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SIMILARITY AND INTRUSIONS IN SHORT-TERM MEMORY FOR CONSONANT-VOWEL DIGRAMS

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Subjects listened to lists of six consonant-vowel digrams presented at the rate of 0·8 sec./digram and copied them as they were being presented. Immediately after finishing copying the list, they attempted ordered recall of the six digrams. The digrams in each list were chosen from a population of eight digrams consisting of all digrams that can be constructed from the consonants "f" and "n," the vowels "ā" and "ō," and the two orders "CV" and "VC." Intrusions tended to be similar to the presented digram, and the frequency of an intrusion was a monotonic increasing function of degree of similarity to the presented digram. The ordering of intrusion frequency for each similarity type was from greatest to least: $+-+$ (same consonant, different vowel, same order), $++-$, $-++$, $-+-$, $+--$, $--+$, $---$. The findings indicate that forgetting is not all-or-none, that digrams are coded in terms of phonemes, and that initial vs. terminal position is a distinctive feature of consonants, but not vowels, in short-term memory.

Conrad (1964) and Wickelgren (1965) have shown that intrusion errors in short-term recall of letters and digits tend to have a vowel or consonant phoneme in common with the correct letter or digit. Wickelgren's study suggested that vowel similarities were more important than consonant similarities, but the study was far from systematic with respect to this question. Letters and digits are an unsystematic population of combinations of phonemes. The number of different vowel phonemes is smaller than the number of different consonant phonemes in the letters and digits, and a few vowel phonemes (ē, ĕ, ā, ī, ōō) are found in many letters and digits, while no consonant is found in a similarly large number of letters and digits.

There was some indication in Wickelgren's study that common-consonant intrusions had to have the common consonant in the same serial position in the sequence of phonemes composing an item, while common-vowel intrusions were less dependent on the relative position of the vowel. Thus, "g" (/jē/) and "j" (/jā/) were frequently confused in recall, as were "s" (/ĕs/) and "x" (/ĕks/), but "k" (/kā/) and "x" (/ĕks/) were not. At the same time "h" (/āʃ) and "j" (/jā/) were confused even more often than "j" (/jā/) and "k" (/kā/), etc. However, there are extremely few comparisons of this kind that can be made with letters and digits, and it takes a huge sample to get enough cases of these types of errors to make a meaningful comparison.

Wickelgren's study, at best, is only suggestive regarding the relative importance of consonant similarity, vowel similarity, and position similarity in producing intrusions in short-term recall. Furthermore, there are no cases where one letter consists of the same two phonemes as another letter, but in the opposite order. Would this sort of similarity produce a very high probability of confusion between the two letters in short-term recall? How would the frequency of this sort of intrusion compare to the frequency of intrusions that had a common consonant or vowel in a common position, and how would each of these frequencies compare to the frequency of intrusions having either a consonant or a vowel in common with the correct item, but in a different position? Finally, how would each of these three types of intrusion frequencies compare with the frequency of intrusions that have no phoneme in common with the correct item? Previous studies only indicate that intrusions tend to be phonemically similar to the correct item; they do not evaluate the relative importance of consonant, vowel, and position similarity in producing intrusion errors. This is the purpose of the present study.

Method

Procedure

One sec. after a "ready" signal, subjects listened to a list of six consonant vowel digrams and copied them as they were being presented. Immediately after finishing copying, they covered what they had copied and attempted ordered recall of the list (by filling-in six boxes). Presentation was at the rate of 0·8 sec./digram, and about 23 sec. was allowed for recall, followed immediately by the "ready" signal for the next trial. The entire experiment was recorded on tape and lasted about 1 hr.

Design

The digrams were the eight possible digrams that can be constructed out of the two consonants "f" and "n," the two vowels "ā" and "ō," and the two orders "CV" and "VC" (i.e. fā, āf, fō, ōf, nā, ān, nō, ōn). Subjects knew what the item population was. One hundred lists were used in the experiment. There were two types of lists, lists consisting of a random arrangement of six different digrams and lists consisting of a random arrangement of five different digrams one of which was used twice (but not adjacent to each other). Four lists in every block of five lists were of the former type, and one list was of the latter type. The only reason for having some lists with repeated items was to prevent subjects from ruling out a digram in recall because they had used the digram already in recall of the list. Cognitive strategies like this would simply add variance to the intrusion data or reduce the number of intrusions by increasing the number of omissions.

Subjects

Subjects were 13 M.I.T. undergraduates taking psychology courses; they participated in the experiment as part of their course requirements.

Results

The purpose of having subjects copy the digrams during presentation was to separate the errors in perceptual recognition from the errors in recall. Only the digrams copied correctly were scored for correct ordered recall. The per cent. correct recall after correct copying was virtually the same for the eight different digrams, varying from 60 per cent for "nā" to 70 per cent. for "ōf." The Spearman rank order correlation between per cent. correct recall of a digram and the number of times that digram was given as an intrusion was 0·88 ($p < 0{\cdot}01$). This indicates that the small differences in frequency of correct recall were partly or completely the result of different response biases for different digrams.

Table I reports the frequency of correct ordered recall and the frequency of each type of error for each of the eight digrams. The data in Table I are totals for all subjects and all lists. What defines a type of error in Table I is its similarity to the presented digram. A three-dimensional vector is used to describe the type of similarity of an intrusion to the presented digram. The first dimension is "+" if the consonant in the intrusion is the same as the consonant in the presented digram and "−" if it is different. The second dimension is "+" if the vowel in the intrusion is the same as the vowel in the presented digram and "−" if it is different. The third dimension is "+" if the consonant-vowel order is the same in the intrusion as in the presented digram and "−" if it is different.

TABLE I

FREQUENCY OF CORRECT AND INCORRECT ORDERED RECALL

Presented digram	*Correct digram*	*Intrusion similarity types*							*Omissions*	*Copied incorrectly*
	+++	++−	+−+	−++	+−−	−+−	−−+	−−−		
fā	642 (67%)	āf 38	fō 51	nā 28	ōf 31	ān 23	nō 19	ōn 17	105	73
āf	567 (63%)	fā 62	ōf 79	ān 31	fō 20	nā 26	ōn 14	nō 13	92	123
fō	622 (62%)	ōf 75	fā 86	nō 35	āf 13	ōn 40	nā 15	ān 16	107	83
ōf	587 (70%)	fō 35	āf 42	ōn 23	fā 16	nō 27	ān 18	nā 7	85	57
nā	531 (60%)	ān 59	nō 43	fā 44	ōn 31	āf 23	fō 17	ōf 34	111	108
ān	586 (66%)	nā 32	ōn 44	āf 26	nō 18	fā 40	ōf 27	fō 19	100	83
nō	484 (61%)	ōn 51	nā 25	fō 39	ān 26	ōf 43	fā 23	āf 14	93	73
ōn	571 (67%)	nō 41	ān 34	ōf 38	nā 14	fō 29	āf 9	fā 17	99	58
Total	4590 (64%)	393	404	264	169	251	142	137	792	658

The ordering of total intrusion frequency for each similarity type was from greatest to least: +−+ (same consonant, different vowel, same order), ++− (same consonant, same vowel, different order), −++ (different consonant, same vowel, same order), −+− (different consonant, same vowel, different order), +−− (same consonant, different vowel, different order), −−+ (different consonant, different vowel, same order), −−− (different consonant, different vowel, different order). We can determine if the frequency of one type of intrusion differs significantly from the frequency of another type of intrusion by applying the Wilcoxon Matched-Pairs Signed-Ranks test to the differences between these frequencies for the 13 subjects ($N = 13$ in each comparison). Every similarity type of intrusion can occur in response to every type of presented digram, and every similarity type of intrusion includes each of the eight digrams once in response to different presented digrams. Therefore, the totals for each similarity type of intrusion are not affected by differences in the number of times each digram was presented and copied correctly, nor are the totals affected by differences in response biases for different digrams.

TABLE II

2 × 2 CONTINGENCY TABLE FOR "ōf"–"nō"

		Recalled		
		nō	Not nō	
Presented	ōf	27	141	168
	Not ōf	169	1423	1592
		196	1564	1760

$\chi^2 = 4{\cdot}04$

By a two-tailed Wilcoxon test, intrusions of type +−+ did not occur significantly more often than ++−, but each occurred significantly more often than each of the other five types of intrusion (each $p < 0{\cdot}01$, except $(++-) > (-++)$ at the 0·02 level). Intrusion −++ did not occur significantly more often than −+−, but each occurred significantly more often than +−−, −−+, and −−− (each $p < 0{\cdot}01$). Intrusion +−− occurred more often than −−+ and −−−, but the differences failed to reach statistical significance. Intrusions −−+ and −−− were virtually identical in frequency.

Since the number of times each digram was presented and copied correctly was not equal for all digrams and the "response biases" were not equal for all digrams, it is not possible to draw valid conclusions by simply comparing the raw frequencies in different cells of the error matrix in Table I. However, we can compute a χ^2 value for each entry in the table which represents the degree to which the entry exceeds (+) or falls short of (−) the frequency expected by chance. The χ^2 value for each entry is that associated with the 2×2 contingency table formed as indicated in Table II for the entry "ōf"–"nō."

Table III reports the χ^2 value associated with each entry in the error matrix, computed as in Table II, but excluding the frequencies of correct recall. If frequencies of correct recall are not excluded, all one gets is a large number of negative χ^2 which merely means that subjects tended to recall correctly. We are interested in whether some types of errors are more frequent than others.

TABLE III

χ^2 VALUES FOR EACH INTRUSION IN TABLE I

Presented digram	*Intrusion similarity types*						
	++−	+−+	−++	+−−	−+−	−−+	−−−
fā	āf 21·1	fō 34·7	nā 7·5	ōf −1·8	ān −0·4	nō −0·7	ōn −3·5
āf	fā 15·9	ōf 34·1	ān 0·1	fō −3·4	nā 1·6	ōn −11·3	nō −9·1
fō	ōf 14·2	fā 48·9	nō 0·5	āf −8·1	ōn 0·8	nā −3·5	ān −11·0
ōf	fō 13·1	āf 51·4	ōn 0·1	fā −5·8	nō 4·0	ān −0·1	nā −3·7
nā	ān 37·6	nō 9·9	fā 0·3	ōn 0·0	āf 0·0	fō −6·9	ōf −4·5
ān	nā 14·7	ōn 15·8	āf 2·5	nō −1·1	fā 1·3	ōf −4·2	fō −1·3
nō	ōn 24·8	nā 2·5	fō 7·2	ān 0·0	ōf 0·7	fā −6·1	āf −2·4
ōn	nō 25·4	ān 8·6	ōf 0·6	nā 0·4	fō 2·7	āf −4·1	fā −6·8
Total ..	155·5	175·9	10·1	−13·5	5·0	−31·6	−35·8

The frequencies of any two types of intrusions can now be compared by applying the Wilcoxon Matched-Pairs Signed-Ranks test to the eight difference scores between the χ^2 values for the two types of intrusions. All of the comparisons that were significant by the differences for each subject totalled over the eight presented digrams were significant by the differences for each presented digram totalled over the 13 subjects. Furthermore, by this latter test, +−− occurred significantly more often than −−− ($p < 0.05$, two-tailed). Confirming all of the significant differences by the latter test was possible only because the relative frequency of each type of intrusion was extremely consistent for different presented digrams.

DISCUSSION

Not only are intrusions likely to have some phoneme in common with the presented item, but the probability of an intrusion appears to be a monotonic increasing function of the degree of similarity to the presented item. Similarity in this study is in terms of same vs. different consonant or vowel phonemes and same vs. different consonant-vowel order, and each of these three dimensions of similarity is clearly an important determinant of the probability of an intrusion.

However, there is only an insignificant tendency for intrusions with consonant and vowel both different from the presented digram to have the same consonant-vowel order. Also, intrusions with the same vowel as the presented digram, but a different consonant, are only insignificantly more likely to have the same consonant-vowel order than the different order. However, intrusions with the same consonant as the presented digram are overwhelmingly more likely to have the same consonant-vowel order than to have the different order.

The findings of the present experiment indicate that the degradation of a memory trace, whether by decay or interference, is not all-or-none. There are intermediate states where only part of the trace is above the level of competing traces, and what is recalled is similar to what was presented by virtue of the parts of the trace that are above the level of competing traces. Thus, differences in frequency for different types of intrusions provide information on the "parts" of the memory trace. It would be very difficult to account for the present findings without assuming that the trace for a consonant-vowel digram is composed of at least semi-independent traces for the consonant, the vowel, and the consonant-vowel order. However, the results suggest that, while the nature of the consonant and the nature of the vowel are always important dimensions of similarity, the relative position is important only for consonants and only when the trace for the correct consonant is above the level of competing traces. It would describe the data more accurately to say that there are two dimensions of similarity: (1) consonant similarity, with three values (same consonant in the same position, same consonant in the different position, different consonant) and (2) vowel similarity, with only two values (same vowel, different vowel). The trace for the consonant can be lost in two stages; the trace for the vowel is lost in only one stage.

From a structural point of view, this difference between consonants and vowels might result from the following. Suppose there is only one internal representative of a vowel in short-term memory, but there are two internal representatives of a consonant, one for the initial consonant phoneme and one for the terminal consonant phoneme. These two representatives of the "same" consonant must either be overlapping or have strong long-term associations between them, because intrusions with the same consonant in the different position are more likely to occur than intrusions with the different consonant, other factors being equal (i.e. $+--$ intrusions occur more often than $---$ intrusions, significantly more often in one of the two analyses, and $++-$ intrusions occur significantly more often than $-+-$ intrusions). At the same time the internal representative of an initial consonant must be somewhat different from the internal representative of a terminal consonant because intrusions with the same consonant in the same position are much more likely to occur than intrusions with the same consonant in the different position (i.e. $+-+$ intrusions occur significantly more often than $+--$ intrusions and correct responses, $+++$, occur significantly more often than $++-$ intrusions). When the trace for the consonant has been degraded to the point where the incorrect consonant is recalled, the trace for consonant-vowel order appears also to have been lost (i.e. $--+$ intrusions are not significantly more frequent than $---$ intrusions and $-++$ intrusions are not significantly more frequent than $-+-$ intrusions). It fits the intrusion data of the present study very well to assume that the internal representative of a consonant-vowel digram is composed of an internal representative of the consonant phoneme and an internal representative of the vowel phoneme, with initial or terminal position being a feature of the consonant, but not the vowel.

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