unnecessary, but because the set of elements searched (i.e. the set of distinctive patterns made up of digit plus marker) is always of size one.

The second alternative is suggested by results of Yantis and Jonides (1984). Instead of merely informing the subject of a location, the marker automatically attracts visual attention to that location. A search for the marked location thus starts at its goal point, and, if the target element appears in close temporal proximity to the marker, finds it in the first location searched. Thus, we find no array-size effect, not because search is unnecessary, but because the *order* of the (self-terminating) search places the target element first.

6. Experimental Test of the Alternatives

Both of the explanations above depend on the marker being visual. To test them we compared visual and tactile markers with a new set of six subjects in Experiment 7. We used a 50 msec vibration of a fingertip as the tactile marker (see Figure 9), and taught subjects a correspondence between six fingers and the six display locations.[17] To help, we incorporated schematic fingers in the displays. (See Figure 10, which contains the sequence of displays on a sample trial.) In some trial blocks the marker was visual, as shown, and in others, tactile. Because of improved equipment, we were able to reduce array duration to 50 msec in this experiment. Subjects had 14 hours of practice, mainly to learn the tactile-visual correspondence, followed by 22 hours of testing.[18]

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16. Personal communication.

17. We used the index, middle, and little finger on each hand; preliminary testing suggested that discriminability was better with this combination than with three adjacent fingers on each hand.

18. We used array sizes of $s = 2, 3, 4, 5$, and 6, and probe delays (in msec) of -350, -150, -50, 150, 350, and 650.

Approximate Invariance of RT with Array Size for Leading and Simultaneous Probes

Some Alternative Explanations:

1. *Marker-target integration*. Appropriately timed visual marker is integrated with target element, making it distinctive; search is then fast (Hochberg).

2. *Shift of visual attention.* Abrupt visual marker automatically attracts visual attention and search starts at marked location (Yantis-Jonides), finding target if timing is appropriate.

3. *Direct access* by spatial position when memory is sufficiently young.

Figure 8

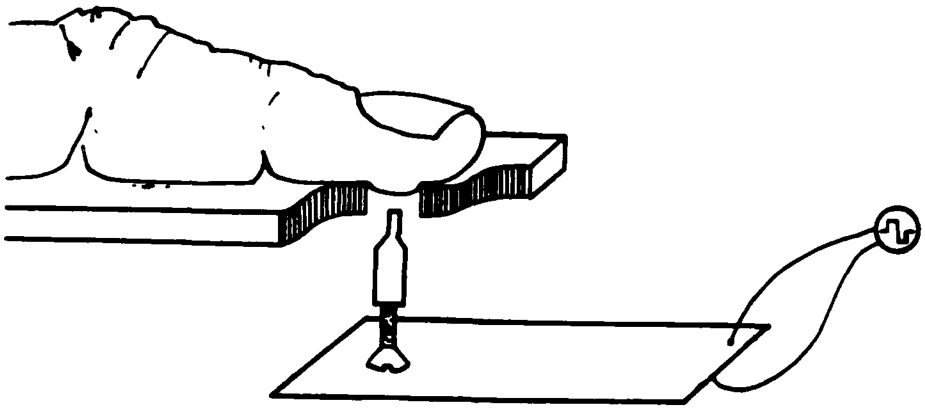

Figure 9

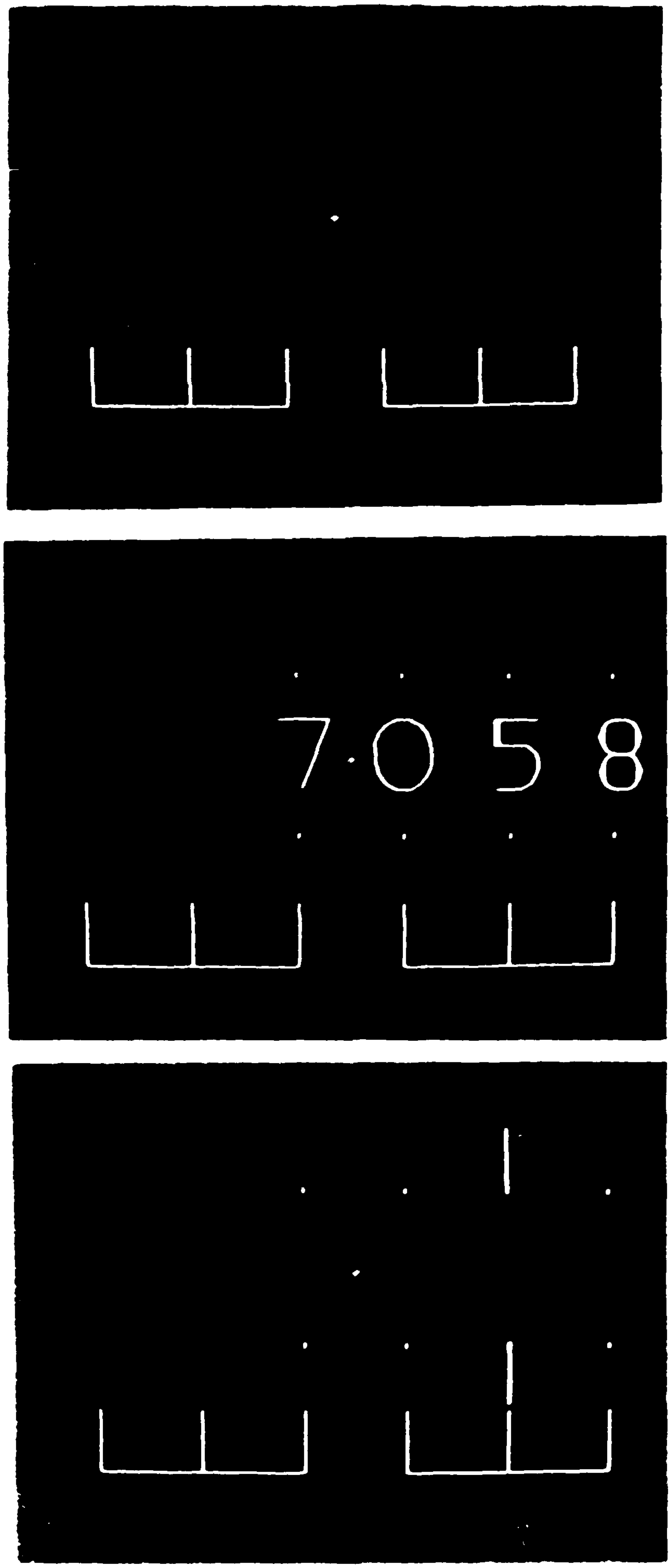

Figure 10

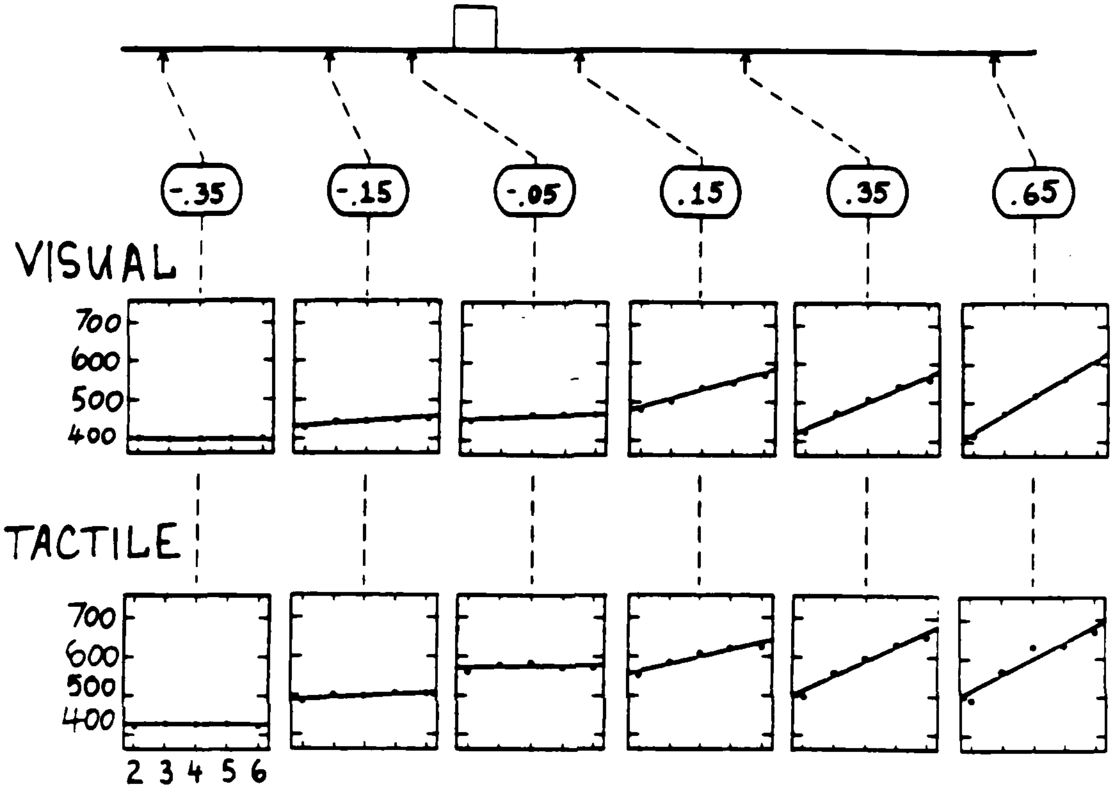
-.35
-.15
-.05
.15
.35
.65
VISUAL
700
600
500
400
TACTILE
700
600
500
400
2 3 4 5 6

Figure 11

Functions relating mean reaction time to array size at each of the six delays and for each of the two probe modalities are shown in Figure 11. The tactile data are somewhat less orderly than the visual, but slopes of the fitted lines agree well across modalities.[19] These plotted values are based on the more sophisticated (regression) analysis.

Among other things, these data demonstrate how misleading it may be to study arrays of only one size. Consider the effects of increasing positive probe delays: Delaying the probe shortens RT for small arrays while lengthening RT for large arrays.

Slopes of the twelve reaction-time functions from Experiment 7 are shown in Figure 12. Agreement between modalities is good. For both modalities, probes that just precede the array produce a negligible effect of array size.[20] For comparison, Figure 13 shows slopes from the earlier experiments on a similar plot.[21] Tactile markers convey information, but they are unlikely to add visual distinctiveness to a numeral, nor automatically cause a shift of visual attention. To explain performance with early markers we are left with the direct-access property.

7. Tests of Three Alternative Explanations for the Presence of an Array-Size Effect at Long Probe Delays

The second finding to be explained is the rapid emergence of an array-size effect as the probe is delayed. Does this necessarily mean a rapid loss of the direct-access property? Figure 14 lists the four explanations we have considered.

---

[19] We added the new early delays to insure that we would cover the range of rapid change for both modalities. To our surprise it proved unnecessary to adjust the tactile probe delays relative to the visual, even though greater intercept values for the tactile markers suggest slower discrimination.

[20] With a probe delay of -350 msec it seems likely that subjects had time between marker and array to shift their fixation from the center of the display area to the marked location; that subjects did this tends to be supported by data on the effect of absolute position. Given such a shift in eye position, which guarantees foveation of the target element, the retrieval mechanism may be fundamentally different. The slight increase in slope at -150 msec (relative to -350 msec and -50 msec) is reliable; it may indicate an array-preprocessing operation whose duration increases with array size. Such an operation might be reflected in the RT only when the marker leads the array appropriately: Delaying the marker slightly could cause the preprocessing operation to be "masked" by an overlapping process of discriminating the marker; With additional delay of the marker the preprocessing operation could be completed before the RT clock started.

[21] These values were derived from the multiple-regression analysis applied to data from Experiments 3, 4, and 5.

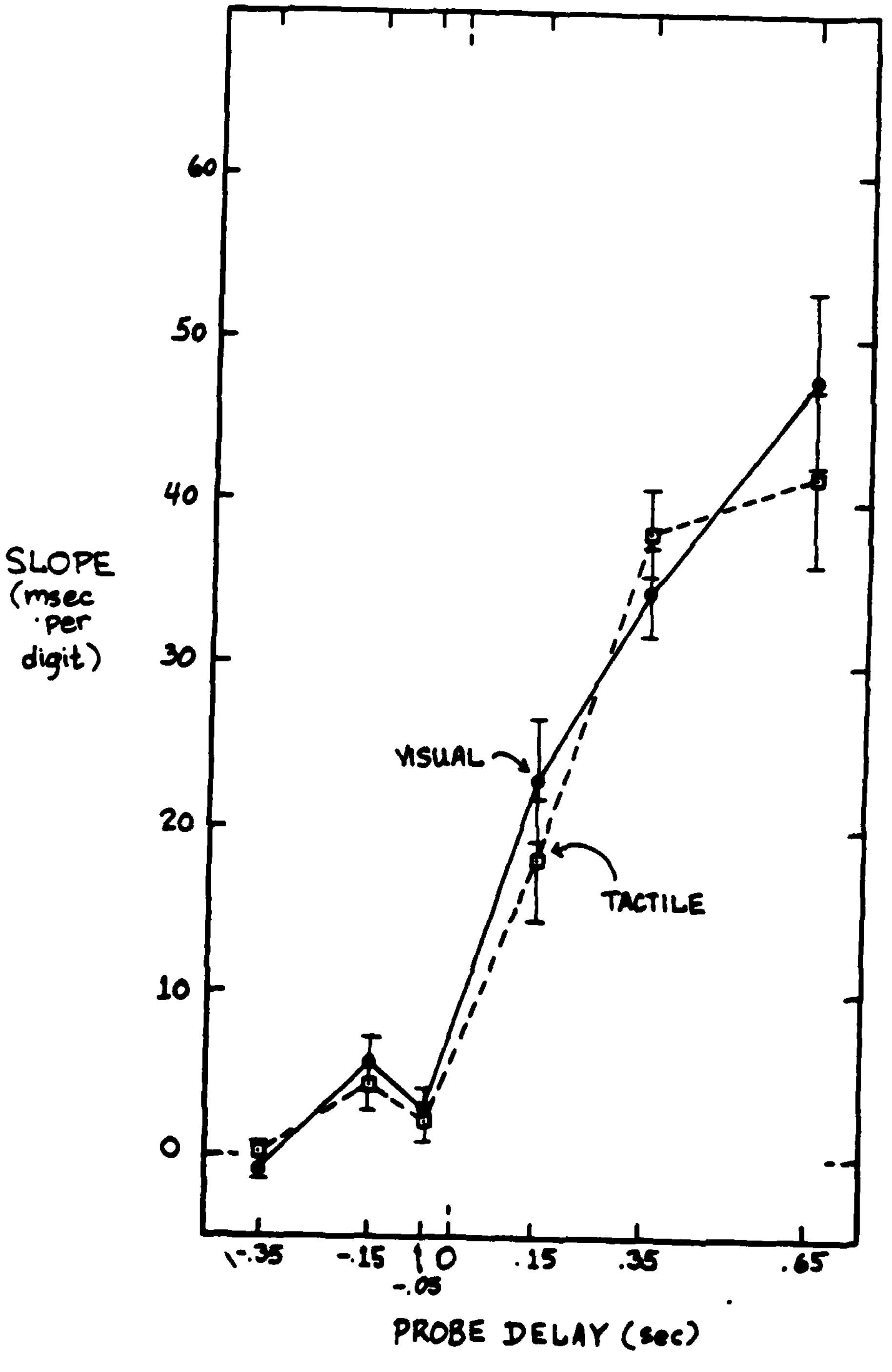
SLOPE (msec per digit)
60
50
40
30
20
10
0
VISUAL
TACTILE
-.35
-.15
-.05
0
.15
.35
.65
PROBE DELAY (sec)

Figure 12

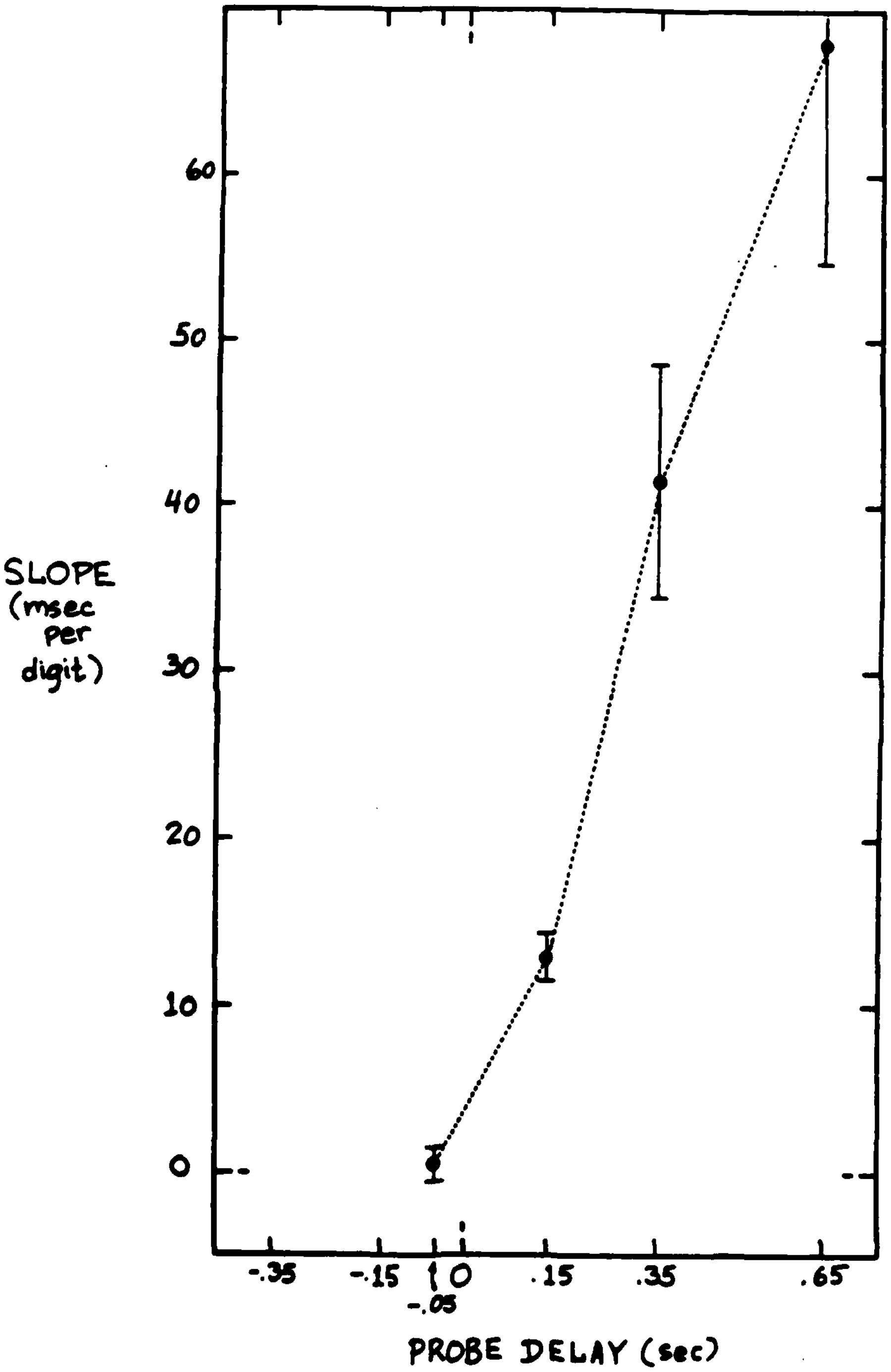
SLOPE (msec per digit)
60
50
40
30
20
10
0
-.35
-.15
-.05
0
.15
.35
.65
PROBE DELAY (sec)

Figure 13

7.1 *Spatial Uncertainty*

For the first alternative we begin with the observation that it takes time for a subject to discriminate the location of the marker. This discrimination time may be shorter when the location of the marker is less uncertain. Suppose the array is small. Then while the subject awaits a delayed probe she learns where the array elements are, and hence where the marker might be. This reduction with delay in spatial uncertainty would favor small arrays (especially if visual attention could be concentrated in the region outlined by the registration dots). Thus we might observe an array-size effect even while the direct-access property persisted, because of an indirect effect of array size on the time to discriminate the marker.

To test this possibility we used a -50 msec marker in Experiment 8, but displayed the registration dots 2/3 second in advance, to reduce spatial uncertainty (more for smaller arrays) by marking the set of locations to be occupied by the forthcoming array. The effect of array size was still negligible.

7.2 *Response uncertainty*

For the second alternative explanation, we begin by noting that the time to organize and execute a response from a small set of alternatives may be shorter than from a larger set.[22] If the subject identifies the array elements while awaiting a delayed probe, then smaller arrays are favored with smaller response sets. If this altered the duration of response operations, we would obtain an array-size effect. To test this possibility we used an early marker in Experiment 9, but specified the response set in advance, by sequentially displaying the array digits in a random order at one location and requiring subjects to name them aloud as they were displayed.[23] The effect of array size was still negligible.

7.3 *Memory load*

According to the third alternative explanation, as the subject awaits a delayed marker she identifies the array elements and stores them in working memory. The resulting memory load is greater for larger arrays. This load slows

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[22] For the naming of *displayed* numerals this effect has been found to be very small, although systematic. (See, e.g., Experiment 5 in Sternberg, 1969; note that the small effect reported of number of stimulus-response alternatives *combines* effects on stimulus-processing and response-organizing operations.) Under the conditions being considered here, however, the numeral is not displayed at the time the response is required.

[23] This procedure also mimicked any possible contribution to the array-size effect with delayed probes of differential priming across array sizes of the encoding of the numeral to be named -- priming that might result from the subject's encoding of the array numerals while she awaited the probe. See Eichelman (1970), Proctor (1981), and Walker (1978), for example, on such priming effects.

Effect of Array Size (*s*) on RT for Delayed Probe

Some Alternative Explanations:

1. Reduction of *spatial uncertainty* of forthcoming marker, as positions of array elements are registered, favors small *s*.

2. Reduction of *response uncertainty*, as array elements are identified, favors small *s*.

3. As array elements are identified a *memory load* develops that slows other processes. (Load increases with *s*.)

4. *Loss of direct-access* property as memory ages.

Figure 14

the naming response and produces an effect of array size (because load size equals array size), even though the direct-access property persists. One of the necessary conditions for this alternative is that a memory load should slow the naming response to a marker.[24] In an attempt to reject this possibility we imposed an auxiliary memory load of varying size on the subject in Experiment 10 before presenting an array with an early marker.[25] To our dismay, we obtained a load effect. It was smaller than the normal array-size effect with a delayed probe, but substantial, nonetheless. More experimental clarification is needed.[26] For the present, we are forced to admit that our favored explanation of the emergence of an array-size effect -- the last one in Figure 14 -- may therefore be invalid. The direct-access property may persist for a time, but be camouflaged by something else.[27]

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[24] The other necessary condition is that the array does indeed generate a load on working memory.

[25] We imposed the load by presenting a spoken sequence of digits. We attempted to induce the subject to actively maintain the load by then presenting a spoken test digit from the list, instead of the marker, on some trials. The correct response on those trials was to pronounce the name of the digit in the list that had followed the test digit, under time pressure. (See Sternberg, 1967, for results from this procedure using visual presentation of sequence and test digit.)

[26] It should be emphasized that the discovery of a load effect does not, by itself, validate the third alternative explanation; it must also be shown that such a load is in fact generated during the long probe delays in the normal task.

[27] If the direct-access property is in fact rapidly lost, it is worth considering why. One possibility is that the initial representation is referred to retinal coordinates, but that it changes rapidly into a representation that is referred to more abstract non-retinal spatial coordinates, thereby causing the marker-array mapping to change from "direct" tc "indirect".(Turvey, 1978, p. 111, suggested that an initial short-lived representation is probably tied to retinal coordinates.) The similarity of our findings for tactile and visual markers seems to argue strongly against this idea as an explanation of the direct-access property and its possible rapid elimination, because the mapping from tactile marker to visual array would have to be "indirect" at all delays.

References

Averbach, E., & Coriell, A. S. (1961)
Short-term memory in vision.
Unpublished manuscript.

Coltheart, M. (1980)
Iconic memory and visible persistence.
Perception & Psychophysics, *27*, 183-228.

Coltheart, M. (1984)
Sensory memory.
In H. Bouma & D. Bouwhuis (Eds.), *Attention & Performance X*, Hillsdale, N. J.: Lawrence Erlbaum Associates, 259-285.

Eichelman, W. H. (1970)
Stimulus and response repetition effects for naming letters at two response-stimulus intervals.
Perception & Psychophysics, *7*, 94-96.

Kahneman, D., Treisman, A., & Burkell, J. (1983)
The cost of visual filtering.
Journal of Experimental Psychology: Human Perception and Performance, *9*, 510-522.

Proctor, R. W. (1981)
A unified theory for matching-task phenomena.
Psychological Review, *88*, 291-326.

Sperling, G. (1960)
The information available in brief visual presentations.
Psychological Monographs, *74*, (11, Whole No. 498).

Sternberg, S. (1967)
Retrieval of contextual information from memory.
Psychonomic Science, *8*, 55-56.

Sternberg, S. (1969)
The discovery of processing stages: Extensions of Donders' method.
In W. G. Koster (Ed.), *Attention and Performance II*, Acta Psychologica, *30*, 276-315.

Sternberg, S. & Knoll, R. L. (1985)
Transformation of visual memory revealed by latency of rapid report.
Unpublished manuscript.

Sternberg, S., Knoll, R. L., & Leuin, T. C. (1975)
Existence and transformation of iconic memory revealed by search rates.
Unpublished manuscript.

Turock, D. L. (1985)
A new technique for measuring transformations of visual memory.
Unpublished manuscript.

Turvey, M. T. (1978)
Visual processing and short-term memory.
In W. K. Estes (Ed.), *Handbook of learning and cognitive processes, Volume 5: Human information processing*. Hillsdale, N. J.: Lawrence Erlbaum Associates, 91-142.

Walker, P. (1978)
Short-term visual memory: The importance of the spatial and temporal separation of successive stimuli.
Quarterly Journal of Experimental Psychology, *30*, 665-679.

Yantis, S. & Jonides, J. (1984)
Abrupt onsets and selective attention: evidence from visual search.
Journal of Experimental Psychology: Human Perception and Performance, *10*, 601-621.

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