

# Instructions determine scanning order in short-term judgments of relative order

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## Abstract

Short-term memory for relative order has been investigated only a few times and findings are variable. While three studies found search to be self-terminating, Sternberg (1969) reported forward scanning whereas Muter (1979) and Hacker (1980) reported backward scanning. Here we test whether differences in instructions could account for these discrepancies. Using a 2AFC paradigm, subjects judged which of two probe items was presented later or earlier, or judged whether two probes were in the same or reversed order as on studied lists of 3-6 consonants. Forward self-terminating scanning was observed with the “earlier” instruction, while backward self-terminating scanning was observed with the “later” instruction. Results were mixed with the “intact” instructions. In sum, our findings suggest that participants can perform short-term judgments of relative order with self-terminating search either in the forward or backward direction, and instruction-wording plays a significant role in determining the dominant scanning direction.

**Keywords:** serial order memory; judgment of relative order; self-terminating search; memory scanning

## Introduction

Judgment of relative order plays a prominent role in learning and memory. In a judgment of relative order paradigm, given a list of items, subjects are later tested on the relative order of two items from the list. Several studies have attempted to elucidate the memory-scanning process underlying judgment of relative order in short lists.

In self-terminating processing, the search terminates when a positive match is encountered. In exhaustive processing, the search continues regardless of a positive or negative match. While flat serial position effects can be predicted by both self-terminating and exhaustive searches, substantial serial position effects are considered definitive evidence of self-terminating processing (Townsend & Wenger, 2004). Self-terminating search has been replicated in studies by Sternberg (1969), Muter (1979) and Hacker (1980). However, the direction of the search is different across the three experiments. Forward scanning was reported by Sternberg (1969), while Muter (1979) and Hacker (1980) each found backward scanning. We attempted to explain these discrepancies.

These three studies are summarized in Table 1. Subjects in each experiment were presented lists, and tested on the relative order of items using two-item probes. The

differences in scanning directions could be explained by four hypotheses. The first hypothesis is that the wording of the instructions orients subjects to scan from the beginning of the list or from the end of the list. In Sternberg’s (1969) task, forward scanning was reported when instructions were to determine whether the items are in the correct order. Contrary to this, Muter (1979) and Hacker (1980) each reported backward scanning when subjects were instructed to identify the item that was more recent. The second hypothesis is that the differences in scanning directions are due to the length of the retention interval. In both Sternberg (1969) and Muter’s (1979) experiments, the retention interval was 1000 msec; conversely, it was 100 msec in Hacker’s study (1980). Indeed, Forrin & Cunningham (1973) have reported a “recency effect” (also interpretable as backward scanning) in the simpler item-recognition variant of the Sternberg (1967) class of paradigms with retention intervals of less than 2500 msec. Thus, there is an interpretation confound in Muter (1979), and Hacker’s (1980) results. For the Sternberg (1969) task, the “recency effect” may have been overpowered by other factors that led to forward scanning. The third hypothesis is that scanning direction is a result of procedural differences, such as the addition of the forward recall attempt and presentation of the list twice. Eliminating both factors resulted in backward scanning. The last hypothesis is that scanning direction is a result of different material types. Forward scanning was observed with digits, while backward scanning was reported with nouns and consonants.

We manipulated the instructions, while holding other experimental factors constant. This resulted in three different judgments of relative order tasks. The “intact” instruction parallels Sternberg’s (1969) experiment, while the “later” instruction parallels Muter (1979) and Hacker’s (1980) experiments. In addition, we included the “earlier” task for completeness. The retention interval was increased to 2500 ms to avoid recency effects that have confounded interpretation of the related item-recognition paradigm.

	Sternberg (1969)	Muter (1979)	Hacker (1980)
<b>Material type</b>	Digits	Nouns	Consonants
<b>List length</b>	3-6	4 or 10	10-14
<b>Number of list presentations</b>	2	1	1
<b>Retention interval</b>	1000 msec	1000 msec	100 msec
<b>Forward recall attempt</b>	Yes	No	No
<b>Instruction</b>	“Decide whether the left-to-right order of the pair was the same as its temporal order in the list, or reversed.” (Sternberg 1969; p. 452)	“Press Key 1, 2, or 3 if the top test item had been presented more recently in the list, and Key 4, 5, or 6 if the bottom test item had been presented more recently in the list.” (Muter, 1970; p. 163)	“Identify the more recent of the two items.” (Hacker, 1980; p. 653)
Keys indicate level of confidence			
<b>Scanning direction</b>	Forward	Backward	Backward

Table 1. Summary of the three judgments of relative order paradigms.

## Methods

### Participants

Fifty-nine undergraduate students participated as part of required credit for an introductory Psychology course. Fifteen participants performed the “later” task, sixteen performed the “earlier” task, sixteen performed the “intact1” task, and eighteen performed the “intact2” task.

### Materials

Stimuli consisted of sixteen consonants from the English alphabet displayed in capital letters: B, C, D, F, G, H, J, K, L, M, N, P, Q, R, T, and V. Each stimulus in a list was drawn without replacement from a pool of 16 consonants, with the restriction that they did not appear in the two preceding lists. There were equal probabilities of appearances for each consonant and in each list position. List length was randomly determined. The experiment was created using pyEPL, the Python Experiment-Programming Language (Geller, Schleifer, Sederberg, Jacobs, & Kahana, in press).

### Procedure

The paradigm is similar to Sternberg’s (1969) procedure. Study lists of 3-7 consonants were displayed sequentially. An orienting stimulus (\*) was shown at the beginning of each list for 1000 msec with an interval of 125 msec before the first list item appeared. Each list item was presented for 575 msec with an inter-stimulus interval of 175 msec. Following the last item in the list, there was a delay of 2500 msec, after which a two-item probe was displayed. Subjects

responded with the keys ‘.’ and ‘/’. Instructions encouraged subjects to respond as quickly as possible without compromising accuracy. After a post-trial delay of 500 msec, an arbitrary key was pressed to continue to the next trial. There was a delay of 400 msec before the onset of the next orienting stimulus.

In the “earlier” and “later” tasks, subjects were instructed to determine which of two probe items appeared earlier or later on the study list, respectively, by pressing the corresponding keys. If the earlier or later item was the left probe item, the ‘.’ key was pressed. If the earlier or later item was the right probe item the ‘/’ key was pressed. In the “intact” task, subjects were instructed to indicate, in a “yes/no” procedure, whether or not the probe items were presented in the same or reversed order as they were in the study list. To look for possible stimulus-response congruency effects, “intact1” responded “yes” with the ‘/’ key and “no” with the ‘.’ key, while “intact2” responded “yes” with the ‘.’ key and “no” with the ‘/’ key.

Each experimental session comprised of 1 block of 8 practice trials, followed by 9 blocks of 20 trials, for a total of 188 trials. In the practice block, immediate feedback on accuracy (correct/incorrect) was given after each trial. The experimenter remained in the testing room during the practice block to ensure that subjects understood the procedure. At the end of each of the 9 blocks, feedback on overall accuracy (%) and reaction time (ms) was given. To initiate to the next block, ‘p’ was pressed. Keyboard responses for both accuracy and response time were logged.

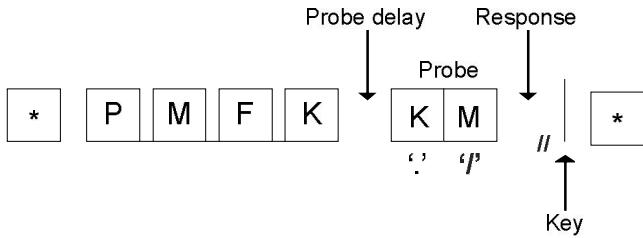


Figure 1. Schematic of the “earlier” task using a four-item study list. Following the orienting stimulus (\*) consonants were displayed sequentially. After a delay of 2500 ms, a two-item probe was presented. Subjects responded with the keys ‘.’ or ‘/’ before pressing an arbitrary key to initiate the next trial. In this example, M (‘/’) is the correct answer.

## Data analysis

Errors were infrequent (less than 15% per participant) and not included in any analyses.

**Serial position analyses** The linear regression slopes of the serial positions of the earlier and later probe items were compared for each experimental task. The study position of the earlier item was held constant, while the parameter was the study position of the later item. For example, in list length 6, when the earlier item is in study position 1, paired probe combinations can include later items in study positions 2, 3, 4, 5 and 6. In a given list length, any combinations that involve the last study position of the later item show no regression slopes. The mean response times for any trial that include a particular combination of probe positions were reported.

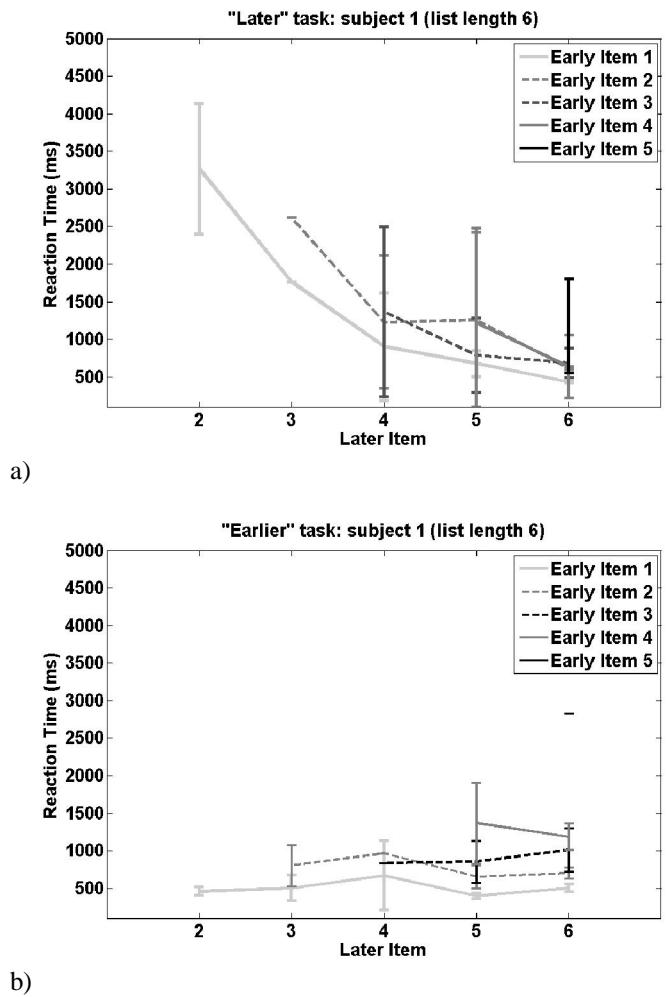
In Table 1, mean slope for the position of the later and earlier probe items were averaged across subjects for each experimental task and compared to zero. All list lengths were included.

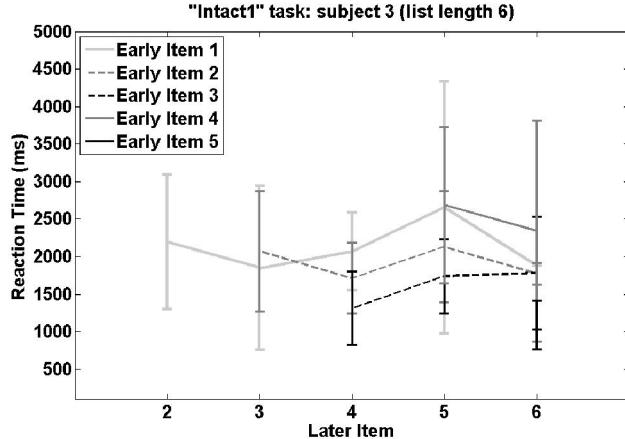
## Results

The regression slopes for the position of the later probe items for list length 6 are shown in Figure 2. In Table 1, significant negative slope for the later probe item was observed in the “later” tasks ( $p < 0.05$ ), and significant positive slope for the later probe item was observed in the “intact2” tasks ( $p < 0.05$ ). Significant positive slope for the earlier probe item was observed for the “earlier” tasks ( $p < 0.05$ ), and significant negative slope for the earlier probe item was observed for the “intact2” tasks ( $p < 0.05$ ).

	Later-item slopes	Earlier-item slopes
Later	-181.4*	-17.2
Earlier	11.8	244.1*
Intact1	33.9	17.0
Intact2	109.3*	149.1*

Table 2. Mean slope for the position of the later and earlier probe items. Slopes are in msec/item. \*  $p < 0.05$ , two-tailed test comparing mean slope against zero.





c)

Figure 2. Mean reaction time as a function of serial position of the earlier item (separate lines) and the later item (horizontal axis). Error bars denote 95% confidence intervals. Data are plotted for one example subject for each instruction.

## Discussion

Substantial serial position effects were observed, suggesting that processing is self-terminating, rather than exhaustive (Townsend & Wenger, 2004); this replicates prior findings (Sternberg, 1969; Muter, 1979; Hacker, 1980). A forward self-terminating search leads to two predictions (Figure 3): the slope is positive for the study position of the earlier item, and the slope is zero for the study position of the later item. Thus, when subjects scan from the beginning of the list, response latency is dependent on the serial position of the earlier item, but not the serial position of the later item. On the other hand, a backward self-terminating search would predict negative slopes for the study position of the later item, and zero slope for the study position of the earlier item. Thus, when subjects scan from the end of the list, response latency is dependent on the serial position of the later item, while the serial position of the earlier item has no effect.

Our results show that there is an instruction effect as the regression slopes in the “earlier” task are significantly positive for the position of the earlier item, while showing non-significant slopes for the position of the later item. The opposite is seen in the “later” task, where slopes are significantly negative for the position of the later item, where as slopes are non-significant for the position of the earlier item. This suggests that when the instruction is to “choose the earlier of the two items,” subjects search from the beginning of the list, displaying forward self-terminating scanning. Conversely, when the instruction is to “choose the later of the two items,” subjects search from the end of the list, displaying backward self-terminating scanning. The “intact” tasks show mixed results. The regression slopes in the “intact1” task are non-significant for the serial position of the earlier item or the later item. Conversely, in “intact2”,

regression slopes are significantly positive for the position of both the earlier and later item. Thus, the “intact” tasks do not fit naturally into simply self-terminating search in the forward or backward direction. This suggests either a more complex strategy or high subject variability in strategy.

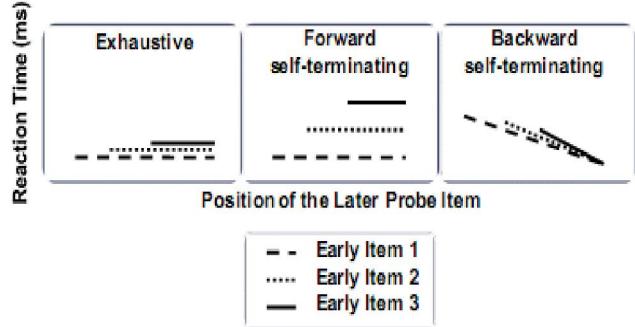


Figure 3. Interpreting regression slopes for positions of later and earlier probe items.

Our results for the “later” instructions are consistent with data from Muter (1979) and Hacker (1980), in that a robust backward, self-terminating search is observed. Thus, we can conclude that factors in their experiments, such as the short retention intervals and material types, are not the only cause of backward, self-terminating processing. Sternberg (1969) reported forward, self-terminating, however it was unclear whether the result was a consequence of forward serial recall and presentation of the list twice. By eliminating both factors, but otherwise, using the same paradigm, scanning order in the “intact” tasks is unclear and seems more variable. This suggests that forward serial recall and presentation of the list twice may have influenced subjects in Sternberg’s task to scan more consistently with a forward strategy. Finally, robust and consistent forward scanning order was seen for the “earlier” instructions, which can be viewed as the counterpoint to the “later” instructions, suggesting that forward and backward scanning strategy may both be comparably accessible to subjects and that instructions may modulate a choice between the two scanning directions.

While we refer to forward and backward scanning, which implies serial comparison models, other studies have shown that parallel comparison models can also account for this. Thus, an alternate account of our findings could be made within parallel models; rather than referring to scanning order, one could map forward and backward scanning to matching-operation speeds being inversely or directly proportional to recency, respectively.

In sum, we report an effect on scanning direction of wording of the instructions. In Sternberg’s (1969) task, the instruction was to determine whether the probe items were in the correct order and subjects appeared to scan from the beginning of the list. In contrast, in Muter (1979) and Hacker’s (1980) experiments, the instruction was to choose

the more recent of two probe items and subjects scanned from the end of the list. Thus, our findings show that performance of judgment of order is dependent on the instructions, which influences the choice of strategy. We suggest that specific instructions draw the subject's attention either predominantly to the start or the end of the list, biasing the subject to scan forward or backward, respectively.

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### **References**

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