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# Visual suffix effects on the Optacon: A test of changing state, primary linguistic, and attentional theories

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An experiment compared the effects of an alphabetic and a nonalphabetic suffix on the serial recall of letters of the alphabet presented with the visual display of the Optacon, a reading aid for the blind. The Optacon presents "changing state" stimuli, that is, those that change over time during presentation. The results showed generalized decrements from the suffixes in the absence of recency in the control condition and no specific end-of-sequence suffix effect. The findings contradict the theory that recency and end-of-sequence suffix effects, characteristic of most auditory, and a few visual, stimuli, are presented in the recall of all changing state stimuli, and provide some support for the Shand and Klima view that stimuli that map into the primary linguistic mode of the subject do exhibit such properties. Additionally, the finding that both an alphabetic and a square suffix led to equivalent decrements from a suffix contradict some attentional theories of the effects of suffixes on visual stimuli.

A suffix may be defined as an extra not-to-be-recalled item appended onto a to-be-recalled list. Although recall is not required, this additional item frequently reduces recall of earlier items. This performance decrement has been studied most frequently with auditorily presented, serially recalled, alphanumeric stimuli. In this modality and with these stimuli, the most common effect of the suffix is to reduce the recency effect characteristic of auditory serial recall.

Crowder and Morton (1969) attributed this end-of-sequence performance drop to interference created by the suffix with long-lasting sensory traces generated by auditory stimuli. In the absence of the suffix, these traces were thought to serve as an extra information source that through a rehearsal mechanism, was helpful in recall.

With respect to the visual modality, Crowder and Morton (1969) hypothesized that recency and end-of-sequence suffix effects would not be found because visual sensory traces last too brief a time to provide information at the time of recall.

However, although visual-auditory differences were frequently as predicted, recent work has presented serious challenges to this theory. Campbell and Dodd (1980) demonstrated the presence of both recency and end-of-sequence suffix effects with lipread stimuli. Shand and Klima (1981) showed similar effects with congenitally deaf users of American Sign Language. One explanation for these effects, first suggested by Campbell and Dodd (1980) and elaborated by Gardiner, Gathercole, and Gregg (1981, 1983), has been that termporally presented visual stimuli, by sharing the "changing state" temporal qualities characteristic normally of the auditory modality but only rarely of the visual modality, may "act auditory." That is, recency and end-of-sequence suffix effects are characteristic of changing state versus static stimuli rather than of auditory versus visual stimuli.

Shand and Klima (1981), however, challenged the changing state hypothesis. They reported recency and end-of-sequence suffix effects not only for sign language stimuli presented in the standard moving format, but also for such stimuli presented as static pictures. Gardiner et al. (1983), however, suggested that these results may not be definitive. The picture signs of Shand and Klima, although static, have motion indicated in them and thus may involve implicit processing of changing state stimulus aspects.

However, data from this laboratory (Manning, 1980), in common with the data of Shand and Klima (1981), suggest that the changing state hypothesis may be incorrect. We (Manning, 1980) presented subjects with alphanumeric characters drawn through the air with a pen on a card background on which no mark was made. Although decrements that increased toward the end of the sequence, were present in the suffix condition, the large specific effect on the last item was not present. Furthermore, the type of recency characteristic of auditory stimuli was also absent.

In an effort to test further the changing state hypothesis, we performed an experiment using the visual display of the Optacon, an instrument designed as a reading aid for the blind. The Optacon consists of a camera that runs

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over visual material and transmits impulses to a 24×6 array of vibrating pins that produce a tactual display (see Craig, 1976, for more details on the Optacon). The Optacon also has a visual component consisting of illuminated dots, each one corresponding to a pin, which, like the tactual component, receives input from the camera and which serves as a monitor for the tactual display.

The visual display is similar to the Times Square News Display in that it consists of lights that go on and off successively and thus appear to move. The display then clearly meets the requirement of producing changing state visual stimuli.

Furthermore, it does this in the absence of being related to the primary linguistic code of the subject. Speech and lipread stimuli, in the case of normal subjects, and American Sign Language, in the case of the deaf, fit these requirements. Thus, the display provides an indirect test of the view of Shand and Klima (1981) that it is the primary linguistic code, rather than changing state stimuli, that is crucial in recency and end-of-sequence suffix effects. According to the views of Shand and Klima, the Optacon-produced stimuli should *not* lead to recency or end-of-sequence suffix effects.

This study also tested for other effects of a suffix on visual stimuli. It should be noted that these effects have frequently not been the same as those found with auditory stimuli, in that recency is generally not present and the accompanying performance decrements do differ from the standard auditory effects. Nonetheless, if one is to understand modality differences, these effects are of interest in themselves. A major theory of the effects of attentional variables on visual recall, Kahneman (1973; Kahneman & Henik, 1977, 1979) includes an explanation of the effects of suffixes on visual stimuli. The Kahneman model is based on the hypothesized inability of subjects to exclude certain irrelevant visual stimuli from attention. According to this view, learning involves the formation of grouped units, found in an early phase of perception. Selective allocation of attention is thought to be possible within, but not between, perceptual units. Thus, if a suffix forms part of a unit, its presence cannot be ignored and a performance decrement will occur, whereas, if it can be segregated, decrements will be lessened.

Kahneman and Henik (1977) predicted and provided evidence that when stimuli and suffixes are presented *simultaneously*, decrements from suffixes are related to both the perceptual grouping of the sequence and the suffix. However, at least two studies (Hitch, 1975; Manning, 1980) have reported decrements from visual suffixes on sequentially presented stimuli. One may argue that in such situations stimuli comprise separate units rather than tight perceptual groupings and thus that decrements from a suffix should not occur. The fact that these performance drops are present suggests either that perceptual or other forms of grouping may occur with sequential stimuli or that such grouping does not fully explain visual suffix effects.

Additionally, it may be noted that in the case of the Hitch (1975) experiment, which used sequentially presented "static" stimuli, both recency and end-of-sequence suffix effects were far smaller than is characteristic of auditory stimuli. The Manning (1980) study used changing state stimuli; its results, described above, also were not typical of auditory presentation. Furthermore, the Manning study used very slow presentation rates.

Given these findings, what explanations might be available? Another version of an attentional model might predict that suffixes that are physically dissimilar from sequences might be more discernible and thus easier to exclude from attention. Using the previously described stimuli drawn through the air, Manning (1980) presented data that contradict this view, by showing that a brush stroke across an index card led to greater suffix effects than did a letter of the alphabet. Because this stimulus was clearly discernible from the letter stimulus, it should have been easier to exclude from attention than would a more similar letter of the alphabet. Apparently, although this stimulus was discernible, such was not the case.

In an attempt to test further the discernibility view of the suffix effect with different visual stimuli, we compared the effects of an alphabetic suffix, the letter Z, with the effects of a square suffix. Although the square was of approximately the same size as the alphabetic characters, it was thought that its homogeneity would make it clearly discernible from the rest of the sequence.

## METHOD

### Subjects

Thirty-six Hunter College students participated in the experiment.

### Apparatus

The apparatus, partially described above, consisted of a Model RIC Optacon, which can convert reading matter into tactual and analogous visual alphabetic characters. The Optacon camera contains a 6×24 photosensitive array connected to a visual array approximately 6×12 cm in size. Material is presented such that a subject perceives it to move from right to left. See Craig (1976) for further details about the Optacon.

The Optacon camera was mounted on a Portable Line Scanner (Model Y2A). This machine, also manufactured by Telesensory Systems, Inc., is a mechanical device consisting of a spring-loaded arm that automatically moves the camera at a fixed rate in a straight line.

### Procedure

A practice session was given to the subjects to familiarize them with the stimuli, which were generated by the Optacon camera's running over sans-serif letters typed with an Elite Gothic IBM Selectric ball. The subjects were presented sequences of seven letters, each sequence consisting of the letters H, J, L, Q, S, X, and Z, presented once in each sequence. The subjects proceeded to the test session when they had correctly identified all of the stimuli in five successive sequences. All subjects met criterion on the first five sequences or shortly thereafter.

In the test session, the subjects received 18 sequences of six letters. (The letter Z, which served as a suffix, was never included in the sequences.) The 18 sequences consisted of 12 in which each of the six letters appeared once and 6 in which a different one of the six letters appeared twice in combination with four of the five other letters. The latter sequences were included to reduce guessing on the basis of previously presented letters.

Each list contained 12 suffixed sequences, 6 with Z as a suffix and 6 with a square as a suffix. The square was the stimulus generated by the camera running over a 2×2 mm filled-in Letraset square (the square was approximately the same size as the width of the 12-point elite type used for the letters). Additionally, 6 sequences served as a control and were composed only of the six letters learned. The three conditions were arranged in a random block design.

Three lists were constructed and given to different subjects. The three lists were composed of the same three blocks of six sequences, but differently ordered. Sequence order within a block was also generated randomly across lists.

Stimuli were presented at a rate of about one letter every 2 sec, with an interletter blank interval of about 2 sec. This rate allowed only one letter at a time to be perceived. The subjects were instructed to recall aloud and in order the sequence of six consonants and to omit any suffix that might have been appended. The recall period (the interval between the last stimulus of one sequence and the start of the next sequence) was 10 sec.

## RESULTS

An item was counted as correct if and only if it appeared in recall in the position it was presented in during presentation. All statistical tests are reported at the .05 level. A 3 (control, Z, or square suffix)×6 (serial positions) analysis of variance was performed on the recall data. Both the main effects of suffix [$F(2,70)=15.97$, $MSe=2.27$] and of serial position [$F(5,175)=74.45$, $MSe=1.07$] were significant due to impaired performance in the suffix conditions and to the strong primacy effects, respectively. No recency was evident in the control condition. These data are shown in Table 1. The suffix×serial position interaction was not significant [$F(10,350)=1.63$, $MSe=.83$].

Duncan multiple range tests were performed at each serial position; the suffix×serial position interaction error term was used to calculate the statistics. At all positions, as shown in Table 1, there were significant differences between the control and the most extreme mean and the control and the least extreme mean. The two suffix conditions differed from each other only at Positions 2 and 4, and the directions of these differences were opposite from each other.

The overall similarity of the effects for the two suffixes were further demonstrated by orthogonal comparisons in which the control condition (mean=4.63) was compared with the suffix conditions combined (mean=3.93) and the Z (mean=3.88) with the square (mean=3.99) suffix. The combined suffix conditions led to reliably poorer performance than the control [$F(1,70)=31.41$], whereas the Z and the square suffixes did not differ significantly from each other ($F<1$; both $MSes=2.27$).

**Table 1**
**Comparisons of Recall in Suffix and Control Conditions at all Serial Positions for the Visual Modality in Experiment 1**

| | Serial Position | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Control | 5.67 | 5.28 | 4.86 | 4.39 | 3.97 | 3.64 |
| Square Suffix | 5.17 | 4.36 | 4.42 | 3.97 | 3.25 | 2.75 |
| Z Suffix | 5.11 | 4.78 | 4.19 | 3.39 | 2.92 | 2.86 |

*Note—A vertical line between values indicates a significant Duncan multiple range test ($R_2 = .35$, $R_3 = .38$). Scores represent the mean number of responses correctly recalled at each serial position (maximum is 6).*

## DISCUSSION

These results demonstrate a generalized decrement resulting from the two suffixes. The finding that these stimuli, like the visual stimuli in Manning (1980), involve changing state presentation but do not lead to recency or standard end-of-sequence suffix effects provides an important test of the views of Campbell and Dodd (1980) and of one hypothesis proposed by Gardiner et al. (1981, 1983). These researchers hypothesized that recency and suffix effects would be present with the changing state visual stimuli. The current work provides the third counterexample to this theory (Manning, 1980; Shand & Klima, 1981) and the first one in which both the finding is noted in the text of the experimental report and normal subjects are used.

What, then, might be the source of these effects? Shand and Klima (1981) proposed and provided evidence that the primary linguistic code of the subject may be the relevant variable in the presence of recency and end-of-sequence suffix effects. Gardiner et al. (1983), however, discussed the necessity for further research on this variable. We wish to point out that, although the data here and in Manning (1980) are consistent with the primary linguistic coding hypothesis and the data presented by Shand and Klima are interesting and compelling, certain differences exist between their results and the standard end-of-sequence suffix effect. Although recency is clearly present, and the suffix produces an end-of-sequence decrement, the effect is smaller than usual. Furthermore, recency still remains in the suffix condition. Thus, we agree with Gardiner et al. (1983) that further research is in order before strong support should be given to this theory.

With respect to the other findings in this study, the presence of a suffix effect with the square suffix and the lack of any difference between the Z and square suffix conditions suggest that any simple perceptual discrimination theory is unlikely to explain the effects of these suffixes. The Z suffix is similar to the sequence to be recalled; the square suffix is clearly different perceptually and in all probability different in noticeability, and thus should be easier to exclude from attention.

Thus, it appears that perceptually dissimilar visual stimuli can have greater effects (Manning, 1980), the same effects (the current experiment), or lesser effects (Kahneman, 1973) than a more similar suffix. It would be useful to know, but apparently not that obvious to determine, whether a particular visual stimulus would lead to a greater or lesser performance decrement in its role as a suffix.

Additional questions may be raised by this research. In the visual modality, both the shapes of recall curves and of the decrements from suffixes differ considerably. Such differences have been found in this laboratory and in others. We suspect these differences may, as in the auditory modality, relate to difficulty factors in recall, task requirements (see, Manning, 1984), and the types of stimuli presented. Recent work in this laboratory (Manning, 1983) has suggested that changing state stimuli may be of two types and that both types may be different from static visual stimuli. Further work needs to be done in this area.

In summary, then, we can say that we have demonstrated suffix effects in a modality in which the suffix effect has been infrequently studied. In using the Optacon to present the stimuli, we have extended the work on suffixes to a very different presentation format from that which has been used before. Furthermore, we have demonstrated major inadequacies both in changing state and in certain types of attentional theories as explanations of our results and have lent limited support to the Shand and Klima (1981) primary linguistic hypothesis.

## REFERENCES

CAMPBELL, R., & DODD, B. (1980). Hearing by eye. *Quarterly Journal of Experimental Psychology*, **32**, 85-99.

CRAIG, J. C. (1976). Vibrotactile letter recognition: The effects of a masking stimulus. *Perception & Psychophysics*, **20**, 317-326.

CROWDER, R. G., & MORTON, J. (1969). Precategorical acoustic storage (PAS). *Perception & Psychophysics*, **6**, 365-373.

GARDINER, J., GATHERCOLE, S. E., & GREGG, V. H. (1981, November). *Lipreading and auditory memory.* Paper presented at the meeting of The Psychonomic Society, Philadelphia.

GARDINER, J., GATHERCOLE, S. E., & GREGG, V. H. (1983). Further evidence of interference between lipreading and auditory recency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **9**, 328-333.

HITCH, G. J. (1975). The role of attention in visual and auditory suffix effects. *Memory & Cognition*, **3**, 501-505.

KAHNEMAN, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice Hall.

KAHNEMAN, D., & HENIK, A. (1977). Effects of visual grouping on immediate recall and selective attention. In S. Dornic (Ed.), *Attention and performance VI.* Hillsdale, NJ: Erlbaum.

KAHNEMAN, D., & HENIK, A. (1979). Perceptual organizational attention. In M. Kubovy & J. Pomerantz (Eds.), *Perceptual organization*, Hillsdale, NJ: Erlbaum.

MANNING, S. K. (1980). Tactual and visual alphanumeric suffix effects. *Quarterly Journal of Experimental Psychology*, **32**, 257-267.

MANNING, S. K. (1983, November). *When do visual suffixes act auditory?* Paper presented at the meeting of The Psychonomic Society, San Diego.

MANNING, S. K. (1984). Effects of difficulty variables and type of suffix on serial recall. *American Journal of Psychology*, **97**, 71-87.

SHAND, M. A., KLIMA, E. S. (1981). Nonauditory suffix effects in congenitially deaf signers of American Sign Language. *Journal of Experimental Psychology: Human Learning and Memory*, **7**, 464-474.

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