Perceptual groups as coding units in immediate memory

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The relation between memory and perceptual unitization was investigated. Serial strings of 12 letters were presented for S's immediate recall. According to one grouping of successive letters, the string was a series of four familiar acronyms such as YMCA-PHD-FBI-TV; according to a different grouping, the same string appeared to be utter nonsense. A prior study had investigated recall as related to groupings determined by temporal proximity of elements. The present studies examined two bases for grouping by visual similarity—the physical size of letters and the color of successive letters. Adjacent letters tended to be grouped together (and unitized in recall) if they were the same size or the same color. If the letters grouped together formed familiar acronyms, recall was greatly facilitated. Thus, whether a string of letters is perceived as meaningful and familiar depends greatly on how stimulus variables determine the groupings within the string.

The present experiments concern the effect of perceptual grouping upon chunking in immediate recall and are addressed specifically to the effect of having the perceptual groups correspond or not to codable verbal units. These experiments follow up earlier studies by Bower & Springston (1970). Those studies showed that Ss' immediate recall of a letter series of codable acronyms was better when temporal pauses segregated the series into codable acronyms (e.g., TV FBI JFK YMCA) than when the pauses were located away from the acronym boundaries (e.g., IC BML BJT WAUP). The hypothesis was that at intake, S segments the letter series into perceptual groups (according to temporal contiguity of successive elements) and then tries to determine via a "dictionary look-up" whether each perceptual unit matches a single conceptual node in long-term memory (corresponding to that perceptual group of letters). If a match is obtained (i.e., if the memory already has a single node corresponding to, say, TWA), then that node is addressed and used in the temporary memory structure being established during input for the purpose of guiding the ensuing recall test. If the perceptual unit does not activate a matching single unit in long-term memory (e.g., BJT), then a new memory node has to be set up and the three letters attached separately to it by rehearsal. The result, of course, is poorer recall due to there being more new linkages to be learned in the latter case.

The present experiments extend the prior work by examining another perceptual variable that promotes grouping. The earlier experiments had produced grouping by varying the temporal *proximity* of successive spoken elements, with pauses between successive segments of the series. But proximity is only one of the so-called Gestalt laws of grouping (see Wertheimer, 1923). Another grouping variable that seems applicable to verbal learning materials is *similarity*. The rule is that stimulus elements that resemble one another will tend to be grouped together in the perceptual field. A common illustration in introductory textbooks, for instance, is a row of circles and pluses appearing as alternating pairs, as in ○○++○○++. In this case, the elements are grouped subjectively into pairs according to similarity of their shapes. Alternative bases for grouping would be similarity in size (e.g., OOooOOoo) or in color (e.g., ●●○○●●○○). In the experiments below, these variations were used with a series of acronyms presented visually and simultaneously as a horizontal string of equally spaced letters. In Experiment 1, the successive letters were grouped on the basis of their physical size; in Experiment 2, successive letters were grouped according to the color of the letters. Across different strings of acronyms, several different perceptual groupings of the string were suggested by varying the letter sizes or letter colors. The expectation throughout was that immediate recall would be best when the perceptual groups corresponded to the acronym units which S already had in his lexical memory.

METHOD

The overall design of both experiments is identical to that of Experiment III in Bower & Springston (1970), which may be consulted for details not cited here. Each S viewed and then immediately recalled many different strings of 12 letters, comprising several instances of four different experimental types of items. In Experiment 1, there were three instances of each string type, comprising 12 trials in all; in Experiment 2, there were eight instances of each type, comprising 32 trials in all. Each string was composed of four acronyms—a quadrigram, two trigrams, and a digram, in that order or in the reverse order. Half the strings had the quadrigram at the beginning and will be called Q strings (e.g., YMCA-DMZ-FBI-TV); half the strings had the digram at the beginning and will be called D strings. Half of the Q strings and D strings were presented in such manner as to promote a 4-3-3-2 grouping, and half in such manner as to promote a 2-3-3-4 grouping. The Ss were shown each letter string on a flash card for 5 sec, and then wrote their immediate recall of it for 15 sec on score sheets marked off into rows of 12 letter spaces for each string. In Experiment 1, the stimulus variable promoting grouping was the physical size of the letters in the series. Strings were presented as 12 black handprinted letters on 8 x 11 in. white pasteboard, exposed by an E standing at the front of a room about 6-10 ft away from small groups of 2-6 seated Ss. Tall (6-in.) and short (1.5-in.) letters occurred in either the serial pattern 4-3-3-2 or the serial pattern 2-3-3-4. The series always began with tall letters, and the letters were evenly spaced across the row (e.g., YMcadMZFbitv). In Experiment 2, the color of successive letters was used to promote grouping. The first letter group was always red, the second was blue, the third brown, and the last green. The colors occurred either in the pattern 4-3-3-2 or in 2-3-3-4.

The colored letters were handprinted ¾ in. high on 5 x 8 in. flash cards, which were shown one at a time by E sitting across a table from S. The Ss in Experiment 2 were tested individually; those in Experiment 1 were tested in small groups of 2-6.

The three (or eight) instances of the four different string types were presented in three (or eight) blocks of four strings, with each string type appearing once in random order in each block. The Ss in Experiment 1 were 29 summer school Ss recruited by a college newspaper ad and were paid $1.75 for their services in this and in another unrelated experiment; the Ss in Experiment 2 were 12 students fulfilling a service requirement for their introductory psychology course at Stanford.

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Table 1
Mean Letters Correctly Recalled for the Four Types of Sequence for Experiments 1 and 2*

	Stimulus Grouping	String Type		Mean
		Digram First	Quadrigram First	
Experiment 1 (Size)	4-3-3-2	6.2 (.27)	8.0 (.34)	7.1
	2-3-3-4	9.3 (.33)	7.2 (.29)	8.3
	Mean	7.8	7.6	
Experiment 2 (Color)	4-3-3-2	6.6 (.29)	8.1 (.31)	7.4
	2-3-3-4	8.7 (.34)	7.7 (.29)	8.2
	Mean	7.6	7.9	

**The standard error is in parenthesis beside each mean.*

RESULTS

Each S's protocol was scored for the number of letters correctly recalled in their correct positions, segregated according to the type of string. The results of primary interest are shown in Table 1, which reports mean letters correctly recalled for the four item types and two experiments. The most obvious result in both halves of Table 1 is the strong interaction in the pattern of numbers; D strings are best recalled when the physical group structure is 2-3-3-4; Q strings are best recalled when the grouping is 4-3-3-2. We call these "compatible" (as opposed to "incompatible") strings, since in these cases the sequence of physical groups is compatible with the sequence of acronyms. In Experiment 1, with sizes, recall of compatible strings averaged 8.67 letters, whereas incompatible strings averaged 6.71 letters. This difference is significant beyond the .001 level by a t test for correlated means, $t(28) = 5.73$. In Experiment 2, with colors, recall of compatible strings was 8.38 letters, as contrasted to 7.15 for incompatible strings. Although the compatibility effect is smaller than that in Experiment 1, it is quite significant statistically, $t(11) = 3.27$, $p < .01$. Given the ordinary stability of the memory span, even the 17% improvement [of (C-I)/I] in Experiment 2 due to compatibility is striking.

An ancillary and unexpected finding apparent in Table 1 is that strings presented with a 2-3-3-4 grouping are recalled better than strings grouped in a 4-3-3-2 pattern. The effect is significant in both experiments, though weaker in Experiment 2 than in Experiment 1. Assuming that Ss read the strings in normal left-to-right order, this difference may reflect difficulty in repetitively rehearsing the first several groups of a string (as later ones are read in) when the initial group produces a heavy memory load. A similar effect in the same direction was observed in the earlier Experiment III of Bower & Springston (1970) with acoustically presented letters, grouped according to temporal pauses.

Integration of the Serial Responses

Since it is claimed that the compatibility effects represent the alliance vs conflict between the acronym and the perceptual groupings, the recall protocols were examined for evidence of summation vs conflict of these two organizations. The associative integration of the serial responses can be inferred from the pattern of correlations between recall and nonrecall of successive letters across the string. The transition-shift-probability (TSP) measure computed below is based on the idea that whole chunks tend to be recalled in an all-or-none fashion. If the elements in Serial Positions n and $n + 1$ belong to the same recall chunk, then they should tend to be recalled together or nonrecalled together. On the other hand, if these adjacent elements belong to different recall chunks, then one chunk may frequently be recalled without the other, so that Elements n and $n + 1$ should be less correlated than in the former case. The TSP is a quick index of the degree of correlation of recall between adjacent elements. The TSP is defined as the joint probability of a shift either from recall of Element n to nonrecall of Element $n + 1$ or from nonrecall of Element n to recall of Element $n + 1$. For a chunked series, the TSP index is large on the transition into the first element of a chunk, but is appreciably smaller for transitions within a chunk (see Bower & Springston, 1970). Using the logic in the reverse direction, one can identify S's chunk boundaries operationally by the appearance of large spikes followed by troughs in his TSP profile across serial positions.

Turning to the present results, Fig. 1 plots the TSP profile for two of the conditions of Experiment 1. The other conditions reveal similar effects but are not shown in order to avoid visual clutter. For the conditions shown, the acronym pattern was 2-3-3-4; the size grouping was 2-3-3-4 for the compatible condition (solid dots) and 4-3-3-2 for the incompatible condition (open circles). First, the TSP profile for the compatible condition shows spikes and troughs at the expected locations—that is, spikes for transitions 2-3, 5-6, 8-9, and troughs elsewhere. The only deviation is the slightly high final point at the 11-12 transition; this was apparently caused by Ss' writing down the final letter of the string first but then forgetting the rest of the quadragram. Second, the TSP profile for the incompatible condition (4-3-3-2) shows some conflict between the two organizations, with the physical

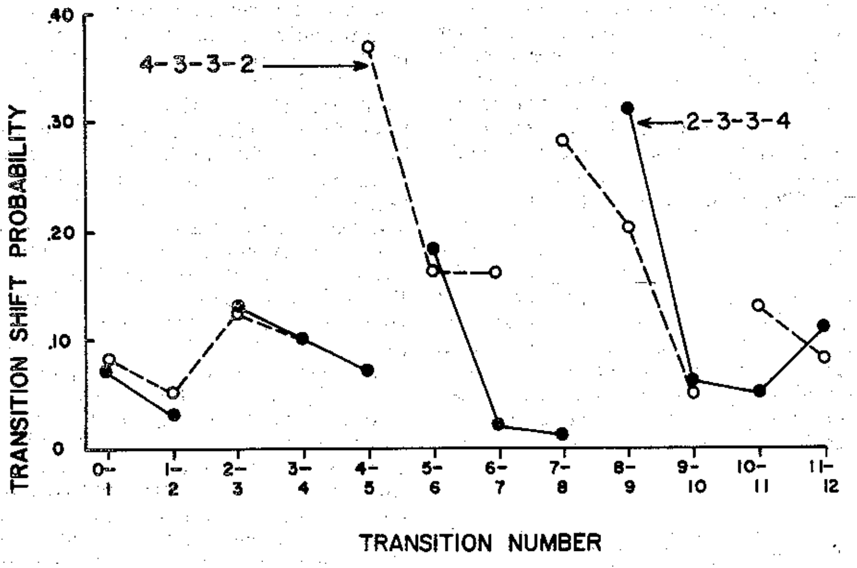

Fig. 1. Transition shift probability profiles for D strings according to whether the size groups were compatible at 2-3-3-4 (filled dots) or were incompatible at 4-3-3-2 (open circles). A break in each curve signifies the transition between perceptual groups. The point plotted above 0-1 is just the probability of an error on the first letter.

grouping "winning out" over the acronym grouping. The TSP points are plotted with a break between the size groupings. The physical grouping variable predicts relatively large spikes at transitions 4-5, 7-8, and 10-11; in the data, each of these probabilities is larger than its adjacent neighbors. An influence of the acronym structure is evident from a high TSP at transition 2-3, which marks the transition from a familiar digram into a familiar trigram. The profiles for the other incompatible conditions showed the same effects, in fact revealing more "acronym-prominence" than is apparent in Fig. 1. Thus, the conclusion from examining the TSP profiles is as expected; perceptual similarity of adjacent letters promotes grouping of like elements into perceptual units which enhance or diminish recall according to the extent to which the perceptual chunks do or do not correspond to known acronyms.

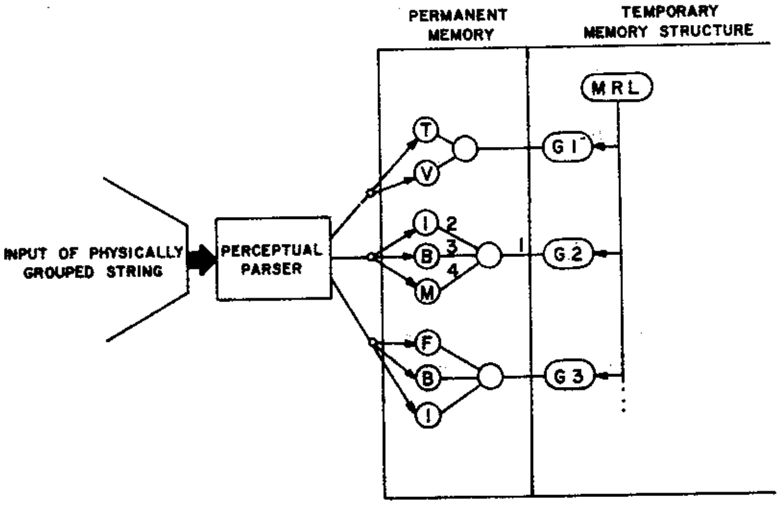

Fig. 2. Schematic representation of the associations established in the temporary memory structure to mediate recall of the grouped string TV-IBM-FBI. These are activated as the output of the perceptual parser. They happen to already be associated in long-term memory, so their single node is associated to the G_i node representing the i^{th} group in the most recent list. See text for details.

DISCUSSION

Let us just briefly review our theoretical interpretation of these results. It is supposed first that S learns a supraspan letter string by establishing temporary associations between an internal element (called "most recent list" or MRL in Fig. 2) and a list of memory nodes representing the successive groups of the string (denoted G_1, G_2, . . ., in Fig. 2). The resultant memory structure of a study trial is illustrated in Fig. 2, showing the temporary associations established between group nodes and nodes of LTM representing successive letter groups in the series to be learned. It is further supposed that a "perceptual parser" divides the letter string into perceptual groups on the basis of physical characteristics (i.e., according to Gestalt laws of proximity, similarity, etc.). There is an automatic attempt to match each perceptual group to known contents in a content-addressable memory. If the perceptual group of letters is an acronym familiar to S (e.g., IBM), by definition that means that S has already associated the letters together into a single node. This single node can then be used in building the temporary memory structure needed to recall the 12-letter series. For example, if the second group in a 2-3-3-4 string is IBM, then S need only associate the second hypothetical "Group 2" element to the node in long-term memory representing the meaningful acronym IBM. On the other hand, if the letter string had been a nonsense trigram like MBI, then a content-addressable look-up would have found no single node corresponding to prior familiarity and/or meaning associated with MBI. Therefore, S would have to establish a new chunk node (Estes, in press, calls it a "control" element), associate M and B and I in that order to this node, and then associate this node to the hypothetical "second group" element on the temporary memory list S is constructing as he studies each letter string.

These remarks simply explicate in detail the content of the old theory that familiar material is easier to remember than unfamiliar material because there are fewer novel associations to be acquired. As may be seen in the above hypothetical account, a known acronym requires only one association to be established (e.g., that link labeled 1 in Fig. 2), whereas an unfamiliar trigram requires about four distinct associations—the three letters to their control node (labeled 2, 3, 4 in Fig. 2) and the control node linked to the nth group element on the temporary memory list (labeled as Link 1 in Fig. 2).

Our experiments have examined the influence of physical similarity (in size and color) of letters upon the tendency of the perceptual parser (see Fig. 2) to assign successive letters to the same perceptual group, and how this organization in turn affects S's ability to encode and remember the letter strings. Earlier studies had proven the effectiveness of temporal (and spatial) proximity of successive elements upon perceptual grouping and subsequent recall; the present experiments extend these findings to physical similarity. Adjacent letters that look alike (in size or color) tend to be grouped together by the perceptual parser. The perceptual groupings in turn determine the letter groups which are "looked up" in memory. By this means, when a perceptual group breaks across the boundary between two acronyms, S may not recognize either acronym since neither one is the perceptual unit with which S's memory is queried. Similar results have been reported by Bower & Winzenz (1969), who found that Ss neither recognized nor improved their recall of letter (or digit) strings which were grouped differently on each learning trial. The present results substitute a lifetime of prior learning of familiar acronyms for the few trials of learning of artificial letter series by Bower and Winzenz. But the results are compatible in each instance; physical groupings of the learning material which conflict with earlier learned groupings will not produce much recognition or recall. For best recall, it is best that the series be presented according to the groupings that S already knows.

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