AMERICAN JOURNAL OF PSYCHOLOGY
December 1976, Vol. 89, No. 4, pp. 669–679

Mental set and mental shift revisited

Amos Spector and Irving Biederman
Oakland University and State University of New York at Buffalo

In 1927, Jersild found that alternately subtracting 3 from a two-digit number and giving the common opposite to a word in a mixed list of numbers and words was faster than the average speed of subtracting 3s from a pure list of numbers and giving the opposites to a pure list of words. Experiment I replicated those findings: mixed lists were slightly, albeit nonsignificantly, faster than pure lists. Experiments II, III, and IV were designed to determine why changes of set did not slow performance on mixed lists: the results suggest that a shift of operations will take little or no time if the stimulus can serve as a retrieval cue for the operation to be performed on it. But changes of set will have a large effect when the selection of the appropriate operation requires that one keep track of previously performed operations.

Consider a serial vocal reaction-time task with lists like the following. With a *pure number* list like '47 25 76 57 68 74 53 76 . . . 42 21,' the items printed vertically down a sheet of paper, the subject is to proceed down the list as fast as possible, subtracting 3 from each of the numbers. Thus, his responses would be '44 22 73 . . . 18.' With a *pure word* list like 'hot above man weak good after above sick . . . come good,' the subject is to go down the list giving an opposite to each of the words. Thus, his responses would be 'cold below woman . . . bad.' And with a *mixed* list like '47 hot 25 above 76 man 57 weak . . . 21 bad,' the subject is to go down the list subtracting 3 from each of the numbers and giving an opposite to each of the words. Thus, his responses would '44 cold 22 below . . . good.'

In 1927 Arthur T. Jersild, in an article entitled "Mental Set and Shift," reported that such a mixed list would yield reaction times that were slightly faster than the average of two such pure lists. Such a counterintuitive result[1] seemed worthy of replication, hence Experiment I below. Experiments II, III, and IV were designed to identify the conditions under which a sizable *shift loss,* the expected slowing effect of the changes of set a mixed list requires, would occur.

EXPERIMENT I

This experiment attempted to replicate Jersild's 1927 experiment, but with several methodological modifications. Jersild's subjects always started with a pure list in counterbalanced ABBA order, where each A represents one of the two pure lists and each B represents one of the two mixed lists. If learning from trial 1 to trial 2 was greater than on subsequent trials, the order of tasks would have favored the mixed lists. Inspection of Jersild's data over the 16 trials revealed that the advantage of the mixed lists might be reduced, but not entirely eliminated, if such practice effects had been completely balanced.

Two additional variables were studied: stimulus format and rate of shift. Since the printed *sheets* Jersild used to present the items afforded the opportunity for preview, a condition was administered in which the items were printed on a deck of *cards*. Presumably, this latter format would reduce preview. Words and numbers in Jersild's mixed lists alternated after *every* item: word, number, word, number, . . . To vary the rate of shift, one of the mixed lists in this experiment alternated after every *second* item: word, word, number, number, word, word, . . . List length also differed between the two experiments. There were 25 items on Jersild's lists, but only 20 on our lists.

METHOD

Subjects and lists

The subjects were 48 students. All were from Hilbert College. There were 40 two-digit numbers and 40 words with common opposites (e.g., 'cold,' 'below') used to make four 20-item pure lists, two of each type (words or numbers), and four 20-item mixed lists. The words were taken from Woodworth and Wells's (1911) association tests, which Jersild employed in his 1927 study. Each mixed list was composed of half of the items from one of the pure word lists and half of the items from one of the pure digit lists. Since each mixed list was composed of different halves of the pure list, the two mixed lists had no items in common. A single- and double-alternating version of each mixed list was constructed.

Design and procedure

Each subject responded to two pure lists and two mixed lists (one alternating after every item, the other after every second item). Half of the subjects responded to the printed sheets, and half the subjects to the cards. The sheet or deck of cards was presented to the subject face down. On signal from the experimenter, the subject turned over the sheet (or top card). Subjects were fully informed of the nature of the task and of the specific list before each list was presented. Half the subjects started with a mixed list, and half with a pure list. All 24 orders of the four lists were used. Lists were drawn so that the items in a subject's mixed lists differed from the items in his pure lists. But, over subjects, items and lists were balanced. Subjects were instructed to "go as fast as possible without making any errors." Timing was done by the experimenter with a stop watch.

RESULTS AND DISCUSSION

While the direction of the effect was as Jersild reported, with reaction times to the mixed lists faster than to the pure lists, the difference in the times to perform the pure and mixed lists was negligible: 34.04 and 33.90 sec respectively [$F(1, 45) < 1.00$]. The main effect of format (cards or sheets) fell just short of significance [$F(1, 45) = 3.13, .05 < p < .10$], with the sheets requiring less time (32.0 sec) than the decks of cards (35.9 sec). The interaction between list type (pure or mixed) and format was significant [$F(1, 46) = 4.16, p < .05$]. The pure lists were slower than the mixed lists with the sheets (32.7 and 31.3 for pure and mixed lists respectively) but faster than the mixed lists with the cards (35.4 and 36.5 for pure and mixed lists respectively). The difference between the pure and mixed lists with the sheets was not significant [$t(23) < 1.00$]. A weaker form of Jersild's results was, therefore, replicated in this experiment: with the items printed on sheets (as in Jersild's study), the mixed lists were *not* slower than the pure lists. That is, no shift loss was obtained. With the sheets, the advantage of the mixed lists averaged 70 msec per item, slightly less than the 96 msec per item that can be calculated from Jersild's data.

The reversal of the relative speeds of the mixed and pure lists with the cards as format suggests that preview might have played a role with the sheets. This would not make the lack of a shift loss with the sheets any less interesting, for it would suggest that the efficiency of reading-in (i.e., previewing) information of one type was reduced when responding to and previewing information of the *same type*. But the cards, although producing slower reaction times on the pure lists than did the sheets, did not necessarily eliminate preview. The eye/voice span may have enabled the subject to turn to the next card while responding to the present one.

EXPERIMENT II

A shift loss in Experiment I could have been obscured by either of two factors. One is the opportunity for preview: while responding to one kind of item the subject was able to see the next item on the sheet (and possibly in the cards). The second factor is the predictability of the types of item: even if the subject did not utilize preview, the mixed items (numbers and words) alternated in regular and thus predictable fashion. In both cases, the subject could prepare for the different type of item before he started to process that particular one. Experiment II projected the items singly with words and numbers intermixed in what looked to be a random fashion. Thus, both preview and predictability were eliminated.

METHOD

Subjects and lists

There were 24 students, 12 males and 12 females, who served as subjects. They participated in one 25-min session as part of their course requirement in introductory psychology. With but minor changes, the items were the same as used in Experiment I.

Design and procedure

Each word or number was projected by a Kodak Carousel projector onto a screen. The average visual angle subtended was 1 deg 5 min for the numbers and 3 deg 15 min for the words. Reaction times were recorded by a voice key whose activation also terminated the slide. The intertrial interval was approximately 4 sec with a 750-msec auditory warning signal. The major variables balanced in Experiment I were also balanced here. Words and numbers in the mixed lists were presented in a 'random' fashion so as to reduce the predictability of the type of item.

RESULTS AND DISCUSSION

Table 1 shows the mean correct reaction times. A two-way analysis of variance of these reaction times revealed that the effect of item type (words or numbers) was highly significant: giving opposites was 244 msec faster than subtracting 3s [$F(1, 23) = 21.38, p < .001$]. Mixed lists were slower than pure lists by 35 msec, but this effect was not significant [$F(1, 23) = 2.77, .1 < p < .25$]. Giving opposites was completely unaffected by mixing: all the effect of block type (pure or mixed lists) was on subtracting 3s. This produced an interaction of block type by item type that fell just short of significance [$F(1, 23) = 4.14, .05 < p < .10$].

Eliminating both preview and predictability did produce a slight, though nonsignificant, advantage of the pure over the mixed lists. Most of the gain in speed on the pure lists is probably attributable to the elimination of preview, since there is some evidence to suggest that the predictability of the *kind* of information to be presented has little effect on reaction times. Biederman (1973) studied a mental-arithmetic task in which two digits were added, subtracted, or multiplied, and in which the operator symbol (+, ×, or −) could be presented either before or after the digits. He found that when the subjects were uncertain about the

Table 1. Mean correct verbal-reaction times, in milliseconds, as a function of item type and list type; Experiment II

	Item type		
	Words	Numbers	M
Pure lists	1,207	1,417	1,312
Mixed lists	1,208	1,486	1,347

order of the operator symbol and digits, reaction times were almost identical to those when the order of presentation of the operator symbol and digits was constant and therefore highly predictable. In the current investigation, the elimination of both preview and predictability in Experiment II did not lead to a larger advantage of the pure over the mixed lists than did the possible elimination of just preview alone in Experiment I: a 55-msec advantage of the pure over the mixed lists with the cards in Experiment I compared to a 35-msec advantage of the pure lists in Experiment II.

The failure to obtain a sizable shift loss with the discrete trials in Experiment II is evidence against several explanations which would posit that *interference* on the pure lists in Experiment I obscured shift losses on the mixed lists. Two sources of such interference have been proposed. One kind is based on the possibility that simultaneous processing is possible under the procedure of Experiment I. That is, more than one item may be processed at a time. The possibility of preview, discussed above, is an example of simultaneous processing, although simultaneous processing could also refer to the reading-in of more than one item at a time or to the central processing of more than one item. Whatever the possible loci of simultaneous processing, the interference explanation assumes that simultaneous processing is less possible when the items are of the same type, as they are on a pure list. Jersild referred to this as "mutual interference."

A second possible source of interference on the pure lists derives from the work of Bills and Robinson (Bills, 1931, 1935a, 1935b; Robinson and Bills, 1926), who suggested that homogeneous (pure) lists are more likely to suffer 'mental blocks.' They defined a mental block as a temporary stop in a continuous task and, using tasks such as continuously writing or saying 'a b a b a b . . .' or 'a b c d e f a b c d e f . . .,' found that as task homogeneity and response competition increased, so did the tendency toward more frequent and longer mental blocks. However, Bills (1935b) also found that introducing 'artificial blocks' (rest periods) during the subject's performance eliminated this tendency. These artificial blocks were less than 2 sec long, as were the 'natural' blocks shown by the subjects.

If Bills and Robinson's findings hold in tasks like Jersild's, then pure lists, being more homogeneous than mixed ones, should lead to more mental blocks. However, this should be so only for continuous tasks where the intertrial interval is reduced to a minimum. If the task is one of discrete trials (as in Experiment II), blocking should disappear, since the relatively long intertrial intervals (4 sec) would serve as artificial blocks. Further, the discrete trials in Experiment II should eliminate the simultaneous (e.g., eye/voice overlap) processing that might favor the mixed task in Experiment I. Since the shift loss in the discrete-trial tasks of Experiment II did not exceed that in the self-paced tasks of Experiment I, mental blocking and mutual interference would appear to be of only minor consequence in accounting for the lack of significant difference between pure and mixed lists.

One additional result of Experiment II is important. If there is necessarily an effect of a shift between two operations, one should be able to observe repetition effects in the mixed lists. When the same operation was required successively, and presumably, no mental shift was needed, the reaction times to the second and third repetitions should be shorter than to the first operation. The data from the mixed lists were, therefore, analyzed for such repetition effects. No such effects were found, for either the numbers or the words as stimuli.

For the present experiment, then, the effect of changes of set — the disadvantage of mixed as compared to pure lists — was small and nonsignificant. What might produce a large effect?

EXPERIMENT III

It is not too difficult to conjure up tasks in which changes of set might have a sizable effect. Consider, for example, tasks in which subjects have to alternately subtract 3 and add 3 to successive two-digit numbers or must alternately respond with an opposite and then a similar word in a list of words. Compared to tasks in which only one of these operations has to be applied, these mixed tasks in which the item does not unambiguously indicate which operation is to be applied should be considerably slower (Biederman, 1972; Shaffer, 1965).

Jersild himself (1927) described several conditions in which both operations could be performed on any item. Here, Jersild studied five operations in which subjects performed mental-arithmetic problems on columns of 25 two-digit numbers. In the pure lists, subjects would proceed down a column performing a single operation. In the mixed lists, subjects would alternate between one operation and another. Five pairs of operations were studied: adding and multiplying or adding and subtracting in one of four different ways (+6 −3, +14 −7, +17 −13, or +1 −1). While the procedural details and error corrections preclude a precise statement of the differences between pure and mixed tasks, the mixed lists appeared to require from 1.2 sec (for adding and multiplying) to 1.6 sec (for adding and subtracting +17 −13) more time per *item* than the pure lists. That is, a large shift loss was obtained. And with an association task in which subjects either had to provide an opposite to a word (e.g., 'wet' as a response to 'dry') or an object for a verb (e.g., 'ball' as a response to 'throw'), a shift loss of .675 sec per item was obtained, about half that with the mental arithmetic but still quite large. That is, when subjects proceeded down a column of words alternately giving an opposite and an object, the average time per item was .675 sec longer than the average of the two pure tasks in which only one kind of association was to be given in each column.

In order to demonstrate the effects of ambiguity about the required operation in the present experimental context, Experiment III used lists of numbers only, the subjects adding or subtracting 3 in the pure lists and alternately adding 3 and subtracting 3 in the mixed list.

METHOD

Subjects and lists

The subjects were 12 graduate students at the State University of New York at Buffalo, all volunteers. Three lists of 24 two-digit numbers each were prepared. The numbers were chosen at random and randomly assigned to the three lists, except for these constraints: that none of the 72 numbers appear more than once; that the digit 0 not appear first in any number; that the digits 0–9 appear second as equally often as possible; that in dividing the 72 numbers into three different lists, the digits 0–9 again appear as second digit as equally often as possible; that no two numbers with the same second digit follow each other. This was done to eliminate the effect of a just-performed operation with essentially the same problem. Such an effect could facilitate performance in a pure list and hinder it in a mixed one. The three lists were each printed on a sheet of paper in three 8-number columns.

Design and procedure

Each subject added 3 to each number in one list, subtracted 3 for the second list, and alternated between adding and subtracting 3 for the third list. Lists, tasks, and orders were all balanced over subjects. Timing was done with a stopwatch to the nearest .1 sec.