FREQUENCY JUDGEMENTS OF SOUNDS AND WORDS

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by

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A Thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

Department of Psychology
Memorial University of Newfoundland
September 1977

ACKNOWLEDGEMENTS

I would like to express my appreciation to the following people for their help in the preparation of this thesis.

My deepest graditude is given to Dr. E.J. Rowe under whose supervision this project was carried out and whose professional and interpersonal skills were a constant source of intellectual stimulation, encouragement, and assistance.

Special thanks are due to Dr. R.E. Anderson and Dr. S.D. Moeser of my committee for their comments on earlier drafts.

I am grateful to the School of Graduate Studies and the Provincial Government of Newfoundland for their financial assistance in the graduate program.

To my wife, Gloria, many thanks for her patience and skill in typing this thesis and her personal support throughout this project.

Finally, to the staff of the Psychology Department and fellow students, appreciation is expressed for their friendship and various assistance.

ABSTRACT

Familar sounds and their spoken names were compared in a frequency judgement paradigm. In Experiment 1, subjects heard a long list of either sounds or words with individual items occurring 0, 1, 2, 4, or 6 times followed by an unexpected frequency judgement test. Sounds did not differ from words on mean judged frequency but did display lower within-subject variability than words as well as superior frequency judgement accuracy. It was suggested that the differences found may reflect differential processing within speech and nonspeech auditory memory systems. In Experiment 2, subjects heard a single list containing both sounds and their spoken names but were unexpectedly tested on only sounds or words. In the sounds list, individual sounds occurred 0, 2, 4, or 6 times while their spoken names occurred once for one half and 6 times for the other half of the sounds at each level of presented frequency. Similarly, the words were presented 0, 2, 4, or 6 times while their corresponding sounds occurred 1 or 6 times. The presence of words in the sounds list and sounds in the word list caused subjects to give inflated estimates of the number of times the sounds or words had actually occurred. As hypothesized, this distortion in judged frequency was greater for words than for sounds. This latter result was interpreted in terms of an extension to the auditory modality of Paivio's (1971) dual-coding framework, stressing the existence of dual verbal and nonverbal (imaginal) auditory processing systems for sounds and words.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Psychological investigation into memory for meaningful nonverbal auditory stimuli (i.e. familar environmental sounds) has a rather limited background in contrast to the extensive research conducted on memory for both auditory and visual verbal stimuli and nonverbal visual stimuli (i.e. pictures). Familar sounds are by definition easily recognizable and labelable and hence are readily comparable with their corresponding verbal labels as stimulus items. The principal objective of the present study was to assess some of the factors which influence the learning and retention of familar sounds as compared with their verbal labels. The first section of the introduction reviews previous research that has employed familar sounds as stimulus items. Theoretical emphasis is given to Paivio's (1971) two-process theory which stresses the distinction between verbal and nonverbal memory processes. The assumption is that sounds are represented in memory in the form of auditory images analogous to the representation of pictures in the form of visual images.

Two experiments were conducted investigating performance on sounds and words in a frequency judgement paradigm, in an attempt to assess the role of verbal and nonverbal auditory coding processes. Experiment 1 compared frequency judgements for independent lists of sounds and words under five levels of presentation frequency. In Experiment 2 subjects received a single list containing both sound and word versions of the same concepts presented different numbers of times. Following the list they were asked to judge the frequency of occurrence of only sounds or only words. This design allows one to estimate the buildup in perceived frequency due to sound-to-word and word-to-sound associative transfer and furthermore provides a means of evaluating the availability of verbal and nonverbal auditory memory codes for sounds and words.

Memory for Sounds and Words

The major research concerned with memory for sounds and words has centered on the notion of differential coding for speech and nonspeech auditory material. Empirically, the phenomenon has been most clearly demonstrated in several studies employing selective interference tasks (cf. Brooks, 1968). Rowe, Philipchalk, and Cake (1974) compared recall of sounds and words in the Brown-Peterson distractor paradigm. Subjects attempted to remember sounds or words under either verbal (shadowing poetry) or nonverbal (shadowing music) distractor activities. The result was that recall was inferior for words under verbal distraction but inferior for sounds under nonverbal distraction. In another study Rowe and Rowe (1976) compared sounds and words in the stimulus suffix paradigm (Crowder & Morton, 1969) wherein an extra item affixed to the end of a short list of auditory item produces a decrement in recall of the last few items in the list. A suffix effect was obtained for word lists with a speech suffix but not with a nonspeech suffix while the opposite was true for sounds, i.e. only the nonspeech suffix produced a suffix effect. Both studies indicate differential processing for speech and nonspeech auditory material since memory for sounds is disrupted by nonspeech interfering material while speech material selectively interferes with memory for words.

In agreement with the above conclusion, there are several pieces of evidence which indicate that verbal and nonverbal auditory processing systems can be distinguished at a neurophysiological level. Curry (1967) compared recognition of dichotically presented pairs of either sounds or words with each subject receiving a dichotic pair and then identifying the stimulus that had occurred in the designated ear. He found that words were identified better in the right ear but sounds were identified better in the left ear suggesting that the left cerebral hemisphere is specialized for handling speech sounds while nonspeech sounds are processed predominantly in the right hemisphere. More direct evidence for hemispheric specialization along the speech-nonspeech dimension was discovered by Shallice and Warrington (1974) using a short-term memory test for either speech or nonspeech sounds. They found subjects that showed a specific deficit of auditory short-term retention only with the verbal material. This strongly suggests that there are different neurophysiological mechanisms for processing verbal and nonverbal auditory material.

One explanation offered for these results centers on Paivio's (1971) dual-coding or two-process theory which stress a functional distinction between verbal and nonverbal processes. Pictures are assumed to arouse both a concrete memory representation (nonverbal visual image) and to a lesser extent a verbal label. Similarly concrete words produce both a verbal code and a visual image. In contrast abstract words rely predominantly on the verbal code. In the case of familar sounds it follows that they can lead to the formation of visual imaginal and verbal codes. However sounds also seem to be represented in terms of a nonverbal auditory image distinct from the visual memory code (Philipchalk & Rowe, 1971; Rowe, 1974). While it is assumed that verbal coding is similar for both pictures and sounds the dominant nonverbal codes are different - for pictures they are visual whereas for sounds they are auditory in nature.

As far as the availability of imaginal and verbal coding processes is concerned, memory is hypothesized to be a function of the relative availability of the two codes, the specific effect depending on the task used and the utility of the codes in the particular task. The verbal code is specialized primarily for storage of order information whereas the non-verbal code functions principally for storage of item information. Consequently in ordered recall tasks, nonverbal stimuli (pictures and sounds) are generally remembered more poorly than verbal stimuli (Paivio & Csapo, 1969; Paivio, Philipchalk, & Rowe, 1975; Philipchalk & Rowe, 1971).

In the case of the inferiority of sounds to words in serial recall Rowe (1974) has suggested that sounds have a lower probability of verbal coding. However when memory for order is not required, as in free recall (Philipchalk & Rowe, 1971) or in recognition (Lawrence & Banks, 1973; Philipchalk, 1972) then sounds do not suffer this functional disadvantage.

Beyond these findings however there has been little research into how people make use of verbal auditory coding processes in memory for sounds. One study related to this issue was conducted by Bower and Holyoak (1973). They found that verbal encoding of ambiguous sounds enhanced recognition on a long-term memory task, suggesting that familiar sounds may be encoded verbally to facilitate long-term storage and retrieval.

In summary then the evidence indicates that familiar sounds and their corresponding names are processed in separate speech and nonspeech auditory processing systems. Although the two systems have been distinguished empirically, the dual coding framework suggests that they are not only independent but also interconnected with both systems available for use in memory for either sounds or words. The extent to which each system is available and is involved in memory for a particular stimulus is dependent on the stimulus type itself and the memory task being employed.

Memorial Representation of Frequency

Empirically there are numerous ways one can ask questions about memorial representation of frequency. The most common design and the one used in the present study is to present people with a long list of events (usually words) occurring various numbers of times and then have them judge the absolute frequency of occurrence of each event. The fact that a person can accurately report that a word has been presented a certain number of times implies that the memory system is sensitive to variations in the frequency of events.

Both Howell (1973) and Hintzman (1976) have reviewed the literature on frequency judgement and discussed the major theories of frequency representation. Frequency judgement research has revealed an extensive amount of information but this section will be limited only to those empirical findings that have relevance to the present study. First of all, when subjects have to estimate how often an event has occurred their judgements reliably reflect true apparent frequency. The relationship is generally a logarithmic one, often expressed in psychological terms by Weber's Law of Frequency: perceived frequency is a logarithmic function of presented frequency. In the usual frequency judgement task this manifests itself as an overestimation of low-frequency items and underestimation of high-frequency items (Peterson & Beach, 1967; Begg, 1974). The degree of over - and underestimation relies to some extent on the particular task, instructional set, and type of stimulus materials the subjects receive (e.g. Rose & Rowe, 1976).

Research on the effect of associative frequency upon frequency judgement is relevant to the second experiment reported here. It is well known that distortions in judged frequency are found when items associatively related to the judged items are presented in the same list, For example, Shaugnessy and Underwood (1973) and Leicht (1968) showed that the presence of items conceptually related to a given test item produces an overestimation of perceived frequency. Vereb and Voss (1974) also found evidence for the effects of associative frequency by utilizing the concept of implicit associative response (IAR). The assumption is that people implicitly rehearse certain words (e.g. chair) associated with the word that was actually presented (e.g. table). Vereb and Voss found that frequency judgements of IARs (e.g. chair) were increased by the presence of critical words presumed to elicit the IAR (e.g. table, desk, etc.). Similarly, Johnson et al (1977) have recently found distortions in judged frequency produced by interactions between externally presented and internally generated (imagined) events.

The phenomenon of associative frequency offers a means of assessing the nature of associative transfer between related events. The explicit manipulation of association frequency in the second experiment presented here (i.e. sounds and words of the same concept in the same lists) should have the effect of incrementing judged frequency for either stimulus type. The important question here is whether such hypothesized inflation in perceived frequency will be equivalent for judged sounds and words. For instance, if sounds are named more often than words are coded as nonverbal auditory images then in terms of a dual auditory coding framework sounds would have a higher probability of dual auditory coding. This would produce a higher sound-to-word than word-to-sound associative transfer and hence a larger associative frequency effect for words than for sounds. In fact, any asymmetry in the amount of frequency judgement distortion for sounds and words would aid in assessing the nature of dual auditory processing for speech and nonspeech sounds.

Finally, some experiments have compared frequency judgements for different types of stimulus materials. Ghatala, Levin, and Wilder (1973) obtained frequency estimates for pictures (line drawings of familar objects) and printed words. It was found that pictures were given consistently higher mean judgements and displayed lower within-subject variation around the mean judged frequency than words, with the effect persisting across all levels of presentation frequency. Ghatala and Levin (1973) replicated these results and in addition found superior frequency judgement accuracy for pictures. The authors attributed these effects to the lower background (pre-experimental) frequency of occurrence of the particular pictures used, assuming that even though they represented familar objects the pictures were novel representations of those objects as far as the subject was concerned. According to Weber's law, the occurrence of an item low in background frequency should cause a larger subjective increment in the memory trace for that item than for an item with a high background frequency. Thus in contrast to words the subjective frequency units for pictures are considered to be larger (hence increasing mean perceived frequency) and more stable (giving less variable and more accurate judgements).

As pointed out in a later study concerned with discrimination learning (Ghatala, Levin & Makoid, 1975) background frequency is not the only conceivable construct underlying differences in memory for pictures and words. Either higher concreteness (pictures evoke strong visual images that enhance discriminability and hence memory) or more efficient dual coding (theories proposed by Paivio, 1971) could lead to the superiority of pictures over words in frequency judgement. The latter idea is based on the premise that people are more likely to spontaneously name pictures of simple objects than they are likely to generate visual images to words, i.e. there is a higher probability of two internal codes (imaginal and verbal) for pictures. Whatever the reason, there are differences in frequency judgement performance with verbal and nonverbal stimuli presented visually. Experiment 1 will make the corresponding comparison in the auditory modality.

EXPERIMENT 1

The question of central interest in the first experiment is whether verbal and nonverbal materials influence the relationship between true and judged frequency of occurrence in the auditory modality. There is a lack of direct empirical evidence to serve as a predictive base since this is the first experiment to compare familar sounds and words in a frequency judgement task. Nevertheless some of the research discussed in the introduction has implications for the comparison of sounds and words in this paradigm. Thus if the results for pictures versus words (Ghatala & Levin, 1973; Ghatala et al, 1973) are due strictly to a verbal-nonverbal difference then sounds (like pictures) would be given higher mean frequency judgements, lower within-subject variability around the mean perceived frequency, and more accurate judgements than words for items at the same level of presentation frequency.

Since the frequency judgement task is based more on item information than order information then, in comparison to words, sounds should not suffer the functional disadvantage normally present in sequential memory tasks (Philipchalk & Rowe, 1971; Paivio et al, 1975). Hence for mean judged frequency two possibilities suggest themselves; either sounds will be judged as occurring more often than words, or sounds will be judged equal to words.

Method

Subjects

Seventy-four undergraduates of Memorial University were paid $1.00 for their participation in the experiment. Of these, 26 subjects participated in an initial sounds identification test. The remaining 48 subjects took part in the frequency judgement task.

Materials

The nonspeech stimulus items were familar environmental sounds while the speech items were their corresponding verbal labels. Each sound was a shortened segment of an easily identifiable sound from a set of sound effect recordings used by Rowe et al. (1974).

Procedure

Sounds identification test. In order to ensure reasonable compatibility between temporal parameters for lists of sounds and words (including total list time and presentation durations of the individual items) it was necessary to have sound segments that would be as brief as words yet still be readily identifiable. Shortened segments of 35 sounds were selected ranging in duration from 0.9 sec. to 2.2 sec. with mean presentation time of 1.6 sec. The 35 sounds were recorded on magnetic tape in a random order, each followed by five seconds of silence. The tape was played to a group of 26 subjects who were instructed to write down a name for each sound during the five seconds of silence following its presentation. More specifically, subjects were told to place one label - "the common everyday label used to describe that particular sound" - in the appropriate blank on a prepared answer sheet and to guess if they were not sure.

Each sound was given a labelling consistency rating defined as the proportion of subjects identifying a sound with its common label. The final 25 sounds chosen for the frequency judgement task were those with the highest labelability ratings. The common verbal labels of these 25 sounds, their durations, and their labelling consistency ratings are listed in Table 1.

Frequency judgement test. The sound lists were constructed by re-recording each sound from the master set of 25. The word lists, recorded in a male voice, consisted of the verbal labels spoken at an average duration of one second each. The 25 original items were divided equally among five levels of frequency, with 20 items at four levels of presentation frequency (1, 2, 4, and 6) resulting in a total of 65 study-list presentations; while the remaining five items were included on the test list as items of zero presentation frequency. For both study and test lists each presentation of an item was followed by five seconds of silence. The order of presented items in the study list was random, subject to two restrictions; first, no two occurrences of a particular item would appear adjacent to one another; and second, the placement of an individual item depended on its level of frequency i.e. an item presented twice occurred once in each half of the study list, an item presented four times occurred once in each quarter of the list, etc. For both sounds and words the same 25 items were used to construct a second version of the study list with a different subset of items

TABLE 1

The Verbal Labels, Presentation Durations, and Labelling Consistency Ratings (LCR) of the 25 Sounds.

Label	Duration	LCR*	Label	Duration	LCR*
Cough	1.5	1.00	Whip	1.6	.92
Train	2.3	1.00	Cats	1.9	.85
Doorbell	1.5	.92	Rooster	1.5	1.00
Typewriter	2.2	.81	Baby	1.7	.96
Siren	1.4	.81	Horse	1.8	1.00
Telephone	1.8	.85	Dog	1.3	.96
Drum	2.1	.77	Bowling	2.0	.92
Water	2.0	.77	Church Bell	2.2	.85
Clock	1.5	1.00	Car Horn	0.9	1.00
Cymbals	1.2	.92	Door	1.1	.96
Saw	1.6	1.00	Hammer	1.2	.81
Cash Register	1.1	.92	Bird	1.7	.85
Crow	1.0	.85			
			Mean	1.6	.91

* Expressed as mean proportion of Ss (N = 26) identifying a given sound by its verbal label.

representing each level of presentation frequency. The two versions of the study list were used to offset any effects of specific item representation across specific levels of presentation frequency. The test list consisted of 25 items each presented once, followed by five seconds of silence.

A total of 48 subjects were divided into 4 groups of 12, one group for each of the two versions of the study list for both sounds and words. The subjects in each group were tested in subgroups of three to five. For the study list subjects were simply told to identify and remember each item as it occurred in expectation of an unspecified memory test. They were also informed that some items in the study list would occur more than once. The complete instructions are given in Appendix A. The instructions for the frequency judgement test were given immediately following the study list, with subjects being told to write an estimate of the number of times each item occurred in the study list. The subjects wrote their estimates in the appropriate blanks on prepared answer sheets. The frequency judgement test took approximately 3 minutes to complete.

Results

Three measures of frequency judgement performance on both sounds and words at each of the five levels of presentation frequency (0, 1, 2, 4, and 6) were computed. The measures were (a) mean judged frequency, (b) intrasubject variability estimates, and (c) frequency judgement accuracy. Each measure is dealt with separately below.

Mean judged frequency. The mean judged frequency for sounds and words as a function of presentation frequency is shown in Table 2. A 2 x 2 x 4 x 12 analysis of variance[1] was performed on the data with stimulus type (sounds or words), list version (one or two), presentation frequency (1, 2, 4, or 6) and subjects (12) as respective factors. Because there were so few nonzero frequency judgements given in the condition where presentation frequency was zero, the data for this frequency level was omitted from the analysis. Since list version as a factor had no effect the results for the two versions of the list are combined in the data tables. Although there was a slight but consistent trend across presentation frequency for sounds to be judged lower than words this effect failed to reach significance, $\underline{F}$ (1,44) = 1.52. The only factor producing a main effect was presentation frequency, $\underline{F}$ (3,132) = 273.12, $p < .001$, reflecting the expected increase in mean judged frequency as a function of increases in presentation frequency. The phenomenon of overestimation of low presentation frequency and underestimation of high presentation frequency is present but the effect was not assessed statistically. Mean judged frequency was a fairly accurate reflection of presentation frequency.

Because there were so few nonzero frequency estimates at the zero presentation frequency level parametric statistics were not used. However a chi-square analysis on judgements of items not presented in the study list revealed that sub-

[1]Summary tables for this and all subsequent analyses of variance are given in Appendix B.

jects gave fewer nonzero frequency judgements to sounds than to words, $x^2 = 11.02$, $p < .001$.

Intrasubject variability. The variance attached to subjects' frequency judgements was calculated for each subject for all items with the same presentation frequency. This measure was then averaged across subjects to give the means presented in Table 2. The data for presentation frequency conditions greater than zero were submitted to a 2 x 2 x 4 x 12 analysis of variance with stimulus type, list version, presentation frequency, and subjects as factors.

Sounds were associated with significantly lower intrasubject variance than words, F (1,44) = 4.32, $p < .05$. Presentation frequency was also a significant factor, F (3,132) = 24.20, $p < .01$, reflecting the increase in intrasubject variability with increased presentation frequency. The stimulus type x presentation frequency interaction was not significant, so the difference between sounds and words is not attenuated by variation in presentation frequency. The important conclusion is that in comparison to words individual frequency judgements for sounds deviate less from the mean perceived frequency at each level of presentation frequency. The mean judged frequency is the same in both cases but the variability is lower for sounds. Intrasubject variability can be viewed as an index of discriminability among different levels of presentation frequency. The question of why sounds are superior to words on this aspect of the frequency judgement process will be discussed below.

TABLE 2

Mean Judged Frequency and Mean Intrasubject Variance Estimates as a Function of Presentation Frequency for Sounds and Words in Experiment 1.

Stimulus Type		Presentation Frequency 0	1	2	4	6	Mean
		Mean Judged Frequency					
Sounds	X̄	.03	1.08	2.03	3.64	5.27	2.41
	S.D.	(.06)	(.28)	(.63)	(.91)	(1.14)	(.60)
Words	X̄	.19	1.22	2.12	4.09	5.63	2.65
	S.D.	(.26)	(.42)	(.84)	(1.44)	(1.51)	(.89)
		Intrasubject Variability					
Sounds	X̄	.03	.31	.80	1.88	3.53	1.32
	S.D.	(.17)	(.42)	(.62)	(2.40)	(3.10)	(1.34)
Words	X̄	.33	.81	1.08	3.48	5.51	2.24
	S.D.	(.95)	(.81)	(1.05)	(4.06)	(5.16)	(2.41)

<u>Frequency judgement accuracy</u>. Table 3 shows the mean proportion of frequency estimates that were exactly correct as a function of presentation frequency for sounds and words. The total number of correct judgements (out of a possible 600) for sounds was 308 (52%) and for words 260 (43%). There were too few exact frequency estimates at each frequency level to permit an overall analysis of variance. Accordingly, the data were broken down into two categories - low presentation frequency (the average of levels 0, 1, and 2) and high presentation frequency (the average of levels 4 and 6) for analysis.

A 2 x 2 x 2 x 12 analysis of variance, which revealed a main effect of stimulus type, $\underline{F}(1,44) = 8.80$, $p < .01$, confirmed the superiority of sounds over words. Again the only other effect attaining significance was presentation frequency, $\underline{F}(1,44) = 420.55$, $p < .001$, indicating that accuracy was greater at low than at high presentation frequency. This was true for both sounds and words. This makes sense because as presentation frequency increases then so does the range within which a subject can give an incorrect frequency judgement and therefore the probability of estimating exact frequency is lower.

TABLE 3

Mean Proportion of Correct Frequency Judgements as a Function of Presentation Frequency for Sounds and Words in Experiment 1.

Stimulus Type	Presentation Frequency 0	1	2	4	6	Mean
Sounds	.98	.80	.41	.28	.18	.53
Words	.84	.67	.41	.17	.10	.44

Discussion

Several conclusions are evident from the data. First of all, sounds and words did not differ on mean judged frequency. This agrees with previous research in which no differences in memory between sounds and words were found in tasks based on item information, such as free recall (Paivio et al, 1975; Philipchalk & Rowe, 1971) and recognition (Philipchalk, 1972). However the result is in direct contrast to comparisons of pictures and words in the visual modality (Ghatala et al, 1973) where pictures produced higher mean frequency judgements than words when the presentation frequency was the same for both stimulus types. Thus one suspects that pictures would produce higher mean frequency judgements than sounds. Differences in memory for visual and auditory nonverbal stimuli have been found in free and serial recall tasks, in that pictures are superior to words in both tasks whereas sounds are inferior to words in serial recall and equal to words in free recall (Paivio et al, 1975). However, no studies to date have compared pictures and sounds in a frequency judgement paradigm.

On the other hand there were differences between sounds and words on other measures of frequency judgement. Sounds were associated with lower intrasubject variance about the mean judged frequency and higher accuracy in judging true frequency, than were words. These latter findings correspond to those in the visual mode where pictures also produced lower intrasubject variability and greater accuracy than words (Ghatala & Levin, 1973; Ghatala et al, 1973).

How then do the results fit in with the three possible explanations mentioned above for verbal-nonverbal differences in frequency judgement performance, i.e. background frequency, concreteness, and dual coding? The background frequency theory explains the superiority of pictures over words in frequency discrimination by assuming that pictures, because of their low background frequency, produce subjective frequency units which are "larger" (influencing mean judged frequency) and more stable (influencing accuracy and variability) than for words. If this line of reasoning is applied to the results of Experiment 1 it follows that the size of the frequency units for sounds and words do not differ since the two types of stimuli are equal in terms of mean judged frequency. However, the frequency units may be more stable which would account for the lower intrasubject variance and greater accuracy for sounds. This interpretation is supported by the fact that the sounds used in the present study, even though familar and easily named, were still novel representations of those particular sounds as far as the subject was concerned, i.e. sounds (like pictures) could be classified as items of low background frequency. One difficulty with this interpretation is that it does not explain why pictures and words differ on mean judged frequency whereas sounds and words do not.

A similar problem occurs with attempts to account for the results using an explanation based on the higher concreteness of nonverbal items, which would lead to better accuracy and less variable judgements for both pictures and sounds but would leave unexplained differences observed for picture-word *versus* sound-word comparisons on mean judged frequency. Finally, it is difficult to relate the present results to dual-coding theory, since the nature of dual auditory coding processes for sounds and words has not yet been established. The second experiment examines the relationship between verbal and imaginal auditory codes for both speech and nonspeech auditory material.

EXPERIMENT 2

Experiment 2 was directed toward an analysis of differential effects on the perceived frequency of speech and nonspeech target stimuli presented in the context of associatively related stimuli. Both sound and word versions of the same underlying concept were presented in the same list. The subjects judged the frequency of occurrence of items in the target mode (either sounds or words) with the mode not tested providing the associatively-related stimuli.

Certain predictions emerge from research and theory on the effect of associative frequency and the assumption that nonverbal auditory images and verbal memory representations can act independently and be differentially affected by the associative frequency factor. If a combination of independent auditory codes is used for both sounds and words then associative frequency should have different effects depending on the availability and characteristics of the two codes for a particular stimulus type.

Let us consider the various coding alternatives. If both sounds and words were encoded on the verbal dimension only, then there should be equivalent associative transfer across identical codes for sounds and words and there should be no asymmetrical associative frequency effect. A similar outcome would be predicted from Anderson and Bower's (1973) propositional theory of coding wherein any stimulus, regardless of type, is processed via a unitary conceptual-propositional coding system. Since sounds and words of the same concept would have basically the same propositional representation then associative transfer between sounds and words would be equivalent. A third coding possibility is that sounds are not named but encoded simply as nonverbal images while words are encoded in a distinct verbal code. In this case there would seem to be no basis for an associative frequency effect at all since there would be no common link between sounds and words that represent the same concept.

The final alternative is the dual-coding framework (Paivio, 1971; Paivio & Csapo, 1969; Paivio et al, 1975) which stresses a symbolic distinction between verbal and nonverbal memory systems. Although the dual-coding hypothesis was originally proposed to account for differences between pictures and words in the visual modality, it can also be extended to the auditory modality by postulating the existence of verbal and nonverbal auditory memory systems for both speech and nonspeech sounds. Familar sounds and the spoken names of these sounds constitute quite different stimulus events which nevertheless evoke comparable verbal labels. Although both can be encoded verbally, sounds are stored at least partially as nonverbal auditory images (Philipchalk & Rowe, 1971; Rowe, 1974). The present study carries the analogy a step further by assuming that the spoken name of a familar sound also evokes a subjective nonverbal image similar to the sound it names. Different outcomes for association frequency can be predicted on the basis of how speech and nonspeech sounds are dually encoded in the auditory modality. One possibility, in terms of verbal-nonverbal auditory coding processes, is that sounds have a higher probability to be named than words are likely to be imaged nonverbally. If this were the case than there would be a higher probability of sound-to-word than word-to-sound associative transfer and hence a larger associative frequency effect for words than for sounds.

Method

Subjects

A total of 48 undergraduates of Memorial University were paid $2.00 for their participation in the experiment.

Materials and Design

The lists for Experiment 2 were produced at Haskins Laboratories, New Haven, Connecticut, where the stimuli were generated on magnetic tape using routines designed for use with a Honeywell DDP 224 computer. Twenty-four of the familar nonspeech sounds listed in Table 1 (Churchbell was omitted) and their corresponding verbal labels were used as stimulus items. Mixed-mode study lists were constructed consisting of both sounds and words with one mode representing target events and the other constituting associated events. Thus in the sounds study list sounds were the target events while their corresponding labels were the associated events while the reverse was true for the word study lists. The target items were presented for study and subsequently tested whereas the associatively-related items appeared only in the study list.

From the pool of 24 items, sets of 6 were selected randomly without replacement to represent each of four levels of presentation frequency (0, 2, 4, and 6) for target event frequency. Presentation frequency and associative frequency were factorially combined. The associatively-related items were included such that for each level of presentation frequency each target item had its corresponding representation in the other modality (either as a sound or word) presented either once or six times in the study list. The randomization procedures for placement of individual items within a list and the construction of two versions of the study list were the same as in Experiment 1. An additional restriction was that neither a target event and an associated event nor two associated events of the same nominal stimulus could occur adjacently in the study list.

Each study list lasted 17 minutes and consisted of a total of 156 stimulus presentations: 72 target events and 84 associatively-related events. The test list consisted of 24 target items, either sounds or words, each presented once and each followed by five seconds of silence.

<u>Procedure</u>

The 48 subjects were divided equally into four groups for each of two versions of the study list for both sounds and words. The procedure and instructions were identical to those of Experiment 1 except those aspects directly concerned with the mixed-mode nature of the study list. The instructions appear in Appendix A. The subjects were told they would be hearing both sounds and words during the study list with some items of both stimulus types occurring more than once. Furthermore they were instructed to identify and remember each item as it occurred regardless of whether it was a sound or word. The test list instructions emphasized the fact that subjects would be tested on only sounds or only words (i.e. target items), and further that they should try to ignore the fact that items in the associated mode had occurred in the study list. The subjects wrote their estimates of how many times they thought each test item had occurred in the study list in the appropriate blanks on prepared answer sheets.

Results

The same three measures of frequency judgement performance were computed as in Experiment 1, i.e. mean judged frequency, intrasubject variance attached to mean judged frequency, and frequency judgement accuracy.

Mean judged frequency. The mean frequency judgements for the items in each experimental condition are depicted graphically in Figure 1. As in Experiment 1, the data for the zero presentation frequency condition were analysed separately from that of presentation frequency conditions greater than zero. For the latter a 2 x 2 x 3 x 2 x 12 analysis of variance was performed with stimulus type (sounds or words), list versions (one or two), presentation frequency (2, 4, and 6), association frequency (1 or 6), and subjects (12) as factors. Examination of Figure 1 reveals the obvious effect of presentation frequency, $F(2,88) = 65.82$, $p < .001$, which shows up as the typical increase in judged frequency with increased presentation frequency.

The only other factor reaching significance was association frequency, $\underline{F}(1,44) = 45.76$, $p<.001$, indicating that the mean judged frequency of target items increased as association frequency increased from one to six. With the data collapsed across presentation frequency, two t-tests were conducted comparing association frequency levels one and six under sound and word conditions. As association frequency increased from one to six there was a corresponding increase in mean judged frequency for both sounds, $\underline{t}(46) = 2.98$, $p<.05$, and words, $\underline{t}(46) = 2.53$, $p<.01$ (both one-tailed tests). Hence association frequency had the expected effect of producing an increase in mean judged frequency. Since association frequency did not interact with presentation frequency then the associative frequency effect does not vary with the presentation frequency of the target items.

More interesting in terms of the present research is the finding that the differences in mean judged frequency between association frequency levels one and six is larger for words than for sounds. This was reflected in a stimulus type x association frequency interaction, $\underline{F}(1,44) = 4.17$, $p<.05$, and confirmed by two t-tests showing that sounds and words did not differ when associative frequency was one, $\underline{t}(46) = .60$, but when associative frequency was six, words produced higher mean frequency judgement than sounds, $\underline{t}(46) = 1.84$, $p<.01$ (both one-tailed tests). The finding of no difference in mean judged frequency for sounds and words when associative frequency was one agrees with the results of Experiment 1; but, when associative frequency was six, words were given higher mean frequency estimates than sounds, confirming the hypothesis that association frequency would have a larger effect on words than sounds.

Again list version was not a significant main effect although its interaction with presentation frequency was, $F(2,88) = 10.89$, $p<.01$. This is due to a steeper slope in the line relating mean judged frequency to presentation frequency for one of the list versions. The interaction is not readily interpretable but does not qualify the main conclusions of the experiment since list version did not enter into any other main effects or interactions.

The second-order interaction, stimulus type x presentation frequency, was significant, $F(2,88) = 3.47$, $p<.05$ indicating that the size of the difference between sounds and words decreased with increased presentation frequengy. The third-order interaction, stimulus type x presentation frequency x association frequency, was also significant, $F(2,88) = 3.79$, $p<.01$. The source of this interaction can be seen in Figure 1. The association frequency effect was larger for words than for sounds but this difference varied with the presentation frequency of the target items; it appears from Figure 1 that the difference is larger at presentation frequency level 6 than at levels 2 and 4. No apparent reason for the variation in the size of the association frequency effect with level of presentation frequency presents itself.

The data for the zero presentation frequency level were analysed by a separate analysis of variance with stimulus type (2), list version (2), association frequency (2), and subjects (12) as factors. Here sounds produced lower mean

TABLE 4

Mean Judged Frequency and Mean Intrasubject Variance Estimates as a Function of Presentation Frequency for Sounds and Words under Two Levels of Association Frequency — Experiment 2.

Association Frequency	Stimulus Type		0	2	4	6	Mean
			Mean Judged Frequency				
1	Sounds	X̄	.37	2.22	3.57	4.25	2.60
		S.D.	(.46)	(.93)	(1.24)	(1.53)	(1.04)
	Words	X̄	.51	3.07	4.05	3.71	2.84
		S.D.	(.56)	(1.91)	(2.41)	(1.71)	(1.65)
6	Sounds	X̄	.14	3.21	4.38	4.82	3.14
		S.D.	(.22)	(1.69)	(1.48)	(1.56)	(1.24)
	Words	X̄	1.47	4.37	4.82	6.04	4.18
		S.D.	(1.88)	(2.50)	(2.47)	(2.31)	(2.29)
			Intrasubject Variability				
1	Sounds	X̄	.74	1.46	2.35	4.11	2.17
		S.D.	(1.05)	(1.33)	(3.35)	(7.24)	(3.24)
	Words	X̄	1.07	3.78	6.84	4.71	4.10
		S.D.	(1.82)	(5.72)	(11.45)	(6.67)	(6.42)
6	Sounds	X̄	.15	3.79	3.10	3.07	2.53
		S.D.	(.28)	(4.14)	(4.84)	(3.80)	(3.27)
	Words	X̄	1.85	5.59	4.96	9.33	5.43
		S.D.	(2.31)	(7.95)	(9.32)	(22.02)	(10.40)

frequency judgements than words, .26 versus .99, $\underline{F}(1,44) = 9.15$, $p < .01$. The main effect of association frequency was also significant, $\underline{F}(1,44) = 4.25$, $p < .05$, as was the stimulus type x association frequency interaction, $\underline{F}(1,44) = 10.95$, $p < .01$. The interaction reflects the fact that increasing the number of associatively-related items from one to six produces a larger increase in mean judged frequency for words than for sounds. As Table 4 shows, when association frequency was increased from one to six, there was nearly a threefold increase in mean judgements for words whereas for sounds there was actually a decrease. The pattern of results here supports the findings obtained with non-zero frequencies and can be given a similar interpretation, i.e. associative frequency had a larger effect on judged frequency of words than sounds.

Intrasubject variability. The mean intrasubject variances were computed as in Experiment 1 and are summarized in Table 4. For presentation frequencies greater than zero (2, 4, and 6) sounds had lower variances than words but the effect failed to reach significance in an analysis of variance that included stimulus type (2), list version (2), presentation frequency (3), association frequency (2), and subjects (12) as factors. In fact no main effects or interactions were present.

The results for the zero presentation frequency condition closely resembled those for mean frequency judgements. Thus sounds produced lower variability estimates than words, $\underline{F}(1,44) = 7.36$, $p < .01$. The association frequency factor was not significant although its interaction with stimulus type was, $\underline{F}(1,44) = 8.19$, $p < .01$. With the two list versions combined, intrasubject variability increased for words as associative frequency increased from one to six whereas there was a corresponding decrease for sounds. This effect was modified however, by a stimulus type x list version interaction, $\underline{F}(1,44) = 12.01$, $p<.01$, as well as a stimulus type x list version x association frequency interaction, $\underline{F}(1,44) = 4.74$, $p<.05$. Essentially the variability estimates for words increased with increased association frequency in one list version but decreased slightly in the other whereas sounds decreased in both list versions. In general, for items of zero presentation frequency, increases in association frequency produced higher intrasubject variances for words whereas this did not occur for sounds.

Frequency judgement accuracy. The mean proportion of correct frequency judgements for sounds and words as a function of presentation frequency are presented in Table 5. As in Experiment 1 the analysed data were broken down into two categories of presentation frequency; low presentation frequency (the average of frequency levels 0 and 2) and high presentation frequency (the average of frequency levels 4 and 6). Sounds (.36) were superior to words (.29), $\underline{F}(1,44) = 4.48$, $p<.05$. The presentation frequency factor was highly significant, $\underline{F}(1,44) = 174.38$, $p<.001$, indicating that accuracy was better at low than at high presentation frequencies.

The presentation frequency x association frequency interaction was also significant, $\underline{F}(1,44) = 5.93$, $p<.05$, indicating that at low presentation frequency accuracy was higher when one associatively related item had occurred than six whereas for high presentation frequency the reverse was

TABLE 5

Mean Proportion of Correct Frequency Judgements as a Function of Presentation Frequency for Sounds and Words Under Two Levels of Association Frequency - Experiment 2.

Associative Frequency	Stimulus Type	Presentation Frequency				
		0	2	4	6	Mean
1	Sounds	.82	.31	.17	.07	.34
	Words	.72	.35	.10	.04	.30
6	Sounds	.89	.28	.22	.11	.38
	Words	.60	.26	.17	.13	.28

true, i.e. accuracy was higher when association frequency was six. This result can be interpreted as an interaction between two unique events; the typical over-underestimation phenomenon (Begg, 1974) and the association frequency effect. In the case of low presentation frequency subjects' mean frequency judgements are usually higher than the actual presented frequency. Since associative frequency boosts mean subjective frequency it also increases subjects' tendency to overestimate actual presentation frequency and accuracy will be lowered when association frequency is six. For high presentation frequency the opposite line of reasoning applies. Whereas subjects typically underestimate actual frequency when presentation frequency is high increases in association frequency will increase mean judged frequency and also increase subjects' chances of giving a correct frequency estimate.

Discussion

The primary dependent variable of Experiment 2 was mean judged frequency and the results here were generally in agreement with expectations. Association frequency had the effect of boosting mean judged frequency for both sounds and words. Thus the occurrence in the same sequence of events of both nonverbal sounds and their corresponding verbal labels inflates a person's estimates of the frequency of occurrence of the other stimulus type. The presence of the sounds inflated subject's estimates of the number of times each word had occurred, and the presence of words produced increased frequency judgements for the sounds which they named. These results support previous evidence that distortion in judged frequency can occur when items associatively related to the judged item are present in the same list (Leicht, 1968; Shaughnessy & Underwood, 1973).

A more important finding was that association frequency had an asymmetrical influence upon stimulus type: increases in mean judged frequency due to the presence of associatively related items were usually larger for words than for sounds. This asymmetrical influence of association frequency upon sounds and words has implications for the way in which sounds and words are processed via verbal and nonverbal auditory memory systems. If we reconsider the coding alternatives as presented in the introduction to Experiment 2 it becomes clear that the findings of the present study cannot be handled by any theory that emphasizes one type of auditory coding process alone or proposes seperate noninteracting verbal and nonverbal auditory memory systems. The results can best be explained within a dual-coding framework (Paivio, 1971; Paivio, Philipchalk, & Rowe, 1975) in which both sounds and words are represented in two internal auditory codes (verbal and nonverbal).

It is the sharing of common codes between sounds and words that gives rise to the associative frequency effect. When a sound occurs it is implicitly named and this internal verbal representation becomes confused with the explicit verbalization of the name itself. Similarly the sounds are confused to some extent with the subjective nonverbal images evoked by the words. Why were there larger distortions in judged frequency for words than sounds? As we suggested previously, the result can be explained by assuming that there is a higher probability of dual coding for sounds than words. More specifically, sounds are more likely to be named than words are likely to be imaged in the form of nonverbal auditory images. This would lead to a greater sound-to-word than word-to-sound associative transfer and hence a larger associative frequency effect for words than sounds.

The fact that the sounds showed a high probability of being named supports previous evidence that familar sounds are named to facilitate retention in memory tasks (Bower & Holyoak, 1973). In the present study there were several other factors which probably facilitated naming sounds. First, the presence of labels in the study list itself should facilitate labelling of the sounds. Second, the sounds were chosen to be implicitly named i.e. a pilot group of subjects were able to name the sounds by their given verbal labels with 90% consistency. Finally, the slow presentation rate (5 seconds between events) used in the study sequence should also facilitate naming.

Although the dual-coding framework as put forward here handles the data quite well some of its aspects could be given alternative interpretations. For example, the nonverbal auditory images evoked by words might differ qualitatively from those evoked directly by sounds, i.e. the former might be less likely to match the real sound than the implicit verbalization of a sound is likely to match the sound's name. Analogous arguments have been made in the case of pictures vs. printed words (Snodgrass, Wasser, Finkelstein, & Goldberg, 1974). What is required is a methodology aimed at assessing quantitative vs. qualitative differences within the dual coding hypothesis (c.f. Anderson, 1976). The important thing is that in either case the basic dual auditory coding framework is left intact and furthermore, the predictions for the effect of associative frequency upon judged frequency of sounds and words remains the same.

GENERAL DISCUSSION

Now that we have some evidence for dual auditory coding for speech and nonspeech auditory stimuli it is possible to reconsider the results of the present study as a whole in the light of a more general dual-coding framework. If we want to make comparisons with picture-word differences in frequency judgement (Ghatala et al, 1973; Ghatala & Levin, 1973) it is necessary to invoke three types of memory codes: a verbal code and two nonverbal imaginal codes, i.e. the auditory image and the visual image.

Up to this point the emphasis has been on auditory coding processes with little mention of visual imagery. It would seem to be a safe assumption that simple naturalistic sounds can give rise to visual images as easily as concrete words. With this in mind we can now extend the coding possibilities for the three types of stimulus material - sounds, words, and pictures. Familar sounds produceea strong auditory image, are easily named, and can evoke visual images. Pictures generate strong visual images, are easily named, and conceivably could lead to the formation of auditory images (if the pictures correspond to easily-identifiable sounds).

In contrast, words are predominantly represented in the verbal code but can lead to the generation of both visual and auditory nonverbal images.

Overall comparisons of sounds, words, and pictures on frequency judgement performance reveal two main differences: (1) Both sounds and pictures produce lower variability and higher accuracy in judging true frequency of occurrence than do words; and, (2) in terms of the mean judged frequency of items with the same presentation frequency sounds are judged equal to words while pictures are higher than words. What do these two general observations suggest about the nature of and relationship between the codes? In the former case, the coding patterns outlined above indicate that sounds and pictures have a common difference with words, namely stronger representation in nonverbal coding formats. This could mean that some special characteristic of nonverbal coding (whether concreteness, background frequency, or some other construct) leads to more stable and discriminable memory traces and hence lower variance and higher accuracy in frequency judgements of nonverbal stimuli.

But although pictures and sounds interact similarly with their verbal counterparts in affecting accuracy and variability of frequency judgements pictures enhance mean perceived frequency in comparison to words whereas sounds do not. One possible reason for this is that there are extra mnemonic qualities associated with pictures as stimulus items. It could be that the visual images evoked "directly" by pictures contain a greater amount of detail because of the spatial organizational properties associated with the visual perception of pictures. In contrast, the nonverbal auditory images evoked by sounds do not possess these special visual characteristics. Furthermore, the special qualities of pictures may be lacking (or not present to the same extent) in the subjective visual images evoked by either familar sounds or words. Somewhat analogous arguments have been suggested to account for differences observed in the free and serial recall of pictures, sounds, printed and spoken names of the same concepts (Paivio et al, 1975). The view that seems to be emerging is that it is not only the summative availabilities of multiple codes that influence memory but also the type, quality, and special characteristics of the codes being utilized for a particular stimulus type.

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APPENDICES

APPENDIX A

INSTRUCTIONS (EXPERIMENT 1)

STUDY LIST INSTRUCTIONS

The following experiment involves memory for familar sounds (words)*. Each individual sound (word) represents some common animate or inanimate object in the environment. You are going to hear a long list of such sounds (words), many of which will occur more than once in the study list. Each sound is presented for 1.6 seconds (words - 1.0 seconds). Since these are relatively brief presentation times you should quietly concentrate on each sound (word) as it is being presented. Each item is followed by five seconds of silence during which time you should identify and attempt to remember each item because after all the sounds (words) are presented you are going to have a short 'memory test' on what you heard in the study list. You will be given specific instructions concerning this memory test after you hear all the sounds (words).

TEST LIST INSTRUCTIONS

Now that you have heard all the sounds (words) in the study list you will be given the 'memory test' which involves judging how often you think each of the different sounds (words) each presented only once. Most of these sounds (words) occurred in the study list while some did not appear in the study list at all. Each item is followed by five seconds of silence during which time you should decide the number of times you think each item occurred in the study list and write the result in the appropriate blank on your answer sheet. Guess, if necessary, but be sure to write a number in each blank.

Example: Suppose that the first sound (word) you hear in the test list is 'airplane'. Then if you think that 'airplane' occurred 4 times in the study list then write the number 4 in the first blank on your answer sheet. If you think that 'airplane' did not occur in the study list then write the number 0 in the answer blank. You have five seconds in which to do this after which you will hear the words 'stop writing' on the loudspeaker. The "stop writing" signal indicates that you will hear the next test item in two seconds.

* Subjects heard either sound or word study lists and hence were instructed appropriately.

APPENDIX A

INSTRUCTION (EXPERIMENT 2)

STUDY LIST INSTRUCTIONS

This is an experiment involving memory for familar sounds and words. Each individual sound (word) represents some common aminate or inaminate object in the environment. You are going to hear a long list (17 minutes) composed of sounds and words many of which will occur more than once in the study list. On the average each sound is presented for 1.6 seconds (words ≙ 1.0 second). Since these are relatively brief presentation times you should quietly concentrate on each sound or word as it is being presented. Each item is followed by five seconds of silence during which time you should identify and attempt to remember each item because after all the items are presented you are going to have a short 'memory test' on what you heard in the study list. You will be instructed as to the specific nature of the memory test after you hear all the sounds and words.

TEST LIST INSTRUCTIONS

Now that you have heard all the sounds and words in the study list you will be given the 'memory test' which involves judging how often you think each of the sounds (or words) occurred in the study list i.e. though you heard both sounds and words in the study list, you will be judging only sounds or only words. The test list consists of 24 uniquely different sounds (words) each presented only once. Most of these sounds (words) occurred in the study list while some did not appear in the study list at all. Each item is followed by five seconds of silence during which time you should decide the number of times you think that item occurred in the study list and write the result in the appropriate blank on your answer sheet. Guess, if necessary, but be sure to write a number in each blank.

Example: Suppose that the first sound (word) you hear in the test list is 'airplane'. Then if you think that 'airplane' occurred 4 times in the study list then write <u>4</u> in the first blank on your answer sheet. If you think that 'airplane' <u>did not</u> occur in the study list then write the number <u>0</u> in the answer blank. You have five seconds in which to do this after which you will hear the words "stop writing" on the loudspeaker. The "stop writing" signal indicates that you will hear the next test item in two seconds.

TABLE 1

Summary Table of Analysis of Variance on Mean Judged Frequency - Experiment 1.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	3.10	1.52
List Version (LV)	1	7.92	3.89
ST x LV	1	0.76	0.38
Ss Within groups (S)	44	2.04	
Within Subjects			
Presentation Frequency (PF)	3	174.75	273.12***
ST X PF	3	0.35	0.54
LV x PF	3	1.24	1.94
ST x LV x PF	3	0.82	1.28
PF x S	132	0.64	

***$p < .001$

TABLE 2

Summary Table of Analysis of Variance on Mean Intrasubject Variance Estimates – Experiment I.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	56.88	4.32*
List Version (LV)	1	1.74	0.13
ST x LV	1	5.30	0.40
Ss Within groups	44	13.1	
Within Subjects			
Presentation Frequency (PF)	3	158.04	24.20**
ST x PF	3	8.21	1.25
LV x PF	3	0.85	0.13
ST x LV x PF	3	3.67	0.56
PF x Ss	132	6.53	

*$p < .05$

**$p < .01$

TABLE 3

Summary Table of Analysis of Variance on Frequency Judgement Accuracy - Experiment 1.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	4.04	8.80**
List Version (LV)	1	0.53	1.14
ST x LV	1	1.42	3.10
Ss Within groups	44	0.46	
Within Subjects			
Presentation Frequency (PF)	1	138.48	420.55***
ST x PF	1	0.11	0.34
LV x PF	1	0.76	0.23
ST x LV x PF	1	1.19	3.62
PF x Ss	44	0.33	

*p<.05
**p<.01
***p<.001

TABLE 4

Summary Table of Analysis of Variance on Mean Judged Frequency - Experiment 2.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	26.31	1.71
List Version (LV)	1	4.74	.31
ST x LV	1	12.37	.80
Ss Within groups (S)	44	15.37	
Within Subjects			
Presentation Frequency (PF)	2	55.36	65.82***
ST x PF	2	2.92	3.47*
LV x PF	2	9.16	10.89**
ST x LV x PF	2	1.33	1.58
PF x S	88	.84	
Association Frequency (AF)	1	91.53	45.76***
ST x AF	1	8.34	4.17*
LV x AF	1	2.41	1.20
ST x LV x AF	1	.42	.21
AF x S	44	2.00	

TABLE 4 (cont'd)

Source	df	MS	F
PF x AF	2	2.50	1.79
ST x PF x AF	2	5.30	3.79*
LV x PF x AF	2	3.57	2.55
ST x LV x PF x AF	2	3.03	2.17
PF x AF x S	88	1.40	

* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 5

Summary Table of Analysis of Variance on Mean Judged Frequency for Items of Zero Presentation Frequency in Experiment 2.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	13.22	9.15**
List Version (LV)	1	.50	.35
ST x LV	1	.50	.35
Subjects Within groups (S)	44	1.44	
Within Subjects			
Association Frequency (AF)	1	3.25	4.25*
ST x AF	1	8.37	10.95**
LV x AF	1	.88	.01
ST x LV x AF	1	.26	.34
AF x S	44	.76	

*p<.05

**p<.01

TABLE 6

Summary Table of Analysis of Variance on Mean Intrasubject Variance Estimates - Experiment 2.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	601.81	2.22
List Version (LV)	1	98.56	.36
ST x LV	1	451.20	1.67
Subjects Within Groups (S)	44	270.01	
Within Subjects			
Presentation Frequency (PF)	2	66.71	1.70
ST x PF	2	12.71	.32
LV x PF	2	29.30	.75
ST x LV x PF	2	11.40	.29
PF x S	88	39.24	
Association Frequency (AF)	1	86.77	1.92
ST x AF	1	12.79	.28
LV x AF	1	2.36	.05
ST x LV x AF	1	10.15	.22
AF x S	44	45.24	

TABLE 6 (cont'd)

Source	df	MS	F
PF x AF	2	49.94	.91
ST x PF x AF	2	111.22	2.02
LV x PF x AF	2	77.54	1.41
ST x LV x PF x AF	2	98.01	1.78
PF x AF x S	88	55.12	

TABLE 7

Summary Table of Analysis of Variance on Mean Intrasubject Variance Estimates for Items of Zero Presentation Frequency in Experiment 2.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	24.77	7.37**
List Version (LV)	1	2.09	.62
ST x LV	1	4.00	1.19
Subjects Within groups (S)	44	3.36	—
Within Subjects			
Association Frequency (AF)	1	.23	.17
ST x AF	1	11.18	8.19**
LV x AF	1	16.40	12.01**
ST x LV x AF	1	6.48	4.74*
AF x S	44	1.37	

*$p < .05$

**$p < .01$

***$p < .001$

TABLE 8

Summary Table of Analysis of Variance on Frequency Judgement Accuracy - Experiment 2.

Source	df	MS	F
Between Subjects			
Stimulus Type (ST)	1	1.51	4.84*
List Version (LV)	1	.26	.82
ST x LV	1	.33	1.07
Subjects Within groups (S)	44	.31	
Within Subjects			
Presentation Frequency (PF)	1	66.59	174.38***
ST x PF	1	.19	.49
LV x PF	1	.52	1.37
ST x LV x PF	1	.13	.34
PF x S	44	.38	
Association Frequency (AF)	1	.08	.32
ST x AF	1	.42	1.63
LV x AF	1	.13	.50
ST x LV x AF	1	1.33	5.14*
AF x S	44	.26	

TABLE 8 (cont'd)

Source	df	MS	F
PF x AF	1	1.17	5.93*
ST x PF x AF	1	.52	2.63
LV x PF x AF	1	.19	.95
ST x LV x PF x AF	1	.05	.24
PF x AF x S	44	.20	

* p<.01
** p<.05
*** p<.001

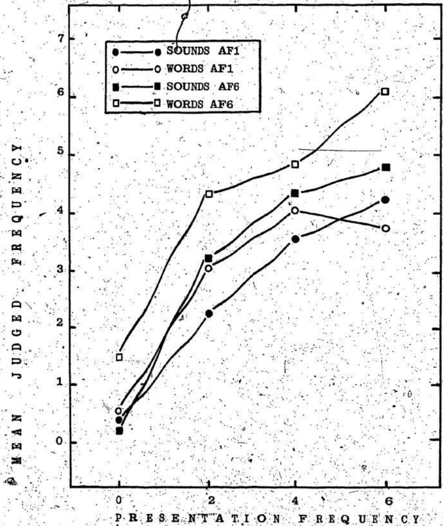

FIGURE 1. Mean Judged Frequency for Sounds and Words as a Function of Presentation and Association Frequency (AF) Conditions - Experiment 2.