Inversion effects in the tachistoscopic perception of number sequences¹

ARTHUR KOESTLER AND JAMES J. JENKINS

CENTER FOR ADVANCED STUDY IN THE BEHAVIORAL SCIENCES

Abstract

Experience suggests that a common error in processing visual sequences is inversion or transposition of two or more adjacent items. This phenomenon suggests that information concerning the identity of items and their positions may be partially separable. A perception experiment was performed with tachistoscopic exposure of 5, 6, and 7-digit sequences. Abundant evidence was found for transposition errors. Further, such errors were distributed in a serial position curve much like that found for errors of single items.

Problem

While information-processing in visual perception has received increasing attention in recent years (e. g., Sperling, 1960; Averbach, 1963; Broadbent, 1963) one common phenomenon of faulty processing which may have some theoretical significance seems to have been ignored. We refer to the inversion (or transposition) of adjacent items in a sequence of numbers shown in a tachistoscope. Though such errors are common enough in bookkeeping and have earned a special proofreader's mark, they are absent from discussions of visual perception or memory span in standard works such as Osgood (1953) and Woodworth & Schlosberg (1954).

Apprehending a series of numerals and subsequently repeating them in their correct sequence must either involve the *ordered* storage of the individual items or the storage of information relating to that order. Both information identifying an item and information defining its place in the sequence must be available to the S for successful performance of the task.

The potential separability of the two kinds of information involved is not easy to demonstrate. If a subject makes a single error of identity, reporting either an incorrect number or a blank, it may indicate that he has lost only identity information. This argument, however, is inconclusive, because if the subject had acquired no information at all regarding the offending item, but complete information regarding other items, the outcome would be the same. The inversion of two digits or the permutation of three or more digits, on the other hand, furnishes a compelling argument because it is *prima facie* evidence that the identity information is accurate while the positional information is incomplete or distorted.

The purposes of the present study were to demonstrate that the phenomenon of transposition could be observed under laboratory conditions and to describe the locus of its probable occurrence in a given sequence.

Method

The stimulus materials were 80 4 x 6 notecards upon which digit sequences were typed in elite type. The 80 sequences were divided into four sets of 20 cards each. The first set showed sequences five digits in length; the second and third sets showed six-digit sequences; the fourth set showed seven-digit sequences. The sequences contained the digits 1-9 with never more than a single digit repeated on a given card. The repeated digit, if any, never occurred without at least one intervening digit. The sets were presented in the order given above. A random arrangement was made of each set. This arrangement was used in the forward order for half the Ss and in reverse order for the remainder. The materials were presented in a mirror-type tachistoscope.

The Ss were 14 undergraduates in introductory psychology courses. The S held a plunger switch which activated the tachistoscope. The E gave a ready signal when the stimulus card was in place. The S activated the tachistoscope when he was ready. He was instructed to say the digit sequence aloud immediately after its appearance, and was encouraged to guess if he was not sure of one or several items. The S always knew how many digits were shown. Responses were recorded on a tape recorder. Only one exposure per sequence was given and the S was not given any information about the correctness of his response.

Two practice sequences with ascending limits were given to accustom the S to the apparatus and to provide the E with some information on threshold. The test sets were then presented. One-minute rest periods were given after each set.

Exposure duration was individually adjusted for each S. Pilot work suggested that transpositions occurred most readily at the point where the S was beginning to miss single digits in the sequence. Therefore, the E attempted to have the exposure interval long enough that the proper number of digits would be reported but short enough that they were not always reported with complete accuracy. After every five cards the E decided whether to keep the exposure the same or to change it. Since there were practice effects in the task and since the task became appreciably more difficult, E continued to modify the presentation time during the course of the experiment. Generally 10 msec. steps were employed in such changes but with an occasional S whose performance was markedly inferior the step span was increased.

Results and Discussion

Responses were transcribed from the tape and scored. The following categories were employed:

C - correct

E - gross error

I - one digit incorrect, or "blank" reported for a single missing digit

T - transposition of adjacent pair of digits with rest of sequence correct

T' - transposition of three or more digits with remainder correct

IT - transposition of two or more digits and one digit incorrect

O - other errors, usually experimental or equipment errors

Results are given in terms of these scoring categories

Table 1
Distribution of Responses by Categories
for Each Stimulus Set. (280 items).

Scoring Code	5 Digits	6 Digits	6 Digits	7 Digits
C	130	60	65	12
E	21	67	47	122
I	50	43	50	21
T	23	23	32	12
T'	2	14	5	9
IT	44	64	73	96
O	10	9	8	8

in Table 1. Examination of the table shows that transposition provides an important source of errors. It is, however, difficult to find a statistical model which would provide a precise evaluation of the statistical significance of such errors. As Woodworth & Schlosberg (1954, p. 697) point out in their discussion of scoring memory span, any scoring system which attempts to provide separate credit for accuracy and order is arbitrary. Thus, any statistical model must make assumptions about the S's strategies on the one hand (e. g., Did the S note that digits can repeat within a sequence and, if so, did this alter his guessing behavior in the appropriate manner?) and the interrelationships of error types (which we do not yet know) on the other. Fortunately, the question is not crucial for present purposes. The only question that need be asked here is whether there is more transposition than would be expected by chance (however chance is to be defined).

We think the answer to that is clear. Of the 140 errors on the five-digit sequences, 69 involve transpositions; of the 211 and 207 errors on the six-digit sequences, 101 and 110 respectively contain transpositions; of the 260 errors on the seven-digit set, 117 contain a transposition. It is evident that until the task becomes exceedingly difficult (and the response unscorable), approximately half the errors involve transpositions. No reasonable "guessing" or chance model we have contrived can account for this finding. It seems simplest to conclude that in a large portion of the errors the S has the correct information as to the identity of some of the digits but has lost the information as to their precise location.

As a first step in describing the phenomenon the distribution of errors over positions was obtained for the simplest errors of both types. Table 2 shows the

Table 2
Position of Errors in Cases of a Single Incorrect Digit

Sequence	Position						
	1	2	3	4	5	6	7
5-digit	1	1	4	34	10	—	—
6-digit	0	2	1	4	31	6	—
6-digit	0	1	3	11	25	10	—
7-digit	0	0	2	0	7	8	4

location of the error for each instance when one digit was incorrect (I error). Table 3 gives the location of the pair of items transposed when only single transposition was observed (T error). It can be seen that both sets of distributions for all sequence lengths show the same serial position effect, suggesting that both kinds of error are susceptible to the same form of interference. If one has all the individual items, he is least likely to have precise position information in the latter half of the sequence. Conversely, if one lacks the identity of an item, it is most likely to be one from a position in the latter half of the list. The most probable transposition for any particular length of sequence appears to involve the inversion in order of the item in the most difficult position in the sequence and the item immediately preceding it.

The psychological nature of each kind of error is not at all clear but it seems likely that future work will help narrow the alternatives. It would be particularly interesting to know, for example, whether transposition is equally common when the experiment is conducted with Sperling's procedure or with a rapid sequential procedure such as that used in short-term memory research.

While we cannot at present make any decision as to the underlying nature of the transposition phenomenon, we feel that this experiment concurs with common experience in pointing to a pervasive distortion in the visual perception and reporting system which theories of information processing must take into account.

Table 3
Position of Transposed Digits in Errors Involving a
Single Transposition

Sequence	Positions Transposed					
	1-2	2-3	3-4	4-5	5-6	6-7
5-digit	0	2	18	3	—	—
6-digit	0	2	1	17	3	—
6-digit	0	5	1	21	5	—
7-digit	0	0	0	3	7	2

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Note

1. The writers are indebted to Donald Foss for collecting and coding the data. Thanks are also due to Professor Douglas Lawrence and Ernest Hilgard of Stanford University and to Professor Arnold Mechanic and Joanne D'Andrea of California State College at Hayward for their generous facilitation of the study.