of cell division is limited by the rate of DNA synthesis. The action of the floral stimulus might then be to promote DNA synthesis without concomitantly promoting the synthesis of antagonist. Such an upset in the normal balance of DNA:regulator could then lead to the continued more rapid DNA synthesis and cell division which is characteristic of the early stages of reproductive development.

The experiments reported here represent part of a more comprehensive study, now in progress, to elucidate the effects of light and dark on cell division in the stem apex of *Xanthium* and other plants in immediate response to photoperiodic induction (*12*).

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12. I thank Dr. J. Bonner, California Institute of Technology, Pasadena, for providing the *Xanthium* seeds from which the experimental plants originated, and Miss E. Hunt for laboratory assistance.

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## Retention in Immediate Memory Estimated without Retrieval

Abstract. *Report of the missing member of a set depends upon retention of the other members presented. Such a missing scan reveals greater retention than does a digit span and, unlike the digit span, better retention of later than earlier presentations.*

Studies of short-term memory have classically depended upon retrieval by recall or recognition methods (*1, 2*). Recently developed methods requiring only partial retrieval from visual short-term memory have shown greater retention than indicated by methods which require complete retrieval (*3*). Investigation of both retention and retrieval would be further advanced by methods permitting study of retention unconstrained by the effects of retrieval. The "missing scan" described in this report provides such a method, affording a greater estimate of retention without retrieval than may be obtained by retrieval.

Retention in immediate memory may be estimated independently of retrieval by requiring subjects to report which member of a set was *not* presented. This does not necessitate either recall or recognition but does presuppose that subjects know the members of the class. The use of overlearned sequences (*4*) provides an apt illustration. If a subject is told that he will be presented with nine randomly ordered numbers of the set 1 to 10 and asked to report the missing number, he must retain the numbers presented to decide correctly which number of the set was missing. Such a "missing scan" may be contrasted with a retrieval method such as the digit span, which requires that the subject recall those numbers which were presented. Both the missing scan and the modified digit span, as tested in this study, involve transmission of the same amount of information, since both specify the same state of the same class of alternatives, although by messages of different lengths.

The subjects of this experiment were ten males without clinically demonstrable mental deficit who were patients on the Neurology Service of the Palo Alto Veterans Hospital. Their ages ranged from 33 to 67, with a mean of 44.8 years. All subjects were tested for both modified digit span and missing scan, half of the subjects taking the former first, the rest taking the latter first. Each test session lasted about 50 minutes.

The test items were the numbers from one to sixteen. Series containing 4, 6, 8, 10, 12, or 14 randomly ordered numbers were prepared so that in the 15 series for each number of items the missing number was randomly 1 through 15. This was achieved by using appropriate segments of the sequence one to sixteen as the classes from which one number was missing. The missing number was never a limiting number of the class. Before *both* digit-span and missing-scan tests the subjects were told the class or sequential series of numbers to which the numbers presented belonged.

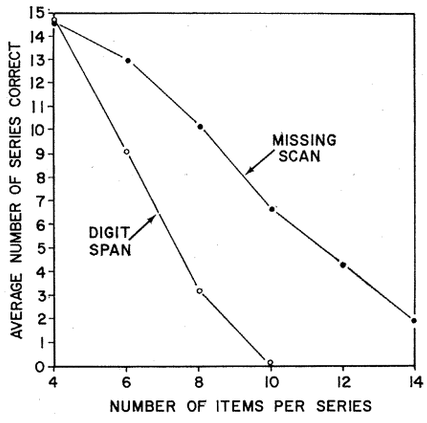


Fig. 1. Average digit span and missing scan of ten subjects.

Subjects were tested individually, the examiner reading the numbers at a rate of one per second. In the missing-scan test subjects were instructed to report the number missing from the series presented. In the modified digit-span test the subjects were instructed to report all of the numbers presented, *without regard to order of presentation.* The usual digit-span test was modified in this manner so that subjects would *not* have to retain the order of presentation as well as the numbers presented. These modifications were designed not only to make the two tests as comparable as possible but also to maximize the estimate of retention obtained with retrieval by the digit span, since one aim of this study was to demonstrate that the estimate of retention obtained without retrieval by the missing scan is greater than the estimate of retention obtained with retrieval by the digit span. Because the same series of numbers were presented in both tests, the only difference between them was in the

Table 1. Comparison of digit span (DS) and missing scan (MS).

| Subject | Items retained | | Errors in first half of list (%) | |
|---|---|---|---|---|
| | DS* | MS* | DS | MS |
| 1 | 7 | 10 | 45 | 80 |
| 2 | 5 | 8 | 32 | 75 |
| 3 | 5 | 9 | 10 | 79 |
| 4 | 4 | 6 | 13 | 73 |
| 5 | 6 | 7 | 24 | 82 |
| 6 | 6 | 9 | 28 | 65 |
| 7 | 6 | 8 | 43 | 87 |
| 8 | 6 | 9 | 42 | 90 |
| 9 | 5 | 10 | 34 | 75 |
| 10 | 5 | 10 | 23 | 84 |
| Mean | 5.5 | 8.6 | 29 | 79 |

*Determined by the method of Woodworth and Schlosberg (*1*).

manner in which the subjects indicated their retention of presented items.

Two findings are noted. First, the missing-scan estimate of retention was greater than the digit-span estimate for all subjects (Fig. 1 and Table 1) (*5*). On the average, the estimate of retention obtained with retrieval by the modified digit span was only 64 percent of the estimate obtained without retrieval by the missing scan (Table 1). Second, in the digit-span test most of the "forgotten" items (errors) were in the second half of any series presented, while in the missing-scan test most of these errors were in the first half (Table 1) (*6*). All subjects showed this reversal of error distribution (*7*).

The significance of the finding that the missing-scan estimate of retention exceeds the digit-span estimate is enhanced by the modification of the digit-span test, which would tend to increase the digit-span estimate. Since the numbers used in the digit-span test were selected from a sequence known to the subject, and could be reported in any order, the probability of guessing correctly would be greater in the modified digit-span than in the missing-scan test. However, all subjects usually reported the numbers practically in the order in which they were presented.

The reversal of error distribution shown in Table 1 raises further considerations. If the missing scan were performed by retaining presented numbers as in the digit span and then comparing retrieved numbers with the known sequence to find the missing number, the estimate of retention by the missing scan should be equal to or less than that by the digit span, and the error distribution of the missing scan should be similar to that of the digit span. These predictions are not borne out by the data, for the results of the two tests are clearly different. Thus, it appears either that different modes of short-term storage are used for retention in the digit span and the missing scan, or that the same storage system is used for both but that the missing scan reveals characteristics of retention in storage while the digit span reflects the effects of retrieval. The latter interpretation seems more probable and leaves open for further investigation the possibility that different operations may be performed upon incoming information prior to storage or that different types of scanning may be used on the same storage (*8*).

The larger estimate of retention given by the missing scan confirms that more is retained in short-term memory storage than may be retrieved, and suggests that methods which do not depend upon retrieval, such as the missing-scan test, may provide the best estimate of retention.

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5. At the 99-percent confidence level it may be asserted that the number of correct series in the missing-scan test exceeds that in the digit-span test for 4, 6, 8, 10, 12, and 14 items per series by —15.9, 8.8, 36.1, 27.4, 12.7, and —3.9 percent, respectively.
6. At the 99-percent confidence level it may be asserted that the percentage of errors in the first half of any series in the missing-scan test exceeds that in the digit-span test by 42 percent. In the digit-span test failure to report any number presented was such an error, while in the missing-scan test reporting that any number actually presented was missing constituted such an error.
7. I thank Dr. Helena Chimura Kraemer, research associate in the Department of Biostatistics of Stanford University School of Medicine, for the statistical analysis.
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## Measurement of a Visual Motion Aftereffect in the Rhesus Monkey

Abstract. *A monkey was trained to discriminate between a shrinking and expanding test figure presented after steady fixation of the center of a rotating spiral. Differential shifts in the animal's perception of size constancy were found for clockwise and counterclockwise rotation of the spiral. The magnitude of the aftereffect was within the range found in human subjects.*

It has long been known that continued observation of a moving pattern will induce an illusion of motion in the opposite direction upon subsequent viewing of a stationary pattern, or test stimulus (*1*). A convenient method of eliciting this illusion is to fixate a rotating disk having a spiral figure drawn on it. During a period of steady gazing at the center of this rotating spiral, it appears to be expanding or contracting, depending on the direction of rotation. When the spiral is stopped suddenly, or when any stationary pattern is viewed, an illusory motion in the opposite direction is clearly seen by virtually all persons.

Nothing specific is known about the physiological mechanisms responsible for this aftereffect, although attempts have been made, perhaps prematurely, to show that brain damage is in some way related to it. Various authors have reported that, among brain-damaged subjects, the aftereffect is absent (*2*), is enhanced (*3*), persists longer (*4*), is of shorter duration (*5*), or is unaffected (*6*). These conflicting findings may be clarified by the perfection of measurement techniques (*7*) and the development of methods for studying the phenomenon in animals, thus making possible selective ablation studies aimed at discovering the mediating structures. This study presents a method of measuring the rate of an aftereffect of this kind in the rhesus monkey.

A three-field mirror tachistoscope was used for alternate presentation of the spiral and a circular test stimulus, both seen at an optical distance of 5 feet. The third field was used for the continuous presentation of a spot of light which served as a fixation point. The fixation point was centered in the field so that it appeared to be in the center of both the spiral and the circle when these were visible. The spiral, which was 8 inches in diameter, is illustrated in Fig. 1 (top). It could be rotated by a synchronous motor in either direction at a speed that was stroboscopically set at 180 rev/min. In a preliminary study with human subjects it was found that this particular combination of spiral and speed of rotation resulted in greater aftereffect rate than any of the other combinations tried (*7*). The spiral was illuminated by four 1.5-watt incandescent bulbs, with diffusing reflectors, whose average distance to the surface of the spiral was about 6 inches.

The circular test stimulus was produced on the face of a 5BP1 cathode ray tube, as shown in Fig. 1 (bottom). The circle, which always appeared with an initial diameter of 3 inches, could expand or contract at preselected linear rates, or it could remain motionless. Its rate of change in size was quantified in