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Effects of auditory versus visual presentation and pronounced versus silent reading on frequency estimates

Pearlman, Ilissa Bloch, Ph.D.

Case Western Reserve University, 1992
EFFECTS OF AUDITORY VERSUS VISUAL PRESENTATION AND
PRONOUNCED VERSUS SILENT READING ON FREQUENCY ESTIMATES

by

ILISSA BLOCH PEARLMAN

Submitted in partial fulfillment of the requirements
for the Degree of Doctor of Philosophy

Dissertation Advisor: Robert L. Greene

Department of Psychology
CASE WESTERN RESERVE UNIVERSITY
May, 1992
CASE WESTERN RESERVE UNIVERSITY

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Jissa Block Pearlman

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EFFECTS OF AUDITORY VERSUS VISUAL PRESENTATION AND PRONOUNCED VERSUS SILENT READING ON FREQUENCY ESTIMATES

Abstract

by

ILISSA BLOCH PEARLMAN

The modality effect is the superior retention of auditorily over visually presented items. The main aim of the present series of studies was to explore the circumstances under which a modality effect in frequency judgements would be found. In Experiments 1-3, subjects performed an incidental learning task while a long word list was presented to them. The first two experiments investigated whether a frequency modality effect would be found in a within- and/or a between-subjects design. The third experiment, also conducted both between and within subjects, investigated whether frequency estimates of pronounced words would exceed those of silently-read words. Experiment 4 used a mixed-list design to explore whether a pronunciation advantage would be found on frequency estimates in an intentional learning paradigm.
Results of Experiments 1 and 2 showed no significant differences in frequency estimates of auditorily versus visually presented words. However, Experiments 3 and 4 showed that frequency estimates were significantly higher for pronounced than for silently read words. This pronunciation effect was seen in both within- and between-subjects designs, and in both incidental and intentional learning paradigms.

Findings of Experiments 1 and 2 are discussed as being in agreement with theoretical formulations about the short-term nature of the auditory modality effect as well as with other empirical investigations of long-term memory. The pronunciation effect found in Experiments 3 and 4 is discussed in terms of seemingly related phenomena, such as the pronunciation effect in recognition studies and the frequency effect in verbal discrimination learning. It is posited that the pronunciation effect may be due to an advantage in memory for self-produced over experimenter-presented information, which is also seen in studies of the generation effect. Additionally, it is hypothesized that the involvement of more than one sensory modality may contribute to the advantage in memory for pronounced over silently read words.
To Sharon Rose,

With the hope that you will grow up to be anything that you want to be.
I would like to thank my research advisor, Dr. Robert Greene, and the other members of my dissertation committee, Dr. Douglas Detterman, Dr. Grover Gilmore, and Dr. Barry Layton. I greatly appreciate their guidance, ideas and encouragement. I also wish to thank the other Case Western Reserve University faculty members whom I have gotten to know (especially Dr. Joseph Fagan, Dr. Donald Freedheim, Dr. James Overholser, Dr. Sandra Russ, and Dr. Milton Strauss), for stimulating my professional development. Likewise, I am grateful to my friends and colleagues.

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CHAPTER 1

Introduction

The modality effect is a well-documented short term memory phenomenon. Numerous studies have found that auditory presentation results in better recall than visual presentation at the last few serial positions of short (7 or 8 item) word lists (Corballis, 1966). The same pattern is found when all items are presented visually, and subjects read some lists aloud and others silently: There is a marked advantage in recall of the last few items for the lists read aloud (Conrad & Hull, 1968).

Crowder and Morton (1969) hypothesized that this auditory recency advantage is due to precategorical acoustic store (PAS), an auditory memory system which lasts for a few seconds. They asserted that information in PAS persists longer than information in visual sensory memory and can therefore affect immediate memory tasks. According to Crowder and Morton's theory, information in PAS is lost due to overwriting by subsequent auditory events and/or decay over time. Because early items have decayed or have been
overwritten in PAS prior to recall, auditory presentation does not exhibit an advantage over visual presentation on recall of these items. However, auditory recall is significantly better than visual recall on the last few list items, because PAS provides extra information about these items for the auditory modality that is not available for visual items.

According to Crowder (1976; Crowder & Morton, 1969), the stimulus suffix effect supports the premise that information about auditory stimuli is held in PAS for a brief time and is subject to displacement by subsequent items. The suffix effect is found when a redundant auditory stimulus occurs between presentation of the last list item and recall of the items. This results in substantial decrements in recall of the last few list items (e.g., Crowder, 1967). Without a suffix, the terminal item(s), because they have few or no subsequent elements, may still be represented in PAS at the time of recall and can more easily be recalled. However, the addition of a stimulus suffix reduces the accessibility of the last few list items in PAS and thereby impairs recall.

Crowder and Morton (1969) posited that the stimulus suffix effect occurs because each auditorily presented item establishes a PAS trace that then becomes
inhibited as a subsequent item is entered into PAS. Crowder (1978) found that the size of the suffix effect was reduced when more than one suffix, rather than just one suffix, followed the word list. Crowder's (1978) lateral inhibition theory states that with multiple suffixes, the first suffix inhibits the target (i.e., the last item on the word list), but then the next suffix inhibits the first suffix, resulting in disinhibition of the target.

Although Crowder and Morton's (1969) PAS account was the most widely accepted explanation in the 1970's of the modality effect, subsequent studies have challenged Crowder and Morton's assertion that the auditory memory store is necessarily precategorical (that is, that it contains only sensory information that has not been meaningfully categorized). Watkins (1972; Watkins & Watkins, 1973) maintained that if the modality effect results from precategorical acoustic storage, then long words will be comprised of more precategorical acoustic units than short words, and consequently, PAS will retain fewer long than short words. However, Watkins (1972) and Watkins and Watkins (1973) found no difference in the modality effects in free and serial recall of four-syllable word lists than
in free recall of one-syllable word lists. This finding indicates post-categorical storage of each word as a unit, rather than precategorical acoustic storage based on syllables.

Salter and Colley (1977) and Harris, Gausepohl, Lewis, and Spoehr (1979) presented additional evidence that the suffix effect can be influenced by postcategorical processing. In both these studies, word list recall was significantly less impaired when the suffix was semantically related to the terminal list item than when it was not. These authors did not necessarily challenge the assumption that a brief auditory memory was the cause of the modality effect; rather, they only questioned Crowder and Morton's belief that such an auditory memory was purely sensory.

Crowder and Morton's (1969) PAS theory has been more fundamentally challenged by findings that lipread and mouthed stimuli may exhibit modality and suffix effects that resemble those found with auditory material. For instance, Campbell and Dodd (1980, Experiment 2) compared the serial position curves of silently lipread, auditory, and visual conditions, and found a substantial recency effect for both the lipread and the auditory lists. Campbell and Dodd (1980, Experiment 3) then tested the effect of an auditory
suffix on two visually presented lists, one which was graphically presented and the other which was lipread. The auditory suffix impaired recall of the terminal item of a lipread list but did not affect recall of the graphic list's terminal item. Campbell and Dodd (1980) conclude that the suffix effect found for the lipread list cannot simply be a mechanism of PAS, because the list was not auditorily presented. They speculate that there may be some form of common processing, perhaps phonological processing, between heard and lipread speech.

Greene and Crowder (1984) further investigated the modality and suffix effects with silent mouthing, lipreading, and auditory presentation of items. Experiment 1 explored the effects of acoustic similarity on silent, aloud, and mouthed lists. Three groups of letters served as stimuli: confusable (i.e., letters that sounded alike), nonconfusable (i.e., letters with different sounds), and mixed, which included all the letters from the other two sets. Type of reading (silent, aloud, or mouthed) was a between-subjects variable, and item confusability was a within-subjects variable.
Overall, mouthing significantly impaired recall. However, a much stronger recency effect was found with mouthing than with silent reading. This modality effect was almost as pronounced as that found in the aloud condition. In addition, for both mouthing and aloud conditions, greater confusability resulted in less of a recency effect and greater similarity to the silent curve. This suggests that auditory and mouthing modality effects may have a common basis.

Greene and Crowder's (1984) second experiment investigated the importance of matching the suffix with the memory list stimuli. Two conditions were used for the test items: reading aloud and silent mouthing. There were three suffix conditions: reading the suffix aloud, silent mouthing, and a no-suffix control condition. All conditions were within subjects.

Like the first experiment, the second experiment found recency effects in the no-suffix control condition with both reading aloud and silent mouthing. However, lists read aloud showed greater recall than mouthed lists. The addition of the aloud or the mouthed suffix impaired recall of both aloud and mouthed lists. However, recall of aloud lists was hurt more by a suffix read aloud, while recall of mouthed lists was more impaired by a mouthed suffix. The
finding that the suffix effect is greatest when the list item modality matches the suffix modality refutes the PAS claim (Crowder & Morton, 1969) that the suffix effect is a result of its acoustic characteristics.

Greene and Crowder's (1984) third experiment found that lipreading exhibits modality and suffix effects similar to those found with silent mouthing. Their findings that modality and suffix effects found with silent mouthing and lipreading are similar to those found with auditory presentation cannot be accounted for by any theory that relies on auditory information, such as the PAS account (Crowder & Morton, 1969). Greene and Crowder (1984) suggest a revised PAS model, in which nonacoustic information that helps one to recognize auditory features, such as visual information about speech gestures, is briefly held in PAS.

In summary, both the precategorical and the acoustic assumptions of Crowder and Morton's (1969) PAS model have been somewhat discredited by more recent experiments. However, the alternative accounts that have been proposed share the assumption that modality effects reflect the operation of some temporary, short-lived information. For example, Watkins and Watkins (1973) proposed that the modality effect is due to a
relatively brief postcategorical acoustic store, where the decaying auditory information is influenced by the semantic properties of the stimulus. Broadbent and Broadbent (1981) and Campbell, Dodd, and Brasher (1983) proposed that the modality effect is due to the persistence of auditory features in a short-term memory store that could also contain information from other modalities. Nairne (1988) and Penney (1989a) suggested that the modality effect reflected the tendency of subjects to rely on auditory coding in short-term memory. These accounts differ from Crowder and Morton's (1969) PAS theory in various ways, but they share the view that the modality effect reflects a temporary store of information.

There have been some reports of modality effects in delayed recall. For instance, Gardiner and Gregg (1979) found modality effects when short distractor periods were included before and after every item. However, the modality effect was restricted to the end of the list. Moreover, since this long-term modality effect is found only in very constrained circumstances, depending on the list items, the distractor activity, and the instructions given (Greene, 1985), it does not necessarily challenge the assumption that modality effects are basically short term in nature.
Modality Effects in Long-Term Memory

Glenberg and Fernandez (1988) discovered that a modality effect occurred on estimates of presentation frequency. This finding could not be accounted for by traditional accounts of the modality effect, which propose that this effect is strictly a short-term phenomenon. Thus, Glenberg and Fernandez's finding represented a fundamental challenge to the conclusion that modality effects are really very brief.

Glenberg and Fernandez (1988, Experiments 4-6) presented subjects with both auditory and visual words in a long list followed by a frequency estimation test. In addition to modality, other independent variables were frequency of presentation (how many times each word was presented in the list) and spacing of presentations (how closely together the same words were presented). An incidental learning paradigm was employed, whereby subjects were not informed in advance of the frequency judgement test but were led to believe that their performance on a different task was of primary interest. Overall, the interaction between modality and spacing was not significant. All three experiments showed that (a) frequency estimates were greater for auditorily than for visually presented stimuli, and (b) the modality effect increased with
actual presentation frequency. However, Experiments 4-6 found little or no modality effect on frequency judgements for the once-presented items.

Glenberg and Fernandez (1988) contend that frequency estimates are based on the number of discriminably different traces of an item that an individual can elicit when tested. Temporal information, such as time of presentation, is one way in which item traces differ from one another. The temporal coding assumption states that time of presentation is more accurately encoded for events that are auditorily presented than for events that are visually presented. If frequency judgements are influenced by temporal information, then according to the temporal coding assumption, modality effects should be found on frequency judgement tasks. Glenberg and Fernandez conclude that the auditory advantage found in frequency judgements supports the temporal coding assumption.

In addition to investigating the effects of presentation modality on frequency judgements, Glenberg and Fernandez (1988, Experiments 1-3) also examined the effects of modality on order judgements (i.e., estimates of which items on word lists had been
presented first and which words had been presented most recently). They found that order judgements for auditorily presented words were more accurate than order judgements for visually presented words at both the beginning and the end of lists, and that increasing the presentation interval between successive items enhanced the auditory advantage. Glenberg and Fernandez assert that the auditory advantage in order judgements provides further support for the temporal coding assumption.

Glenberg and Fernandez (1988, Experiments 4-6) speculate that frequency estimates of one are actually recognition judgements, which may not be sensitive to temporal information. They posit that this insensitivity to temporal information may explain why little or no modality effect was found on frequency estimates for once-presented items.

However, Glenberg and Fernandez (1988) point out that their results differ from those reported by Conway and Gathercole (1987). In Conway and Gathercole's (1987) first two recognition memory experiments, subjects were visually presented with a list of words. Modality was manipulated within subjects by three counterbalanced input response conditions: read silently, mouth silently, and read aloud. In the
fourth experiment, input presentation modality, rather than input response modality, was manipulated within subjects. Words were visually, auditorily, and both visually and auditorily presented. As in Glenberg and Fernandez's investigation, an incidental learning paradigm was employed.

After list presentation, subjects in Experiments 1, 2, and 4 were given a surprise memory test containing the 30 words actually presented and 30 filler words, presented in an unsystematic order. Subjects had to evaluate whether each word was "old" or "new". In the first two experiments, recognition was highest for pronounced words and lowest for silently read words, with mouthed words occupying an intermediate position. This was a through-list, long-term modality effect. In Experiment 4, words that were not heard were not recognized as well as words that were heard at input, regardless of whether the heard words were also read. The main effect of input position and the Input Position x Modality interaction were not significant. Nevertheless, the modality effect seemed confined to items presented early and late in the list.
The design of Experiment 3 was almost identical to that of the first two experiments, except that a surprise free recall, rather than a recognition, test was given. A recency effect was obtained, with pronounced words recalled better than mouthed words, and mouthed words recalled better than silently read words at the last list positions. Thus, the long term modality effect extended to the free-recall paradigm, although the effect here was confined to the last few positions.

In summary, Conway and Gathercole's (1987, Experiments 1, 2, and 4) results indicate that recognition judgements are more accurate for auditorily than for visually presented words, regardless of whether the auditorily presented words are pronounced by the subject or just heard by the subject. Taken together, the findings of Conway and Gathercole (1987) and Glenberg and Fernandez (1988) are important for suggesting that modality may have surprisingly long-lasting effects on memory and may therefore be influencing the nature of traces in long-term memory. The finding of a long-term modality effect is discrepant with expectations from all previous accounts
of the modality effect. The generality of this finding across different experimental designs is therefore an important question.

Four earlier experiments by Hopkins, Boylan, and Lincoln (1972) investigated whether frequency estimates for pronounced words would exceed those for silently read words. In Experiment 1, subjects received four different visually presented lists with 36 words per list, of which 12 words were presented once and 12 were presented twice. Six of the 12 1-words were underlined, and 6 of the 12 2-words were underlined on both of their presentations. Four independent groups received different study instructions. One group pronounced each underlined word once when it was presented, another group pronounced only the not-underlined words, a third group pronounced all the words regardless of underlining, and the fourth group pronounced none of the items. After each study list, subjects were given a comparative frequency judgement test, in which they were told to select the member of each test pair that had been more frequently presented.

Results of the mixed-list groups showed that pronouncing a word increases its apparent frequency; however, frequency estimates were similar between the
group that pronounced all items and the group that pronounced none of the items. The second experiment was similarly designed, incorporating some minor changes. Once again, it was found that comparative frequency estimates for pronounced words exceed those for silently read words in the mixed-list groups only.

The third study showed two lists of words each presented 1-5 times (for a total of 75 positions per list) to two groups of subjects: one group silently studied all items, and the other group pronounced each study word. After each list was presented, subjects were asked to make absolute frequency judgements by indicating how many times each study word had been presented. Results showed that pronunciation had little effect on absolute frequency estimates. However, the fourth study, which added a mixed-list condition, yielded different results. In the pure-list condition, a marginally significant Group x Frequency interaction was obtained. Comparison of the means showed that frequency estimates of pronounced words exceeded those of silently read words at all frequency levels, although there was little difference between groups for the once-presented words. The pattern of the means showed that the higher the actual frequency level, the greater the difference between the estimates of
pronounced and silently read words. Results for the two groups which had experienced both pronounced and silently studied words also showed that absolute judged frequency was higher for the pronounced words than the silently studied words and that the magnitude of this effect was greatest at the higher frequency levels.

Two studies by Hopkins and Edwards (1972) examined the effect of pronunciation on recognition memory. In both experiments, subjects were presented with a list of 50 underlined words and 50 words which were not underlined, and subjects received the same instructions that were given to subjects in Hopkins, Boylan, and Lincoln (1972). Thus, there were a total of four groups in each experiment, two mixed-list groups (pronounce only underlined words, pronounce only non-underlined words) and two pure-list groups (pronounce all words, read all words silently). In Experiment 1, trial words were randomly paired with distractor words to form 100 test pairs, which each contained one new and one old word. Subjects had to indicate which member of each pair was the old one. In Experiment 2, subjects were presented with a list of 200 words (trial words plus 100 distractor items) and asked to identify each word as old or new.
Results showed that, in both experiments, pronounced words in mixed-list designs were recognized significantly better than were silently read words. However, no significant differences were found in recognition judgements of pronounced versus silently read words in the pure-lists designs.

Taken together, results of these pronunciation investigations call into question whether pronunciation increases frequency estimates only when a within-subjects manipulation of pronunciation is used, or whether a pronunciation effect can be obtained in a between-groups design as well. A related question is whether Glenberg and Fernandez's (1988) discovery of a modality effect on frequency judgements would be found in a between-subjects design, as Glenberg and Fernandez's experiments were conducted within subjects.

It should be noted that experiments have found other variables which affect memory only when manipulated in a within-subjects fashion. One such variable is imagery bizarreness (McDaniel & Einstein, 1986). Some investigations of stimulus generation also show a within-, but not a between-, subjects effect (e.g., Begg & Snider, 1987; Slamecka & Katsaiti, 1987), although others have found a between-subjects effect on some memory tests (e.g., McDaniel & Wadill, 1990;
Hirshman & Bjork, 1988; Begg, Snider, Foley, & Goddard, 1989; Crutcher & Healy, 1989). Thus, it seems plausible that modality effects in long-term memory may depend on the nature of the design used.

The first two studies, therefore, were conducted to address two primary questions: (a) Is there a modality effect on estimates of presentation frequency? and (b) if so, is this effect found only within subjects or both between and within subjects?

The first study was based on Experiment 4 of Glenberg and Fernandez (1988). Subjects were presented with both auditory and visual words in a long list followed by a frequency judgement test. Experiment 1 also extended Glenberg and Fernandez's (1988) fourth experiment by adding a between-subjects condition. The same word list presented to the subjects in the mixed-modality condition was visually presented to one group of subjects, followed by the frequency judgement test. Another group received the same list presented auditorily, followed by the frequency judgement test. Experiment 2 used a different procedure, in order to test the generality of the findings.

The third and fourth studies investigated the effect of pronunciation on estimates of presentation frequency. In two within-subjects experiments, Conway
and Gathercole (1987) found a long-term recognition advantage when subjects read words aloud that was somewhat similar to the recognition advantage found when words were presented auditorily. However, no previous investigation had examined the effects on frequency judgements of both auditory versus visual presentation and pronunciation versus silent reading. It was believed that examining both types of frequency "modality" effects in a comparable manner (e.g., with the same experimenter, design, materials, and procedure, except for different presentation/reading modalities) would be a sensitive test of the similarity between auditory presentation and subject pronunciation. Moreover, information would be obtained about whether a differential effect of pronunciation is found in within- versus between-subjects groups. Therefore, the design of Experiment 3 replicated that of Experiment 2, with the exception that all words were visually presented and either silently read or pronounced by subjects. Experiment 4 used a within-subjects design to examine whether the pronunciation effect would be found with intentional learning instructions, as the previous experiment had employed an incidental learning paradigm.
CHAPTER 2

Experiment 1

Method

**Subjects.** Thirty-six students enrolled in introductory psychology classes at Case Western Reserve University served as subjects in partial fulfillment of a course requirement.

**Procedure.** Each subject was presented with a long list of words followed by a frequency judgement test. The presentation frequencies of the tested words were 0 (never having been presented before), 1, 3, or 6. Repetitions of words presented more than once were spaced randomly throughout the list, with five to fifteen intervening items between repetitions.

Subjects were randomly assigned to the within- or the between-subjects modality manipulation. The 12 subjects in the within-subjects manipulation were presented with equal numbers of auditory and visual words with their presentation modality counterbalanced across subjects. All words were one-syllable, four- or five-letter nouns. Lists were comprised of 12 exemplars of each of 4 conditions (2 modalities x 2
frequencies) plus four exemplars of the once-presented auditory and once-presented visual words, for a total of 56 words and 224 presentations. Items were presented in a random order. A ten-word buffer was added on to both the beginning and the end of the list, bringing the total number of presentations to 244.

All subjects were tested in groups of eight to ten people. All items were presented by the experimenter, at the rate of approximately two seconds per item. Each visual item was presented by the experimenter holding up an 8 1/2" by 11" sheet of thick ivory-colored paper, with the word clearly printed in black magic marker. Each auditory item was presented by the experimenter reading the word aloud. (Auditory words faced the experimenter, not the subjects. Auditory words were written with a yellow magic marker on the same type of thick paper used for the visual items, so that the words could not be seen through the paper by the subjects.)

During list presentation, subjects were not told about the frequency judgement task but instead were given an incidental learning task. This task required subjects to circle an "A" or "P" as each item was presented, indicating whether they thought that the item represented an active (A) concept ("capable of
independent movement or change", (Glenberg & Fernandez, 1988, p. 736)) or a passive (P) concept.

The frequency judgement test consisted of 72 words (56 words that had been presented with frequencies of 1, 3, or 6; 8 buffer words, and 8 zero-frequency words). The words with frequencies greater than zero were tested in the same order as their initial presentations, and the zero-frequency words were randomly placed throughout the test list. Each word was presented simultaneously in both auditory and visual modalities by the experimenter saying the word aloud while holding up an 8 1/2" by 11" sheet of thick ivory paper clearly depicting the word printed with black magic marker in lower-case letters. Subjects were given three sheets of paper with a number (1-72) designating each row, followed by the numbers 0-10 spaced out evenly over the width of the page. Subjects were instructed to estimate how many times each given word had been presented, and to circle the number representing each estimate. In the present and following experiments, subjects were told to go at their own pace; nonetheless, all subjects completed each frequency judgement within a few seconds after the word was presented.
The 24 subjects in the between-subjects manipulation were randomly assigned to either auditory or visual groups, with 12 subjects in each of the two groups. The word lists, procedure, and frequency estimation test were the same for the subjects in the auditory group and visual group as for the subjects in the mixed-list condition, with the exception that all study trial words were only presented visually to subjects in the visual group, and all study trial words were only presented aurally to subjects in the auditory group. In both of these groups, the frequency estimation test words were presented simultaneously both visually and auditorily, as in the mixed-list condition.

Data Analysis

Within-subjects condition. In order to determine whether modality influences frequency estimates and, if so, whether this modality effect interacts with true frequency, a 2 (auditory or visual modality) by 3 (presentation frequency of 1, 3, or 6) analysis of variance was performed.

Between-subjects condition. A 2 x 3 analysis of variance was performed, with (auditory or visual)
modality as the between-subjects factor and presentation frequency (of 1, 3, or 6) as the within-subjects factor.

Results

In all experiments reported herein, analyses used a significance value of 0.05. The mean frequency estimates for all conditions of Experiment 1 are shown in Table 1. Modality did not significantly influence frequency judgements in either the within- or the between-subjects design. In both within- and between-subjects designs, the interaction of Modality x Frequency also was not significant. The absence of a modality effect was unexpected, as Glenberg and Fernandez (1988) used a within-subjects design and found that frequency judgements for auditorily presented words were significantly greater than frequency judgements for visually presented words.

Not surprisingly, in each condition, highly significant main effects were found for actual frequency. As Table 1 indicates, regardless of modality condition, both the within- and the between-subjects mean frequency scores are similar to actual presentation frequencies at all three frequency levels.
Moreover, mean frequency estimate scores for the 0-frequency words were substantially lower than were the scores for the once-presented words.

Statistical analyses yielded the following results. The main effect of modality was $F(1,11) = 0.20$, $MSe = 0.09$ for the within-subjects group and $F(1,22) = 2.24$, $MSe = 1.91$ for the between-subjects group. The main effect of modality was larger in the between-subjects analysis than in the within-subjects analysis; however, this was due to a nonsignificant advantage for visual presentation rather than the auditory advantage expected here. The Modality x Frequency interaction was $F(2,22) = 0.36$, $MSe = 0.20$ for the within-subjects group and $F(2,44) = 0.73$, $MSe = 0.33$ for the between-subjects group. None of these values approached significance. The main effects of frequency for the within- and between-subjects conditions, respectively, were $F(2,22) = 239.00$, $MSe = 0.56$ and $F(2,44) = 343.88$, $MSe = 0.33$, in each case easily significant.
In the present experiment, as well as in each of the following three experiments, the within-subjects score listed in that experiment's table for frequency level = 0 is the mean score across all subjects in that condition.
The main finding of interest is that no frequency modality effect was found in either the between- or the within-subjects condition. It was not surprising that a between-subjects frequency modality effect was not found, as all previous investigations of the long term modality effect had been conducted within subjects. Moreover, two studies found that frequency estimates (Hopkins, Boylan, & Lincoln, 1972) and recognition (Hopkins & Edwards, 1972) were greater when words were pronounced aloud versus read silently, only when a mixed-list design was employed. However, the failure to find a frequency modality effect within subjects was unexpected, particularly because such an effect was found in Glenberg and Fernandez's (1988, Experiments 4-6) investigation.

The presentation method employed in Experiment 1 varied from that of Glenberg and Fernandez (1988), which might be one reason why different results were obtained. Experiment 2 was designed in order to determine the generality of the results by seeing whether presentation method is critical. Thus, the method of presentation differed from the one used in Experiment 1.
Method

Subjects. Thirty-nine students enrolled in introductory psychology classes at Case Western Reserve University served as subjects in partial fulfillment of a course requirement.

Procedure. Subjects were randomly assigned to one of two test groups, with fifteen subjects in the within-subjects group and twenty-four subjects in the between-subjects group. All subjects were presented with the same word list and incidental learning task used in the first experiment. Each subject was tested individually.

Subjects in the within-subjects group were presented with the mixed-modality list, with presentation modality counterbalanced across subjects. Visual words were presented on a video monitor. Type (upper or lower) case was counterbalanced across subjects, with visual words presented in capital letters to half of the subjects, and in lower-case type to the other half of the subjects. Auditory words, pronounced by the experimenter, were presented on an audiotape recorder. Subjects were informed that when audiotaped words were heard, the computer screen would
show a row of four x's (xxxx), and that when visual words were depicted on the video monitor, no sound would be emitted from the tape recorder. To ensure that auditory and visual exposure times were consistent, the audiotape sounded a tapping noise every 2 sec, signaling the experimenter to press the return key in order for the next stimulus to be shown on the video monitor.

The twenty-four subjects in the between-subjects condition were randomly assigned to auditory or visual groups, with twelve subjects per group. To keep the design as similar as possible to the within-subjects design, subjects in the auditory group heard each word on the audiotape. Every 2 sec, a tapping sound was heard which signaled the experimenter to advance the computer to the next item. As each auditory item was presented, the video monitor showed a row of four x's. Subjects in the visual condition heard only the taps on the tape player and saw each word on the video monitor, presented at a 2 sec rate following the tapping signal. Half of the words were presented in upper-case type, and the other half were presented in lower-case type (with all repetitions of a word depicted in the case type that was used for the word's initial presentation).
Subjects in both conditions were presented with the frequency-estimation test used in Experiment 1, although the present experiment eliminated the four buffer words that had followed the test stimuli. As in Experiment 1, test items were presented simultaneously in both auditory and visual modalities. In Experiment 2, however, each item was depicted on the video monitor as the experimenter read the word aloud. Subjects were instructed to type in their estimate of the number of times that each word had been presented, from 0 to 10, and then press the return key to see the next word. As in the first experiment, subjects were told to go at their own pace.

Data Analysis

**Within-subjects condition.** To investigate the effect of modality on frequency judgements, a 2 (auditory or visual modality) x 3 (presentation frequency of 1, 3, or 6) analysis of variance was performed.

**Between-subjects condition.** A 2 x 3 analysis of variance was performed, with (auditory or visual) modality as the between-subjects factor and
presentation frequency (of 1, 3, or 6) as the within-subjects factor.

Results
Results were similar to those of the first experiment: no significant main effects of modality were found in either the within- or the between-subjects condition. As would be expected, highly significant main effects were found for actual frequency. A Modality x Frequency interaction was not found in either the within-subjects nor the between-subjects group.

The following F values were obtained. The main effects of modality were $F(1,14) = 0.01$, $MSe = 0.67$ and $F(1,22) = 0.24$, $MSe = 3.10$ for within- and between-subjects conditions, respectively. The main effects of actual frequency were $F(2,28) = 191.04$, $MSe = 0.68$ within subjects, and $F(2,44) = 214.30$, $MSe = 0.48$ between subjects. The Modality x Frequency interaction was $F(2,28) = 0.44$; $MSe = 0.65$ within subjects and $F(2,44) = 0.75$, $MSe = 0.48$ between subjects.

Table 2 depicts the mean auditory and visual scores for each group at each of the four frequency levels (0, 1, 3, and 6).
<table>
<thead>
<tr>
<th>Actual Frequency</th>
<th>6</th>
<th>3</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within-s's</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditory</td>
<td>5.89</td>
<td>4.09</td>
<td>1.75</td>
<td>0.61</td>
</tr>
<tr>
<td>Visual</td>
<td>5.76</td>
<td>4.30</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td><strong>Between-s's</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditory</td>
<td>6.22</td>
<td>4.66</td>
<td>2.27</td>
<td>1.27</td>
</tr>
<tr>
<td>Visual</td>
<td>6.04</td>
<td>4.69</td>
<td>1.81</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Results of the first two experiments do not refute the conventional assumption that the modality effect is due to a short-term memory store that only briefly holds the auditory information. Crowder and Morton (1969) posited that this temporary memory store is both precategorical (i.e., purely sensory) and acoustic in nature, providing extra information about the last few auditorily presented list items. Although subsequent investigations questioned Crowder and Morton's conceptualization of the auditory memory store as precategorical (e.g., Watkins, 1972; Watkins & Watkins, 1973) and acoustic (e.g., Campbell & Dodd, 1980; Greene & Crowder, 1984), they did not challenge the assumption that the modality effect is a short-term phenomenon.

The advantage of pronounced (i.e., read aloud) over silently read items has been thought to result from the same short-term processes that create the auditory modality effect (e.g., Greene & Crowder, 1984). However, Hopkins et al. (Hopkins, Boylan, & Lincoln, 1972; Hopkins & Edwards, 1972) and Conway and Gathercole (1987) found that pronunciation effects do occur in long-term memory when a within subjects manipulation is employed. The objective of Experiment 3 was to further investigate whether the pronunciation
effect, like the auditory modality effect, is only a short-term phenomenon or whether other, more lasting, factors associated with pronunciation result in a significant pronunciation advantage in long-term memory. Experiment 3 extended the design of the previous two studies in order to see whether subjects' frequency judgements would be greater for pronounced than silently read words.

Experiment 3

Method

Subjects. Thirty-six students enrolled in introductory psychology classes at Case Western Reserve University served as subjects in partial fulfillment of a course requirement.

Procedure. Subjects were randomly assigned to the within- or the between-subjects condition, with twelve subjects in the within-subjects condition, and twelve subjects in each of the two between-subjects groups. Subjects individually were presented with the same word list, incidental learning task, and test list used in Experiment 2.

In both conditions, trial words were displayed at a 2 sec rate on a video monitor. Half of the words were capitalized, and half were printed in lower-case
type. Six of the subjects in the within-subjects condition were instructed to read the upper-case words silently and the lower-case words aloud, while the other six were given the opposite instructions. Subjects in the between-subjects condition were randomly assigned to the silent or the pronounced group, with twelve subjects in each group. Subjects in the silent group were told to read all words silently, and subjects in the pronounced group were instructed to read all words aloud.

Test words were presented in the type case (e.g., upper or lower) that they had been shown in the trial phase. In the within-subjects condition, test instructions were counterbalanced so that six of the subjects read all test words aloud, and the other six read all silently. In each of the between-subjects groups (trial words pronounced and trial words silent), respectively, six subjects read all test words aloud and the other six read all test words silently.

Data Analysis

Within-subjects condition. A 2 (aloud or silent reading) by 3 (presentation frequency of 1, 3, or 6) analysis of variance was performed to investigate the
effect of silent versus aloud reading on frequency estimates.

**Between-subjects condition.** A 2 x 3 analysis of variance was performed, with (silent or aloud) reading as the between-subjects factor and presentation frequency (of 1, 3, or 6) as the within-subjects factor.

**Results**

Examination of the means depicted in Table 3 shows that words read aloud were judged to have occurred more often than words read silently. The only exception to this finding is that, in the mixed-list condition, the mean frequency estimate score for once-presented silently-read words was slightly larger than that for once-presented pronounced words.

A significant main effect was found for reading condition in both within- and between-subjects groups. Moreover, a highly significant Reading Condition x Frequency interaction was seen in the within-subjects group. Examination of the simple effects revealed that the effect of pronunciation on frequency judgements was significant for words that had been shown three and six times, respectively, but not significant for words that had been presented once. The between-subjects Reading
Condition x Frequency interaction was not significant; however, the overall pattern was similar, with pronunciation having a smaller effect on once-presented words than on words of higher frequency. In both within- and between-subjects groups, the main effect of actual frequency was highly significant. Test condition (pronounced vs. silent) did not have a significant effect on frequency estimates, and therefore, will not be discussed further.

F-values obtained for the main effect of reading condition were $F(1,11) = 24.97$, $MSe = 0.47$ and $F(1,22) = 5.34$, $MSe = 2.69$ for the within- and between-subjects conditions, respectively. In the within-subjects group, the Reading Condition x Frequency interaction was $F(2,22) = 7.73$, $MSe = 0.50$. Examination of the simple effects yielded the following results: For once-presented words, $F(1, 11) = 0.21$, $MSe = 0.45$; for thrice-presented words, $F(1, 11) = 18.79$, $MSe = 0.51$; and for words shown six times, $F(1, 11) = 18.92$, $MSe = 0.52$. The between-subjects Reading Condition x Frequency interaction was $F(2, 44) = 1.43$, $MSe = 0.61$. Although this interaction was not significant, for the sake of completeness, it may be noted that reading condition had a significant effect on words
presented six times \( F(1, 22) = 8.50, \text{MSE} = 1.13 \) and on words presented thrice \( F(1, 22) = 6.04, \text{MSE} = 0.83 \), but not on once-presented words \( F(1, 22) = 0.77, \text{MSE} = 1.95 \). The main effects of actual frequency were \( F(2, 22) = 97.21, \text{MSE} = 1.02 \) and \( F(2, 44) = 158.12, \text{MSE} = 0.61 \) for within- and between-subjects groups, respectively.
<table>
<thead>
<tr>
<th></th>
<th>Actual Frequency</th>
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<tbody>
<tr>
<td></td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Within-s's</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronounced</td>
<td>6.37</td>
<td>4.77</td>
<td>1.65</td>
<td>0.38</td>
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<tr>
<td>Silently-Read</td>
<td>5.10</td>
<td>3.51</td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Between-s's</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronounced</td>
<td>6.88</td>
<td>4.96</td>
<td>2.50</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Silently-Read</td>
<td>5.62</td>
<td>4.05</td>
<td>2.00</td>
<td>0.58</td>
<td></td>
</tr>
</tbody>
</table>
Experiment 3 employed an incidental learning manipulation: Subjects were not told that a frequency judgement task would follow presentation of the trial words, but instead were led to believe that their performance on another task was of primary importance. Experiment 3 followed Glenberg and Fernandez (1988) in employing this peculiar task, which required subjects to determine whether each trial word represented an active or a passive concept. The objective of Experiment 4 was to determine whether the findings of the third experiment were specific to those peculiar methods or would generalize to other situations. Thus, Experiment 4 employed an intentional learning paradigm to investigate the effects of pronounced versus silent reading on frequency judgements.

Experiment 4

Method

Subjects. Eight students enrolled in introductory psychology courses at Case Western Reserve University served as subjects in partial fulfillment of a course requirement.

Procedure. The procedure was identical to that of the within-subjects design of Experiment 3, with the
exception that prior to presentation of the trial list, subjects were informed that after seeing the word list, they would be asked to estimate the number of times that each word had occurred. Moreover, they were not given the incidental learning task.

Data Analysis

Data analysis was identical to that of the within-subjects condition of Experiment 3.

Results

The main effect of reading condition did not reach significance. Not surprisingly, however, the main effect of frequency was highly significant. In addition, a highly significant Reading Condition x Frequency interaction was obtained. Examination of the simple effects showed that the effect of pronunciation on frequency estimates was significant only for words presented more than once. Frequency estimates of once-presented silent items were somewhat larger, on the average, than estimates of singly presented pronounced items. However, mean scores shown in Table 4 revealed that frequency estimates of words presented more than once were greater for pronounced than for silent words. Thus, Experiment 4 provides evidence that the effect of
pronunciation on frequency judgements is not constrained to an incidental learning paradigm, but generalizes to an intentional learning design as well.

The main effect of reading condition was $F(1, 7) = 3.57$, $MSe = 1.43$, and the main effect of frequency was $F(2, 14) = 55.23$, $MSe = 0.78$. The Reading Condition x Frequency interaction was $F(2, 14) = 8.54$, $MSe = 0.65$. The following $F$-values were obtained for the simple effects of reading condition on frequency estimates: for words presented once, $F(1, 7) = 0.86$, $MSe = 2.00$; for words presented three times, $F(1, 7) = 12.02$, $MSe = 0.33$; and for words presented six times, $F(1, 7) = 26.17$, $MSe = 0.40$. Mean scores are shown in Table 4.
TABLE 4
Mean Frequency Estimates for Each Condition in Experiment 4

<table>
<thead>
<tr>
<th></th>
<th>Actual Frequency</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Pronounced</td>
<td>5.89</td>
</tr>
<tr>
<td>Silently-Read</td>
<td>4.26</td>
</tr>
</tbody>
</table>
CHAPTER 3

Discussion

The present experiments found no difference between auditory and visual presentation on frequency estimates. However, pronunciation did have a significant effect on memory for frequency; frequency estimates of words read aloud exceeded those of silently read words. This pronunciation effect appeared to be fairly robust, as it was seen in both within- and between-subjects designs, and in incidental as well as intentional learning manipulations. However, it was found only on estimates of words that had appeared more than once.

Effects of Pronunciation

Support for the effect of pronunciation on frequency judgements is found Hopkins et al.'s (1972) investigation. Hopkins et al. (1972, Experiment 4) found that frequency judgements of words presented in a mixed-list format were significantly greater for pronounced than for silently read words. In contrast, the effect of pronunciation on frequency judgements has
been unclear in studies using pure-lists designs. Hopkins et al. (1972, Experiment 3) found virtually no difference between pronunciation and silent reading groups. However, Hopkins et al. (Experiment 4) found that frequency estimates were somewhat higher in the pronunciation group than in the silent reading group, although the main effect was not significant. The Group x Frequency interaction did approach significance, and examination of the means revealed that the effect of pronunciation increased as the number of times that the word had been presented increased. Thus, the finding here of a pronunciation effect in a within-subjects design is in agreement with the results of Hopkins et al., and the finding here of a pronunciation effect in a between-subjects design is compatible with one of the experiments reported by Hopkins et al.

Investigations of verbal discrimination (VD) learning studies provide indirect support for the effect of pronunciation on frequency judgements. In VD experiments, the subject is shown pairs of verbal stimuli, and the subject's task is to learn which stimulus in each pair has been arbitrarily selected by the experimenter as the correct alternative. The usual procedure is: (a) a list of VD pairs is shown, (b) the
subject guesses which item in each pair is correct, and (c) after each guess, the experimenter tells the subject whether or not the subject's choice is the correct alternative. Pronunciation has been used as an independent variable to test the frequency theory of verbal discrimination (VD) learning, which posits that "the cue for discrimination is the difference in frequency of occurrence between the correct (C) and incorrect (I) alternatives of a VD pair" (Ekstrand, Wallace, & Underwood, 1966, p. 566). The pattern of results of VD studies looking at the effects of various pronunciation manipulations (e.g., pronounce both words in a pair, pronounce only incorrect items, pronounce only correct items) on discrimination learning, supports the premise that pronunciation increases the apparent frequency of an item (e.g., Carmean & Weir, 1967; Kausler & Sardello, 1967; Hopkins & Epling, 1971; Underwood & Freund, 1968; Wilder, Levin, Kuskowski, & Ghatala, 1974). Possibly also relevant here are findings that pronunciation may lead to an improvement in recognition, at least when a within-subjects design is used (Conway & Gathercole, 1987; Hopkins & Edwards, 1972).
One striking aspect of the present set of results is that the effects of pronunciation were confined to repeated words: Frequency estimates of once-presented words were similar in the pronounced and the silent conditions. This finding is particularly notable insofar as there is evidence that pronunciation may improve recognition of once-presented words (Conway & Gathercole, 1987; Hopkins & Edwards, 1972). One explanation for the discrepancy between the findings of these recognition studies and the present Experiments 3 and 4 is that people's basis for estimating whether or not a word occurred may differ depending on whether or not the experiment also included words presented more than once. In other words, the relative frequency of an item may influence the effect of pronunciation on memory.

Support for a relative frequency hypothesis is found in Greene's (1988) investigation of the generation effect on frequency judgements. The generation effect is the advantage in memory for words that the subject has produced over words that were read. Greene (1988, Experiments 4-6) found that generation had no effect on the frequency estimates of words at the lowest true frequency, although generation
did increase frequency judgements of words at higher frequencies. In contrast, generation has been found to significantly increase recognition of once-presented words in experiments which did not include higher frequency levels (e.g., Crutcher & Healy, 1989; McDaniel & Wadill, 1990, Experiment 3; Slamecka & Graf, 1978).

It is possible that the present pronunciation studies and Greene's (1988) generation experiments have a similar pattern of results because pronunciation and generation processes are alike. Both require information that is in some way self-produced rather than externally generated. In both pure- and mixed-list conditions, self-produced material may be more memorable than externally generated information. Also, some evidence suggests that in mixed-list conditions, self-produced material may inhibit memory for the externally generated information (e.g., by selective displaced rehearsal or output interference) (see Hirshman & Bjork, 1988; Slamecka & Katsaiti, 1987).

In addition to the possible advantage of pronunciation because it is self-produced, pronunciation may show an advantage in frequency judgements because it involves more sensory modalities than does silent reading. While both pronunciation and
silent reading entail the subject seeing the word, pronunciation also involves hearing the word and saying the word. Thus, there may be more sensory information contained in the memory trace of a pronounced word than in the trace of a word that had been read silently. This greater amount of sensory information may lead to higher frequency estimates.

**Null Effects of Auditory Presentation**

If the pronunciation advantage over silent reading is assumed to occur because vocalized items (a) are self-produced and/or (b) involve a greater number of modalities, then the failure to find a significant auditory modality effect in the first two experiments should not come as a surprise. In most studies of long-term memory, there would be no obvious reason for frequency estimates to be higher with auditory than with visual presentation: Each type of presentation only involves one sensory modality, and neither seems to demand more of the subject's attention than the other. Thus, a modality effect would not have been expected in the present Experiments 1 and 2 because the amount of attention required to process the words did not seem to differ between the two modalities.
A review of the literature supports the premise that there is not an inherent auditory advantage in long-term memory. Bray and Batchelder (1972) found no significant differences in recall of auditory versus visual words in a within-subjects design. Engle and Mobley (1976), employing a between-subjects design, found an auditory recency effect when subjects immediately recalled words after list presentations. However, when recall was delayed until after presentation of all lists, visual superiority was shown at the recency positions and no differences occurred at the prerecency positions. Lehman (1982, Experiment 1) found that child and adult subjects recalled significantly more visual than auditory words presented in a mixed-list format. A significant main effect of modality was not obtained in Experiment 2 (which also included child as well as adult subjects, although there was a significant three-way interaction involving one age group of children). In Experiment 3, a significant main effect was not found for modality. However, there was a significant Grade x Modality interaction: College students recalled significantly more visual than auditory words, in contrast to second and sixth graders, whose responses did not show a significant modality difference.
Studies which included recognition judgements also failed to show that auditory information is retained better in long-term memory. Within-subjects investigations by Hintzman, Block, and Inskeep (1972, Experiment 1) and Kirsner (1974) found that recognition was similar for words that had been presented visually versus auditorily. Penney (1989b) found that visual presentation of items produced higher final recall and recognition than did auditory presentation in both of the task conditions (generate rhymes or associates) that she employed in her between-subjects investigation. Peca, Reid, and Mason (1982), using a between-subjects design with (semantic, structural, or no-task control) task condition and (auditory and visual) modality as independent variables, and recall followed by recognition as dependent variables, found an interaction between input modality and type of task. Subjects in the semantic condition recognized significantly more words that had been presented visually rather than auditorily, and subjects in the control group also tended to recognize more words that had been visually presented. The converse was found for subjects in the structural condition. These findings are particularly noteworthy since the semantic
group task (i.e., to make active/passive judgements of each word) was very similar to the incidental learning task employed in the present studies of the modality effect and in Glenberg and Fernandez's (1988) investigation.

There are two studies that have found an auditory superiority in long-term memory. Conway and Gathercole (1987, Experiment 4) presented a list of 30 words to subjects. Ten of the words were presented auditorily, ten were presented visually, and ten were presented auditorily plus visually. The words were presented in the same order to all subjects, and presentation modality was counterbalanced across subjects. After presentation of the trial list, subjects were given a recognition test consisting of the 30 list words plus 30 new words. Results showed a significant effect of input mode, with subjects correctly recognizing more words that had been presented in the two auditory conditions (auditory-only and auditory-visual) than in the visual-only condition. However, this effect was restricted to the first 10 and the last 10 list words that had been presented. In the middle set of 10 words (i.e., list words 11-20), no significant modality differences were found.
Conway and Gathercole's findings can easily be reconciled with the results of the present Experiments 1 and 2, because the first 10 and the last 10 list items in the present experiments were buffer words that were not counted in subjects' frequency estimate scores. Therefore, the failure to find a modality effect in the present experiments is consistent with Conway and Gathercole's finding of no modality effect for the middle third of their list.

Glenberg and Fernandez's (1988) investigation of the modality effect in long-term memory is the only one that has found an auditory advantage that extends through the entire list. Glenberg and Fernandez found that frequency estimates of auditory words presented three and six times exceeded estimates of visual words. However, no significant modality differences were found for once-presented words. These results resembled the pattern found here when pronunciation was manipulated in Experiments 3 and 4. It is unclear why both Glenberg and Fernandez and the present Experiments 3 and 4 found differences between conditions for words presented three and six times, but not for words presented only once. One possibility is that Glenberg and Fernandez's auditory presentation method, which
employed digitized speech, may have demanded extra effort from subjects to hear and understand the auditory words. If pronunciation also requires subjects to expend additional effort, then it might make sense that the present third and fourth experiments found the same pattern of results that Glenberg and Fernandez found.

In summary, the null effects of modality found in Experiments 1 and 2 seem consistent with the bulk of the previous literature. An important exception is Glenberg and Fernandez's (1988) within-subjects investigation, which employed a procedure similar to that used in the first two experiments and found larger frequency estimates for auditory words than for visual words. Although an explanation has been proposed herein to reconcile the present studies' results with those of Glenberg and Fernandez, it is merely speculative.

In conclusion, results indicate that there is no inherent auditory advantage in long-term memory, at least when measured by a frequency judgement task. Whatever the factors responsible for the modality effect in short-term memory (e.g., a temporary acoustic store), they appear to be brief. However, the pronunciation effect appears to be a longer-lasting
phenomenon. It is hypothesized that several factors might contribute to the pronunciation effect's durability. Pronunciation requires subjects to process self-produced, as well as externally generated, information, whereas silent reading only demands the latter. In addition, pronunciation involves more sensory modalities: Subjects not only see the word, but also hear it and say it. This additional amount of sensory information may result in higher frequency estimates and, more generally, in better retention of pronounced than silent words at either short or relatively long intervals.
References


