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Retroactive interference in short-term recognition memory for pitch.

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RETROACTIVE INTERFERENCE IN SHORT-TERM RECOGNITION MEMORY FOR PITCH

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RECOGNITION MEMORY FOR PITCH

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ABSTRACT

The present studies were carried out to investigate the effects of different retroactive stimuli on pitch discrimination in a short-term recognition memory task. Tones, Gaussian noise, and "blank" stimuli were employed in the retroactive (interference) interval. Tones in the interference interval can enhance memory for pitch if the observer (_O_) employs the interference stimulus as a point of reference. However, if the _O_ tries to ignore the interference stimulus, tones will interfere with pitch discrimination relative to Gaussian noise in the interference interval. Blank interference intervals did not produce any significant forgetting. This result cannot be attributed to the fact that _O_s may have rehearsed or hummed the tone during the blank interference interval. Furthermore, auditory stimuli in the interference interval not only prevent rehearsal but also actively affect the trace of the tone to be remembered. Therefore, the decrease in accuracy of perceptual memory over time in the present studies was attributed to interference rather than decay. Operating characteristics and a posteriori probability functions indicated that a continuous memory system underlies recognition memory for pitch. Both a storage-forgetting model and a diffusion model of perceptual memory described the quantitative results accurately.

INTRODUCTION

Discrimination performance can be studied by a matching procedure in psychophysics (Sorkin, 1962). The task of the observer (O) in this situation is simply to state, after two successive signal presentations, if the signals were the same or different. An extension of this paradigm is the psychophysical method sometimes called "delayed paired comparison." In this task, the Standard (S) and Comparison (C) stimuli are not presented in immediate temporal succession and the interval separating the S and C presentations will be referred to as the interference (I) interval. Therefore, both discrimination and recognition memory are involved in the "delayed comparison" task. Also, if the I interval is relatively short, we can say that the task is a short-term recognition memory (STRM) experiment. This method has been employed successfully in the study of nonverbal or perceptual memory (Wickelgren, 1966b).

The first purpose of the present study was to investigate pitch discrimination in a STRM task employing different stimuli in the I interval. Secondly, the results were used to test two models of perceptual memory: a storage-forgetting model developed in this paper and a diffusion model presented by Kinchla and Smyzer (1967).

Previous to Wickelgren's (1966b) study of STRM for pitch, experimenters usually employed "higher" and "lower" response alternatives and used the difference limen (DL) as a measure of performance (Woodworth & Schlosberg, 1954, ch. 8). Experiments of delayed comparison of pitch have shown that pitch discrimination usually decreases as the duration of the I interval is increased (Bachem, 1954; Wolfe, 1886). For example, Harris (1952) found no decrease in accuracy with a .1 to 1 sec. increase in the duration of the I interval. However, he found an overall linear increase in the difference limen (DL) with increases of 3, 7, and 15 sec. in the I interval. The decrease in accuracy over time is reflected by the increase in the DL. Other early studies of memory for pitch either give insufficient information concerning the decrease in the accuracy of memory over time or have such variability in the results that the exact nature of the forgetting curve is difficult to discern (Koester, 1945; Postman, 1946).

Studies finding no decrease in pitch discrimination with increases in the I interval have employed only one S stimulus (i.e., Anderson, 1914; Irwin, 1937). As pointed out by Harris (1952), long-term memory (LTM) for the S tone would increase over training and could possibly eliminate any STM deficit caused by increasing the I interval. Therefore, studies of STRM should try to reduce any LTM for the S stimulus by employing a sufficient number of different S stimuli.

Kinchla and Smyzer (1967) found the classic time order error in recognition memory for loudness. Suppose that the S and C stimuli are equal and the O has two responses available, "C greater than S" or "C less than S." A time order error is found when the O responds more with one response alternative than another as the I interval increases. The results of the Kinchla and Smyzer (1967) study indicated that the percentage of "C less than S" responses decreased as the I interval duration increased. That is, the second presentation of the same stimulus amplitude tended to sound louder than the first. This result can be explained by a "fading image" of the sensory trace (Woodworth & Schlosberg, 1954, p. 226). Since the trace of the S tone presumably fades over time, the second presentation of the same tone would sound louder than the first. Although time order errors are usually found in memory for loudness (Postman, 1946), there is no apparent time order error in memory for pitch with "higher" and "lower" response alternatives (Koester, 1945; Postman, 1946). The lack of a time order error in memory for pitch would be expected since a "fading trace" of pitch would not bias responding. That is, the memory trace would fade with time but it is unlikely that the trace would become flatter or sharper as it decays.

The experimental evidence to date indicates that STRM for pitch decreases with increases in the I interval duration with no apparent time order error. However, the nature of the forgetting process over time is not known since the effect of different retroactive stimuli on memory for pitch has not been investigated. That is, studies of memory for pitch have usually employed an empty or blank interval as the I interval. Wickelgren (1966b), investigating STRM for pitch, did present a tone during the I interval, but one assumed to be psychophysically distinct from the S and C tones. Thus decreases in STRM of the S tone with increases in the duration of the I tone could hopefully be attributed to a relatively pure decay effect. The results indicated that when the value d' from the theory of signal detection is used as a measure of trace strength, an exponential decrease in STRM over time seemed to describe the data accurately.

It seems likely that STRM for pitch over time would be highly dependent upon the I interval stimulus. For example, the amount of retroactive interference found in memory for letters is positively related to the phonemic similarity of the interfering letters to the letters to be recalled (Conrad, 1964; Wickelgren, 1966a). Therefore, the present study attempted to assess the decrease in accuracy of recognition memory for pitch while varying the psychophysical similarity of the I stimulus to the S and C tones. The present experiments employed Gaussian noise or tones in the I interval as well as "blank" intervals. Furthermore, the I tones employed differed with respect to their psychophysical similarity to the S and C tones. That is, I tones were used that differed from the S tone by as little as 10 Hz. and as much as 90 Hz. A highly distinctive I tone (90 Hz. difference) was also used in the Wickelgren (1966b) study in which forgetting might be attributed to a relatively pure decay effect, free of interference.

It is possible that a psychophysically distinctive stimulus in the I interval does not justify the assumption that the observed decrease in memory over time is due to a pure decay effect. The results of the present study may indicate that the decrease of memory for pitch depends on the I stimulus even though it is psychophysically different from the S and C tones. For example, the rate of forgetting may be larger for an I tone that is 90 Hz. higher than the S tone than one 50 Hz. higher than the S tone. The size of the step in Hz. of the S to I tone may affect both pitch discrimination and forgetting. The view of recognition memory presented here is that this step is an important factor in STRM for pitch.

A storage-forgetting model

At first glance, a theory of STRM for pitch based on consolidation, generalization and decay of memory strength seems sufficient to describe the results of the proposed experiments (e.g., Wickelgren, 1966b). This theory postulates that presentation of an S tone not only increases the strength of a memory trace of that tone but psychophysically similar tones as well. The increase in strength or consolidation of the memory trace of the similar tones is positively related to the psychophysical similarity of the tones to the S tone. Also, the trace strength increases with increases in the tone duration. This assumption is similar to Wickelgren's (1966b) assumption of linear consolidation during presentation of the S tone.

During the I tone interval Wickelgren proposes a pure exponential decay process of S tone memory strength since he assumes that the I stimulus is not affecting the memory traces of the C tones. However, the above theory can be extended to allow for consolidation of the I stimulus and adjacent tones during the I interval. For example, if an S tone is 790 Hz. and the possible C tones are 790 or 800 Hz., constant duration I tones of 810 and 870 Hz. would probably affect recognition memory of the S tone differently. With the 870 Hz. I tone there would be little, if any, generalization to the memory traces of the equal or unequal C tones. On the other hand, with the 810 Hz. I tone, the memory traces of the C tones should also consolidate to some degree. This consolidation would be greater for the memory trace of the unequal C tone since the I tone is more similar to the unequal C tone than to the equal C tone. Since the memory trace for the unequal C tone consolidates more than the equal C tone, the theory would predict that psychophysically similar I tones should decrease recognition memory in this situation.

In contrast to the above, we assume that the sensory traces of the adjacent tones built up by the I tone might have a cueing effect on STRM for the S tone. A similar I tone would then give Os a perceptual anchor or comparison that can be employed to judge the difference between the S and C tones. Thus a psychophysically similar I tone may facilitate recognition memory of the S tone. On the other hand, Os may try to ignore the I tone and a similar I tone would now interfere with pitch discrimination. Therefore, the theory proposed here assumes that I stimuli actively affect the memory traces of the C tones. The nature of the interaction of the I stimulus with the memory traces cannot be explained by simple generalization effects. The experimental situation and the strategies of the Os will probably determine whether a given I stimulus facilitates or interferes with memory for pitch.

The present theory assumes that memory for pitch involves two processes: storage of the stimulus event and the decrease of the sensory trace over time. The parameters of the theory reflecting these processes will enable us to see how they are affected under different experimental conditions. For example, the parameter corresponding to forgetting will indicate how the decrease in memory over time differs with different stimuli in the I interval.

Formalization of the storage-forgetting model

The theory presented here is a strength theory since it determines the O's response with a probability of one from the possible values of memory strength (Wickelgren, 1968b). More specifically, the theory is an application of the basic assumptions of signal detection theory (Green & Swets, 1966). Therefore, the measure of memory strength employed is d', the difference in trace strength between C tones equal (C = S) and unequal (C ≠ S) to the S tone.

Presentation of the S tone increases the trace strength of that tone to some value t and of a similar tone to some proportion of t. The amount of trace strength generalized to other tones is positively related to the similarity of the tones to the S tone. For example, after the S tone presentation, a tone 10 Hz. lower than the S tone will have more trace strength than a tone 20 Hz. lower than the S tone. At the presentation of the C tone, the O searches in memory for the trace of that particular C tone. If the trace strength t of the C tone exceeds some criterion k, the O will report "same." That is,

$$P(\text{same} \mid t) = P(t > k) = P[(t-k) > 0] \qquad (1)$$

Assume that t_s and t_c are the trace strengths in memory of the equal and unequal C tones, respectively. Since the consolidation of an unequal C tone will always be less than an equal C tone, t_s will always be larger than t_c. Therefore, we add a random variable x, which we call noise, at the time of the decision process so that the probabilistic nature of responses can be predicted. This variability could arise from the decision process itself, from the storage and forgetting processes or from both. Thus with the addition of noise, the decision rule becomes:

$$P(\text{same} \mid t_s) = P[t_s - k + x] > 0 \qquad (2)$$

and

$$P(\text{same} \mid t_c) = P[t_c - k + x] > 0 \qquad (3)$$

In order to solve the above equations, we must know the probability density function of the noise distribution. We assume that this is the normal density function with zero mean and standard deviation σ, $N(0,\sigma)$. Therefore,

$$P(\text{same} \mid t_s) = \int_0^\infty N(t_s - k, \sigma) \qquad (4)$$

and

$$P(\text{same} \mid t_c) = \int_0^\infty N(t_c - k, \sigma) \qquad (5)$$

We assume that the criterion value k is the same for presentations when $\underline{C} = \underline{S}$ and $\underline{C} \neq \underline{S}$. Hence, we can determine the relationship between response probabilities. We employ the Z-transformation on P, Z(P), such that

$$Z(P) = Z\left\{\int_a^\infty N(b,\sigma)\right\} = \frac{b-a}{\sigma} \qquad (6)$$

Therefore, Eq. 4 and Eq. 5 reduce to

$$Z[P(\text{same} \mid t_s)] = \frac{t_s - k}{\sigma} \qquad (7)$$

and

$$Z[P(\text{same} \mid t_c)] = \frac{t_c - k}{\sigma} \qquad (8)$$

Solving for k in Eq. 8

$$k = t_c - \sigma \{ Z[P(\text{same} | t_c)] \} \tag{9}$$

and substituting this value into Eq. 7

$$Z[P(\text{same} | t_s)] = \frac{t_s - \{ t_c - \sigma Z[P(\text{same} | t_c)] \}}{\sigma}$$

$$= Z[P(\text{same} | t_c)] + \frac{t_s - t_c}{\sigma} \tag{10}$$

We define the memory operating characteristic (MOC) as a plot of $Z[P(\text{same} | t_s)]$ as a function of $Z[P(\text{same} | t_c)]$. Equation 10 shows that the MOC curve should have a slope of unity. Also, memory strength (d') defined as the difference between the means of the t_s and t_c distributions will have the standard deviation of the noise distribution as the unit of measurement.

In the present study, the unequal C tone was always 10 or 20 Hz. lower than the S tone. Therefore, the difference in memory strengths of the C = S and C ≠ S tones is given by the following equation assuming that $\sigma = 1$:

$$d(S,\ S - X,\ I,\ n_I) = t_s - t_c \tag{11}$$

where $d(S,\ S - X,\ I,\ n_I)$ is the predicted difference in memory strength of an equal C tone of S Hz. and an unequal C tone of S - X Hz. given an I stimulus of value I and an I duration of n sec. The following derivations will be determined for d(·), a measure of relative memory strength independent of k, the criterion value.

The memory strength stored at the S tone presentation is dependent upon pre-trial events and duration of the S tone. Since pre-trial events (i.e., events preceding the S tone presentation) and duration of the S tone were not systematically varied in the present study, they will not be considered here. The discrimination and sensory storage of the S tone can be represented as a variable Δ so that

$$d(S, S - X) = \Delta_X \qquad (12)$$

where d(S, S - X) is the difference in memory strength of an equal C tone of S Hz. and an unequal C tone of S - X Hz. Furthermore, the relative trace strength stored is dependent upon the difference between the equal and unequal C tones so that

$$d(S, S - X_1) = \frac{X_1}{X_2}[d(S, S - X_2)] \qquad (13)$$

For example, suppose there are unequal C tones 10 and 20 Hz. lower than the S tone. Substituting 10 and 20 for X_1 and X_2 in Eq. 13 shows that the relative trace strength stored under the d(S, S - 10) condition is 1/2 the relative trace strength stored under the d(S, S - 20) condition.

We now assume that after storage there is an immediate exponential decrease in the strength of the trace that acts to decrease the stored trace to some proportion π of its strength. That is, after an I interval duration of n sec.

$$d(S, S - X, I, n_I) = \pi^n[d(S, S - X)] \quad 0 \leq \pi \leq 1 \qquad (14)$$

where π is equal to the decrement every sec. Equation 14 gives the geometric analog of the postulated exponential decrease in memory strength. Forgetting does not occur at discrete times but is continuous during the I interval.

However, since the durations of the I intervals employed here were discrete, the geometric representation is utilized for the development of the model and for parameter estimation. The value π is not independent of the I stimulus. As mentioned above, some I stimuli may produce faster forgetting (smaller π) than other stimuli. Blank I intervals should not interfere with the sensory trace of the S tone and any observed decrease in memory over time might be attributed to a pure decay of the sensory trace.

Equation 15 is the general expression that predicts the relative memory strength for an S tone of S Hz. with respect to an unequal C tone of S - X Hz. given an I stimulus of value I, and an I duration of n sec.:

$$d(S,\ S - X,\ I,\ n_I) = \pi^n(\Delta_X) \tag{15}$$

where the value of π is dependent upon the I stimulus value. The value of Δ_X is only dependent on the difference in Hz. between the equal and unequal C tones.

The value of Δ_X can be thought of as an index of sensory storage. The value π is an index of the magnitude of the decrease over time of the memory trace. These two parameters reflect the two psychological processes postulated by the present theory: sensory storage and forgetting.

A diffusion model

Kinchla and Smyzer (1967) propose that memory storage is continuously modified through a random walk process until the time of decision (i.e., the C tone). An input process evokes some value of the sensory variable x_o which is Gaussian distributed with an expected value equal to the actual stimulus value. This value x_o is stored in memory and "diffused" or modified by a random walk process which takes place every 1/q sec. The cumulative effect of the random walk at time t is

$$d_t = KW - (N - K)W \tag{16}$$

where N is the number of steps occurring by time t, K the number of incremental steps, N - K the number of decremental steps and W the step size. Hence, memory (M) at time t is simply

$$M_t = x_o + d_t \tag{17}$$

The random walk increases the value in memory by W with probability P and decreases it by W with probability 1 - P. Since P is assumed to be 1/2:

$$E(d_t) = 0 \tag{18}$$

$$Var(d_t) = \phi t \tag{19}$$

where $$\phi = qW^2.$$

Equation 19 indicates that the variance of d_t increases as a linear function of the I stimulus duration t. Equation 17 shows that the values of the memory trace x_o and d_t are additive. Thus the variance of the memory trace also increases as a function of the I interval duration:

$$\begin{aligned} Var(M_t) &= Var(x_o) + Var(d_t) \\ &= \sigma_o^2 + \phi t \end{aligned} \tag{20}$$

At time t, the C tone gives the O a sensory value X_t equal to the actual C stimulus value which is compared to the value M_t in memory at time t. The O has a response criterion and reports "same" unless the discrepancy between X_t and M_t exceeds this criterion. The measure of memory performance independent of the criterion is

$$d' = \frac{E_o(Y_t) - E_1(Y_t)}{\sigma_o^2 + \phi t} \qquad (21)$$

where $E_o(Y_t) = E(X_t - M_t)$ when $X_t = X_o$

and $E_1(Y_t) = E(X_t - M_t)$ when $X_t \neq X_o$

Therefore, the model predicts decreased STRM for pitch with increased duration of the I interval. Since the changes in memory over time are predicted to be highly dependent on the I stimulus, the variance ϕ of the random walk per unit time will be allowed to take on different values for different I stimuli. Equation 21 shows that ϕ will increase with decreases in memory performance due to different I stimuli. An increase in ϕ could come about by an increase in the number of steps or an increase in the step size of the random walk.

METHOD

Experiment I

Observers.--The Os were four female students attending the University of Massachusetts. They were paid $1.50 per hour for participation in the experiment.

Apparatus.--Two push button Hewlett-Packard audio oscillators (Model 241A) and a Grayson-Stadler noise generator (Model 455c) were used to produce the pure tones and noise respectively. All time intervals were controlled by Hunter interval timers (Model 100-C). The stimuli were presented over matched headphones. The intensity of the tones was 80 db. SPL. The loudness of the noise was subjectively determined by E to equal that of the tones.

Design.--3 S tones (810, 820, and 830 Hz.), 3 I tone durations (1, 2, and 4 sec.), 4 I stimuli (noise, S + 10, S + 50, and S + 90 Hz.), and 2 C - S differences (0 and -10 Hz.) were factorially combined. The 24 possible conditions of S tones x I stimuli x C - S differences were randomized within each block of 72 trials with 1 block at 1 of the 3 possible I tone durations per session with about six sessions per day. Seven different sessions were presented with 4 sessions replicated 7 times and 3 sessions replicated 8 times. The data from the first session was ignored leaving a total of 51 sessions (17 at each I tone duration) for data analysis. Fifty observations were recorded for each O under each of the 72 conditions.

Procedure.--The onset of the S tone started a trial. The S tone lasted 1 sec. and was followed immediately by an I stimulus lasting 1, 2, or 4 sec. The C tone followed the I stimulus and lasted 1 sec. followed by a 5 sec. period in which Os made their decision whether the C tone was the "same" or "different" from the S tone and rated their confidence in the decision on a scale from "1" (least confident) to "3" (most confident). The onset of a trial n to trial n + 1 was 15 sec. giving a blank interval of 7 to 12 sec. before each trial. It was assumed that this interval was sufficient to eliminate any proactive interference from preceding tones and therefore eliminate any possible sequential effects due to signal values of previous trials. Also, if this assumption was not met, the random presentation of events would have presumably balanced out the sequential effects.

Experiment II

Observers.--The Os were fifty University of Massachusetts undergraduates fulfilling an Introductory Psychology course requirement.

Apparatus.--The experimental equipment employed in Experiment I was utilized for recording the stimuli on tape. The Os were run in two groups and the tapes were played at a normal listening intensity over a speaker at the front of the room.

Design.--3 S tones (820, 840, and 860 Hz.), 3 I durations (1, 2, and 4 sec.), 4 I stimuli (blank, noise, S + 20, and S + 90 Hz.), and 2 C - S differences (S = C and S ≠ C) were factorially combined. The 72 possible conditions were randomized within each block of 72 trials. Two tapes of 108 trials each were recorded. Each tape was replicated once giving a total of 432 trials for each O. The results were pooled over S tone frequency so that 18 observations were recorded for each O under each of the 24 conditions.

The two groups of 25 Os each differed with respect to the unequal C tone frequency. The Os under the "easy" condition heard unequal C tones that were 20 Hz. lower than the S tone whereas Os given the difficult condition heard unequal C tones that were 10 Hz. lower than the S tone.

Procedure.--The same procedure as Experiment I was employed with the exception that a 5 point rating scale was employed.

Analysis of results.--Since the present experiments are choice experiments, the analytical tools developed in psychophysics (Green & Swets, 1966) were applied to the data. The O's task was to respond whether the C tone is the "same" or "different" from the S tone and to rate his confidence in his decision. This method has been employed to obtain operating characteristics for individual Os in recognition tasks (Green & Moses, 1966; Wickelgren & Norman, 1966). The memory operating characteristic (MOC) is simply a plot of the probability of a correct recognition as a function of the probability of an incorrect recognition. In the present study, a correct recognition, P(S|S), is defined as O responding same on a trial where the C tone is equal to the S tone. An incorrect recognition, P(S|D), is defined as O responding same on a trial where the C tone is not equal to the S tone. If Os were required to respond same or different without ratings, we would obtain only one pair of response probabilities for each condition. The rating method requires a response from the O indicating the likelihood or odds that the C tone was the same or different as the S tone.

Figure 1 shows that the O in the present study can be viewed as sectioning the decision continuum into n regions corresponding to n-1 criteria and responding by stating in which region the strength of the C tone lies. We also assume that the response "same" for each of the n-1 criteria is the cumulative probability of giving any response-confidence pair to the right of the criterion. Thus the MOC is obtained from these n-1 cumulative probabilities conditional on trials where C = S plotted against the corresponding n-1 probabilities conditional on trials where C ≠ S.

According to the assumptions of the present theories the slope of the MOC curve should be one on normal-normal probability paper. Therefore, to test this in Experiment I, the 5 estimates of d' corresponding to the 5 cumulative

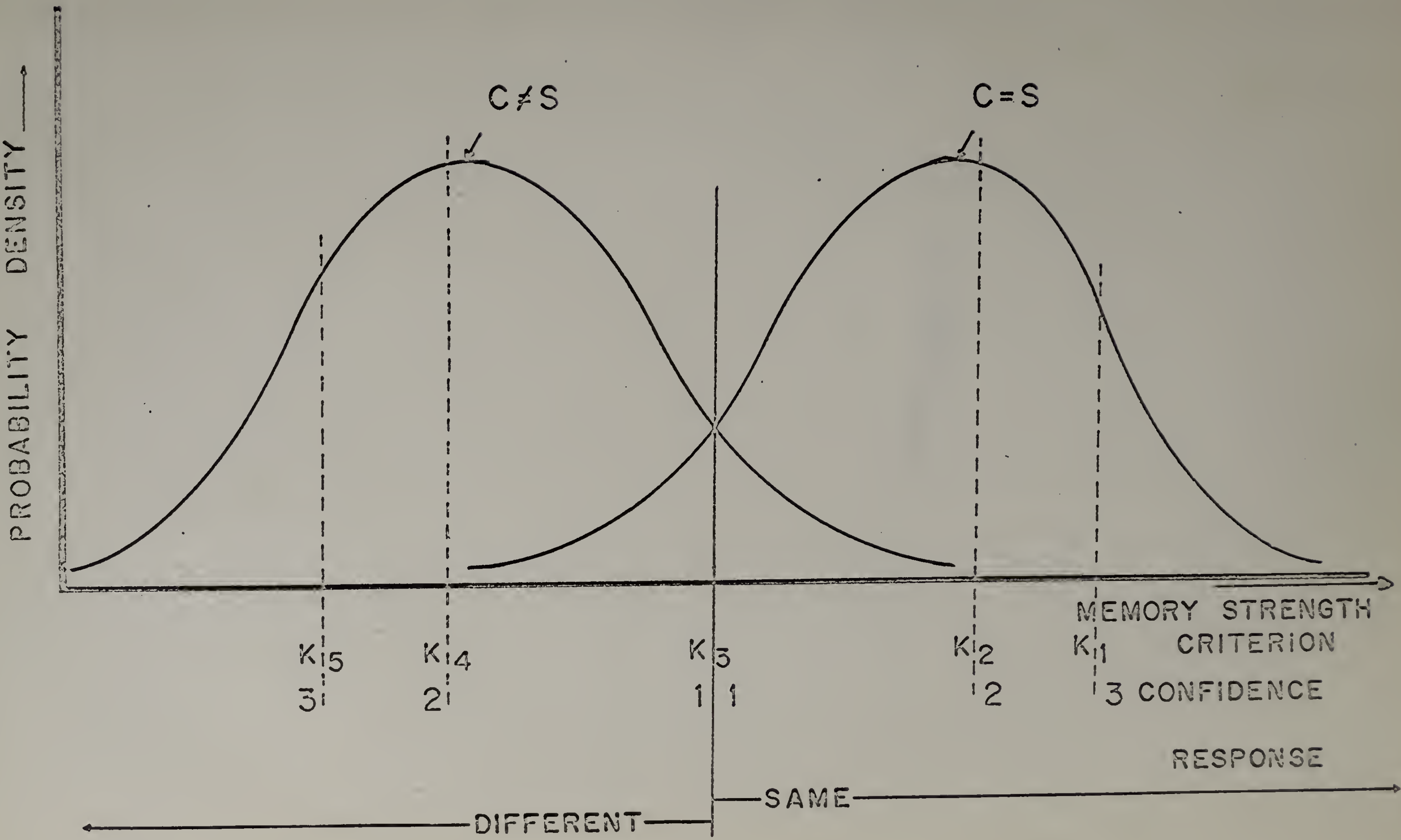

Fig. 1.--Memory Strength Distributions for C Tones that are Equal and Unequal to the S Tone.

correct recognition and incorrect recognition probabilities were treated as repeated measures. These measures were designated as 5 levels of Criterion Value since we assume (see Figure 1) that the O in Experiment I has 5 criteria and that the response "same" for each of the 5 criteria is the cumulative probability of giving any response-confidence pair to the right of the criterion. According to the underlying model that the curves are normal with equal variance, the 5 estimates of d' should not differ significantly from one another.

RESULTS

Experiment I

The cumulative correct, P(S|S), and incorrect, P(S|D), recognition probabilities observed at the 5 criterion values K_i at each experimental condition for each O were transformed to Z-scores. The respective d' values were determined by subtracting Z[P(S|D)] from Z[P(S|S)] at each of the 5 values of K_i. The observed scores of 100 and 0 per cent were treated as 99 and 1 per cent respectively. An analysis of variance of Observers x I Interval Duration x S Tone Frequency x I Stimulus x Criterion Value was performed on the d' values.

Standard tone frequency.--The significant effect of S Tone Frequency on d', $F(2,6) = 26.13$, $p < .001$, and Table 1 show that memory strength decreased as the S tone frequency increased. In this study the unequal C tone was always lower than the S tone. If the Os learned a range of S tone values, they would be more likely to discriminate unequal C tones that were outside or towards the lower frequency end of the range than unequal C tones within the range. This long-term memory of the range of the S tones should decrease incorrect recognition rates. That is, memory for the range of the S tones would not improve correct recognition of an equal C tone but only increase the probability of recognizing an unequal C tone that lies outside the range. Table

Table 1

Average d' Values, Correct, P(S|S), and Incorrect, P(S|D), Recognition Probabilities at K_3 as a Function of S Tone Frequency

S tone	d'	P(S|S)	P(S|D)
810	1.00	.65	.37
820	.78	.66	.45
830	.45	.66	.53

1 supports this idea by showing that P(S|S) at K_3 remained constant whereas P(S|D) at K_3 decreased as the unequal C tone moved to the lower end and outside of the range of the S tones.

Criterion value.--Figure 1 shows that the present theories assume that the underlying trace strengths of the equal and unequal C tones are normally distributed with equal variance. The significant main effect of Criterion Value, $F(4,12) = 15.89$, $p < .001$ indicates that this assumption was not tenable in the present study. Table 2 shows that the value of d' increased as the response criterion for saying "same" became more lax. This result indicates that the MOC curves plotted on normal-normal probability paper would have slopes greater than unity revealing that the variance of the unequal C tone distribution was larger than the variance of the distribution of the equal C tone.

Table 2 and the significant Criterion Value x S Tone Frequency interaction, $F(8,24) = 10.57$, $p < .001$, indicate that the variance of the unequal C tone distribution increased with decreasing S tone frequency. That is, the long-term memory traces for the unequal C tone contributed to the unequal C tone distribution such that more long-term traces were present in the unequal C tone distribution outside the S tone range than within the range.

Interference stimulus.--The value of the stimulus in the I interval significantly affected the observed values

Table 2

Values of d' as a Function of Criterion Value and S Tone Frequency

		Criterion Value				
		strict				lax
Os	S tone	K_1	K_2	K_3	K_4	K_5
SB	810	.65	1.06	1.15	1.39	1.33
	820	.71	.95	1.00	.97	1.03
	830	.41	.53	.58	.58	.55
MR	810	.71	.83	.88	1.03	.97
	820	.60	.71	.76	.76	.78
	830	.56	.58	.54	.51	.53
JK	810	.41	.54	.61	.75	.83
	820	.26	.46	.49	.53	.39
	830	.17	.21	.22	.23	.12
PC	810	.99	1.31	1.42	1.52	1.59
	820	.74	1.02	1.13	1.27	1.07
	830	.36	.63	.50	.72	.55
Average	810	.69	.94	1.01	1.18	1.18
	820	.58	.78	.85	.88	.82
	830	.37	.49	.46	.51	.44

of d', $\underline{F}(3,9) = 7.29$, $\underline{p} < .01$. Table 3 shows that this effect was due to an increase in memory strength as the psychophysical similarity of the I stimulus to the S tone increased.

Interference interval duration.--Although the d' values decreased as the duration of the I interval increased from 1 to 2 to 4 sec., the overall result was not significant. However, Table 3 shows that the simple effect of I Interval Duration was significant, $\underline{F}(2,6) = 6.52$, $\underline{p} < .05$, when the stimulus in the I interval was Gaussian noise.

In addition to d' values, all of the above analyses were also carried out on the difference scores between P(S|S) and P(S|D) at K_3 and on the total per cent correct responses. All sources of variance significant with one of the three dependent measures were also significant with the other two measures.

Response bias.--An analysis of variance of Observers x I Interval Duration x I Stimulus x S Tone Frequency was carried out on the per cent same responses. The overall mean of same responses was 56%. The significant effect of I Interval Duration, $\underline{F}(2,6) = 7.35$, $\underline{p} < .025$, indicates that the per cent same responses decreased from 60 to 57 to 51 per cent as the I interval increased from 1 to 2 to 4 sec. This time-order error reflects an increasing tendency of the Os to respond different as the I interval increased.

Table 3

Values of d' as a Function of I Interval Duration and I Stimulus

		I stimulus			
Os	I duration	S + 10	S + 50	S + 90	Noise
SB	1	1.99	1.14	1.00	.77
	2	1.67	.84	.79	.0
	4	1.33	.58	.33	-.12
MR	1	1.37	.88	.41	.55
	2	1.76	.65	.55	.05
	4	1.49	.65	.49	-.25
JK	1	1.00	.47	.49	.30
	2	.62	.25	.15	.17
	4	.84	.35	.15	.19
PC	1	1.01	.63	1.01	1.17
	2	1.01	.92	1.01	1.10
	4	1.37	.85	.94	.87
Average	1	1.34	.78	.73	.70
	2	1.27	.66	.62	.33
	4	1.26	.61	.48	.17

The significant effect of the I Stimulus, $F(3,9) = 77.99$, $p < .001$, indicates that the per cent same responses increased from 30 to 81 per cent as the difficulty of the task increased. That is, the rank-order of per cent same responses was inversely related to the d' values at the 4 levels of the I stimulus. This tendency to respond same as the difficulty of the task increased was also reflected in the significant effect of S Tone Frequency, $F(2,6) = 11.91$, $p < .01$ (cf. Table 1).

Experiment II

Memory strength.--An analysis of variance was carried out on the d' values obtained from the correct and incorrect recognition probabilities of same responses. Table 4 presents the average values of d' obtained from the d' values of individual Os. The significant Group effect, $F(1,48) = 27.62$, $p < .001$, indicates that memory strengths were larger when the unequal C tone was 20 Hz. lower than the S tone than when the unequal C tone was only 10 Hz. lower than the S tone.

The significant effect of duration of the I interval, $F(2,96) = 54.64$, $p < .001$, shows that recognition memory decreased as the I interval increased.

The stimulus in the I interval also affected recognition memory, $F(3,144) = 65.14$, $p < .001$ such that observed memory strengths were largest under the blank I interval condition.

Table 4

Average Values of d' as a Function of I Interval Duration and I Stimulus for the Difficult, d(S, S - 10), and Easy, d(S, S - 20), Conditions

		I stimulus			
Condition	I duration	S + 20	S + 90	Noise	Blank
d(S, S - 10)	1	.87	.78	1.09	1.50
	2	.73	.49	1.02	1.37
	4	.38	.31	.61	1.13
d(S, S - 20)	1	1.63	1.89	2.59	2.97
	2	1.40	1.49	2.18	2.82
	4	.87	.80	1.80	2.44

Table 4 also shows that performance with noise in the _I_ interval was superior to the _I_ tone conditions.

Response bias.--An analysis of variance was carried out on the per cent same responses for individual _Os_ at each experimental condition. The significant Group effect, $F(1,48) = 10.38$, $p < .005$, indicates that _Os_ in the difficult task were more biased to respond same than _Os_ in the easy task. However, Table 5 shows that this effect was due to the fact that _Os_ in the difficult task were much more biased to respond same under the noise and blank conditions than _Os_ in the easy task, $F(3,144) = 25.22$, $p < .001$.

The significant effect of _I_ Interval Duration on per cent same responses, $F(2,96) = 34.11$, $p < .001$, indicates that the _Os_ became less reticent to respond different as the duration of the _I_ interval decreased. However, Table 5 and the significant effect of the _I_ Interval Duration x _I_ Stimulus interaction, $F(6,288) = 26.04$, $p < .001$, shows that this decrease in same responses with increases in the _I_ interval duration was present only when the _I_ stimulus was a tone.

The fact that _Os_ were biased to respond different under the similar _I_ tone condition while biased to respond same otherwise can be seen in Table 4 and the significant effect of the _I_ Stimulus, $F(3,144) = 60.70$, $p < .001$.

Memory operating characteristics.--Figures 2 and 3 are a plot of the cumulative correct and incorrect recognition probabilities as a function of the _I_ stimulus and the _I_

Table 5

Per Cent "Same" Responses as a Function of I Interval Duration and I Stimulus for Difficult, d(S, S - 10), and Easy, d(S, S - 20), Conditions

		I stimulus			
Condition	I duration	S + 20	S + 90	Noise	Blank
d(S, S - 10)	1	.55	.66	.84	.77
	2	.46	.55	.83	.79
	4	.34	.43	.81	.83
d(S, S - 20)	1	.56	.66	.63	.54
	2	.48	.61	.63	.56
	4	.38	.53	.60	.58

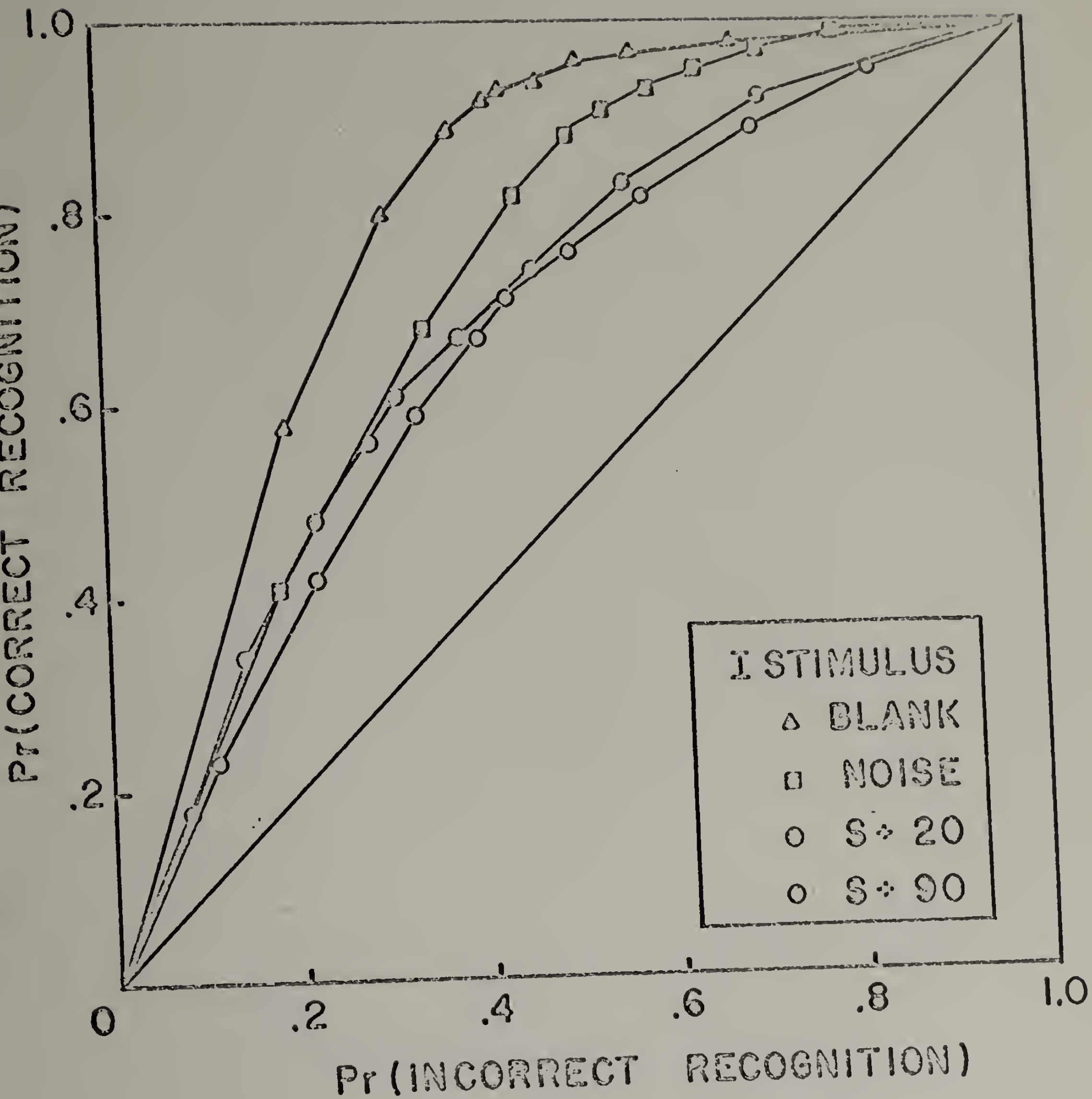

Fig. 2.--Memory Operating Characteristics Pooled Over Os, I Duration, and S Tone Frequency as a Function of the Stimulus in the I Interval.

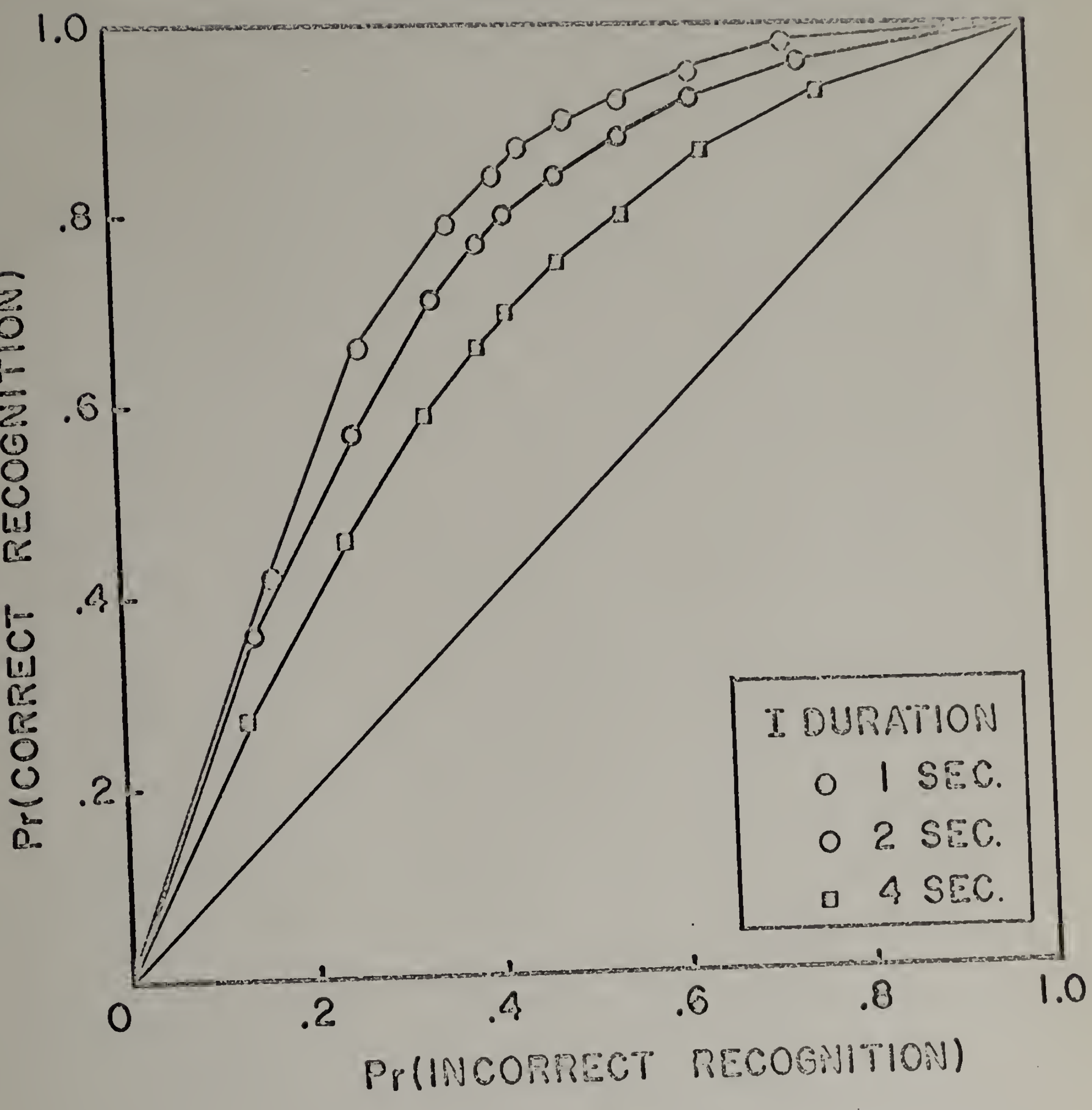

Fig. 3.--Memory Operating Characteristics Pooled Over Os, I Stimulus, and S Tone Frequency as a Function of the I Stimulus Duration.

duration, respectively. The curvilinear MOC curves could be interpreted as evidence for a multi-state memory system but Wickelgren (1968a) has pointed out how a curvilinear OC curve generated by the rating technique could arise from an underlying two-state sensory system. However, the results of a decision-making study (Massaro, 1968) in which the sensory inputs were known indicated that the shape of the OC derived from ratings reflects the sensory system. Plots of the OCs with only two possible inputs were best described by two straight lines whereas the OCs became more curvilinear with increases in the number of possible sensory inputs. Therefore, the results in Figures 2 and 3 are taken as evidence for a continuous perceptual memory system.

A posteriori probabilities.--The a posteriori probability function is a plot of the probabilities of a "same" trial given the response alternatives. This statistic reveals whether, in fact, _O_s can reliably assign confidence ratings such that the amount of confidence in a response is positively related to the likelihood that the response was correct. Figure 4 reveals that confidence in a "same" response is a monotonically increasing function of the probability that the trial was a "same" trial. Although Wickelgren (1968a) has also adumbrated how a two-state sensory system can generate continuous a posteriori probability curves, the result shown in Figure 4 is taken as evidence for a continuous memory system in STRM for pitch. Results of the

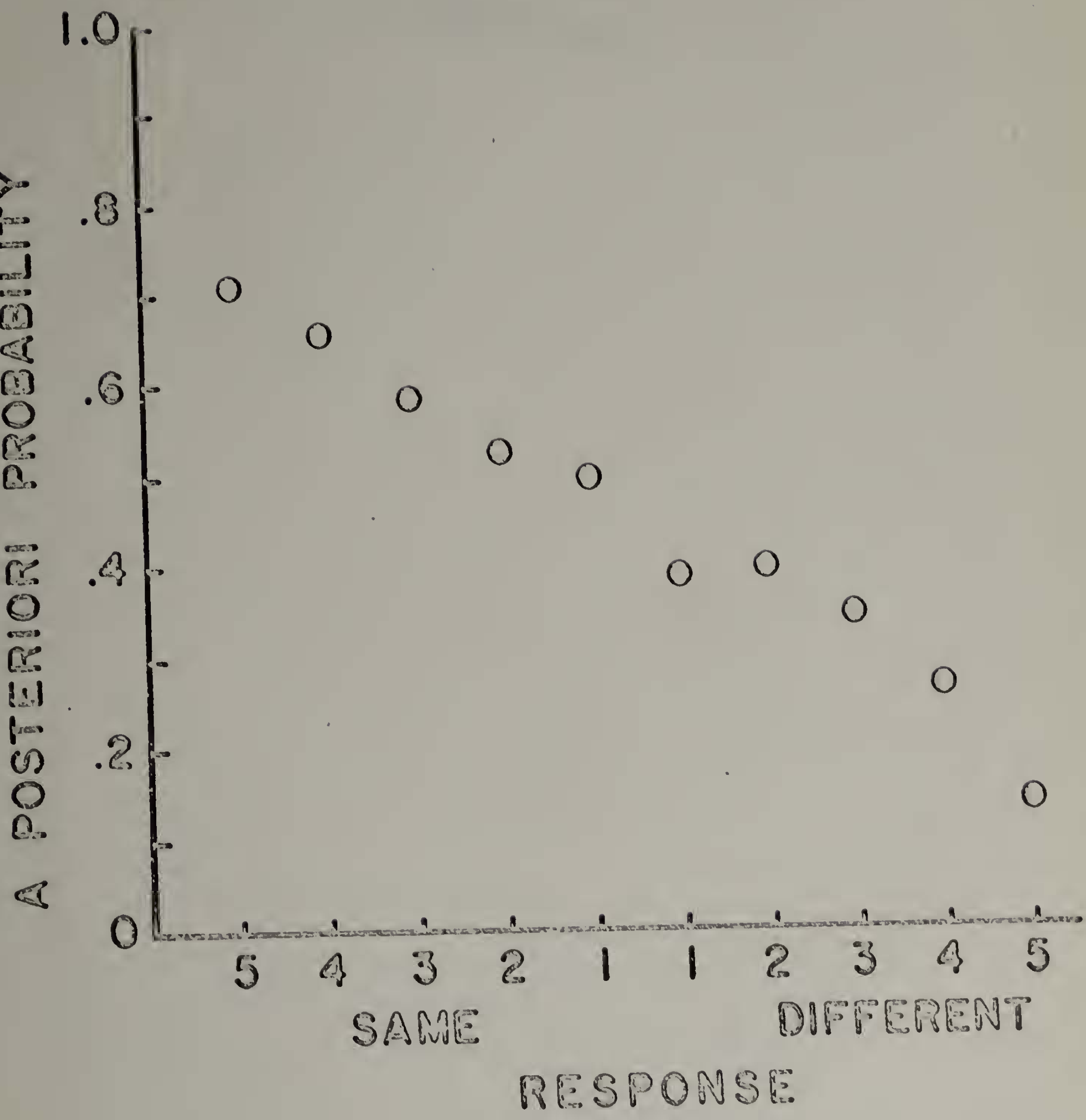

Fig. 4.--The A Posteriori Probabilities of a Same Trial as a Function of the Response Alternatives.

decision-making study mentioned above indicated that the number of confidence intervals Os can reliably employ cannot exceed the number of possible inputs. The a posteriori probability functions derived from trials where Os had only two possible inputs were best described by two horizontal line segments. Furthermore, the number of steps in the plot of the a posteriori probabilities increased as the number of possible inputs increased.

TESTS OF THE MODELS

Estimation of parameters

For tests of the models, the observed d' values were computed by first pooling the correct and incorrect recognition probabilities over Os and S tone frequency. The respective d' values were determined by subtracting the Z-transformation of the incorrect recognition probability from the Z-transformation of the correct recognition probability at each experimental condition.

The models do not predict response probabilities directly, but rather the relative memory strength (d') between the equal and unequal C tones. Therefore, the predicted values of d' were determined by estimating the parameters using a least-squares criterion between observed and predicted values of d'. To determine the goodness of fit of a model, a chi-square value was computed by searching for correct and incorrect recognition probabilities that corresponded to the predicted d' values and minimized the X^2 value between observed and predicted recognition probabilities. Since each d' value predicts two independent recognition probabilities (correct and incorrect), the number of degrees of freedom is found by taking the number of independent conditions minus one, subtracting the number of parameters estimated from the data and doubling this result.

<u>Experiment I</u>

This study had 4 possible I stimulus values and 3 I interval durations. Since the data were pooled over Os and S tone frequency, there were 600 observations for each observed correct and incorrect recognition probability.

Let d(I, n) be the predicted memory strength after an I stimulus of n sec. Therefore,

$$d(I, n) = \pi^n \Delta \qquad (22)$$

for the storage-forgetting model where π is dependent upon the value of the I stimulus.

The predicted values from the diffusion model follow directly from Eq. 21:

$$d(I, n) = \frac{10}{\sigma_o^2 + \phi n} \qquad (23)$$

where ϕ is dependent upon the value of the I stimulus.

Equations 22 and 23 show that both theories require 5 parameter estimates for the 12 independent experiment conditions. Hence, we have 2(12-6) = 12 degrees of freedom. Table 6 presents the parameter estimates and the X^2 values for the respective models. The X^2 values and the observed and predicted recognition probabilities in Table 7 indicate that both theories describe the data very nicely. The estimated values of π and ϕ indicate that the rate of forgetting increased as the psychophysical similarity between the I stimulus and S tone decreased.

Table 6

Parameter Estimates and Minimum Chi-square Values for the Conditions of Experiment I

		Models	
	Conditions	Storage-forgetting	Diffusion
	All	$d(I,n) = \pi^n \Delta$	$d(I,n) = \frac{10}{\sigma_o^2 + \phi n}$
		$\Delta = 1.08$	$\sigma_o^2 = 64.17$
	I = S + 10	$\pi = 1.00$	$\phi = 7.85$
	I = S + 50	$\pi = .82$	$\phi = 76.22$
	I = S + 90	$\pi = .78$	$\phi = 103.20$
	I = Noise	$\pi = .60$	$\phi = 248.22$
x^2		5.32	4.27
df		12	12
p >		.90	.95

Table 7

Observed (Obs) and Predicted Recognition Probabilities for the Storage-forgetting (S-F) and the Diffusion (D) Models in Experiment I

Condition		P(S|S)			P(S|D)		
I stimulus	I duration	Obs	S-F	D	Obs	S-F	D
S + 10 Hz.	1	.53	.52	.52	.13	.15	.13
	2	.46	.46	.46	.12	.12	.11
	4	.45	.46	.44	.12	.12	.12
S + 50 Hz.	1	.75	.76	.76	.44	.43	.44
	2	.67	.69	.67	.42	.41	.41
	4	.56	.54	.55	.33	.35	.35
S + 90 Hz.	1	.77	.79	.78	.50	.49	.50
	2	.73	.74	.73	.49	.49	.50
	4	.65	.64	.65	.47	.48	.47
Noise	1	.92	.90	.89	.73	.74	.75
	2	.87	.89	.89	.80	.80	.79
	4	.79	.79	.82	.75	.75	.73

Experiment II

Experiment II had 4 I stimulus values and 3 I interval durations. Also, the group of Os under the easy condition heard unequal C tones that were 20 Hz. lower than S tone whereas the group given the difficult condition heard unequal C tones that were 10 Hz. lower than the S tone. The correct and incorrect recognition probabilities were pooled over Os and S tone frequency. This gives 450 observations for each recognition probability at each of the 24 experimental conditions.

According to the storage-forgetting model, the relative trace strength Δ stored under the difficult condition should be smaller than the trace strength stored under the easy condition because generalization from the S tone should be greater for the S - 10 Hz. than the S - 20 Hz. tone. More specifically, Eq. 13 shows that the trace strength stored under the easy condition should be twice that stored under the difficult condition. However, the rate of forgetting (π) for a given I stimulus should not differ under the easy and difficult conditions. Hence, this study gives 24 independent predictions of d' with only 5 parameter estimates for the storage-forgetting model.

Equation 21 shows that the diffusion model also predicts that the d' value under the easy condition should be twice the d' value under the difficult condition. Similar to the storage-forgetting model, we make the restriction that the value of ϕ for a particular I stimulus should not differ under the easy and difficult conditions. Therefore, the diffusion model also gives 24 independent predictions of d' with 5 parameter estimates.

Table 8 presents the parameter estimates and X^2 values for the present theories. As can be seen from the observed and predicted recognition probabilities in Tables 9 and 10, both models describe the data fairly accurately. The values of π and ϕ under the no I stimulus condition indicate that the blank I interval produces very little forgetting over time. Unlike Experiment I, the tone conditions produce more forgetting over time than the noise conditions. Furthermore, the similar I tone produced about the same amount of interference as the dissimilar I tone condition.

Although both theories describe the results of the present experiments, the diffusion model does somewhat better than the storage-forgetting model. However, we cannot distinguish between the two theories on the basis of the present experiments.

Table 8

Parameter Estimates and Minimum Chi-square Values for the Conditions of Experiment II

	Conditions	Models: Storage-forgetting	Models: Diffusion
	Difficult	$d(I,n) = \pi^n \Delta$	$d(I,n) = \frac{10}{\sigma_o^2 + \phi n}$
	Easy	$d(I,n) = \pi^n (2\Delta)$	$d(I,n) = \frac{20}{\sigma_o^2 + \phi n}$
	All	$\Delta = 1.17$	$\sigma_o^2 = 54.60$
	S + 20	$\pi = .68$	$\phi = 166.07$
	S + 90	$\pi = .69$	$\phi = 153.00$
	Noise	$\pi = .87$	$\phi = 39.99$
	Blank	$\pi = .98$	$\phi = 10.20$
X^2		14.11	9.21
df		36	36
p >		.99	.99

Table 9

Observed (Obs) and Predicted Recognition Probabilities for the Storage-forgetting (S-F) and Diffusion (D) Models for the Easy Condition in Experiment II

Condition		P(S|S)			P(S|D)		
I stimulus	I duration	Obs	S-F	D	Obs	S-F	D
S + 20	1	.80	.84	.81	.33	.28	.32
	2	.68	.69	.67	.28	.28	.28
	4	.51	.48	.52	.25	.29	.24
S + 90	1	.90	.92	.88	.42	.42	.42
	2	.82	.81	.80	.40	.41	.41
	4	.66	.63	.68	.40	.42	.38
Noise	1	.95	.94	.94	.31	.32	.31
	2	.81	.91	.91	.35	.34	.35
	4	.84	.84	.84	.36	.37	.35
Blank	1	.92	.91	.93	.17	.17	.15
	2	.93	.92	.93	.19	.20	.20
	4	.92	.93	.92	.25	.25	.26

Table 10

Observed (Obs) and Predicted Recognition Probabilities for the Storage-forgetting (S-F) and Diffusion (D) Models for the Difficult Condition in Experiment II

Condition		P(S|S)			P(S|D)		
I stimulus	I duration	Obs	S-F	D	Obs	S-F	D
S + 20	1	.70	.71	.68	.41	.41	.42
	2	.58	.56	.56	.34	.35	.36
	4	.40	.38	.40	.28	.29	.27
S + 90	1	.78	.81	.79	.54	.53	.54
	2	.63	.66	.65	.47	.45	.45
	4	.47	.48	.50	.39	.38	.35
Noise	1	.95	.95	.95	.74	.74	.73
	2	.94	.93	.93	.73	.72	.73
	4	.87	.89	.90	.74	.72	.73
Blank	1	.94	.92	.93	.60	.60	.59
	2	.94	.93	.94	.64	.64	.65
	4	.94	.95	.95	.72	.72	.73

DISCUSSION

The findings of the present study have indicated that a) STRM for pitch decreases as the I interval increases, b) this decrease over time is highly dependent on the stimulus in the I interval, and c) response biases are influenced by both the I stimulus and I duration. Also, by employing a measure of memory strength that is independent of response bias we have shown that the results can be predicted quite well by both a strength theory and diffusion model of perceptual memory.

The present experiments have shown that the effect an I stimulus has on memory for pitch may be highly dependent on the experimental task. In Experiment I, an I tone improved pitch discrimination relative to noise in the I interval. However, in Experiment II, an I tone disrupted pitch discrimination relative to the I noise condition. These two experiments differed in two important respects. First, Os in Experiment I listened to the stimuli over headphones whereas Os in Experiment II heard the stimuli over a speaker at the front of the room. It is likely that it would be much easier to ignore an auditory stimulus presented over a speaker than one presented over headphones. Given that Os in Experiment I were unable to ignore the I stimulus, they could employ it as a perceptual cue for judging the S and C tones.

The second difference between the two experiments was that Os in the first experiment were employed over a period of two weeks whereas Os in the second experiment were given only one session. It is possible that Os in Experiment I only employed the I stimulus after a number of sessions. However, an analysis of the first 432 trials (the number of trials given in Experiment II) revealed that performance during these early trials did not differ from asymptotic or overall performance. Therefore, we can speculate that it was the experimental procedure rather than the practice of Os that led to the opposing results in the two experiments.

Therefore, due to the experimental difference, we can safely say that Os in Experiment II were not approaching the task as Os in Experiment I. This idea is supported by verbal reports. The Os in Experiment I reported using the I tone as a common point of reference whereas Os in Experiment II stated that the I tone "interfered" with their memory of the S tone. This would explain the fact that a significant decrease in memory strength over time was found only under the I noise condition in Experiment I. A tone does not fluctuate over time whereas noise does. A point of reference such as noise that changes randomly over time could only function to disrupt memory. A similar I tone would be a very good reference point that could be employed to judge the difference between the S and C tones. Hence, in Experiment I, a psychophysically similar I tone (S + 10 Hz.) facilitated recognition memory relative to dissimilar tones or noise in the I interval (cf. Table 6). We can conclude from the results of Experiment I that when Os employ the I stimulus as a point of reference, perceptual memory will increase with increases in the psychophysical similarity between the S and I stimuli.

On the other hand, the Os in Experiment II reported that they tried to ignore the I stimulus but that the I tone usually "interfered" with their memory of the S tone. These reports are supported by the results of Experiment II since both I tones were found to interfere with the memory of the S tone.

Both experiments indicated a strong bias of Os to respond same. However, a more detailed analysis revealed that the bias to respond same increased as the psychophysical similarity of the I stimulus to the S tone decreased. As noted above, when there are other stimuli in the situation, Os might employ these as a perceptual anchor. With dissimilar I stimuli, the S and C tones were perceived as very similar to each other relative to their similarity to the distinctive I stimulus. Therefore, Os in the present study required a much larger perceived difference before they said different with a dissimilar I stimulus than with a similar I stimulus.

The Os also became more reticent to respond same as the I duration increased when the I stimulus was a tone. Since time-order errors are not found in STRM studies for pitch using "higher" and "lower" response alternatives (Postman, 1946), the present result is peculiar to same-different tasks. Also, O's bias to respond different as the I interval increased was found only under the I stimulus conditions that produced a high rate of forgetting (cf. Table 5). Therefore, in same-different tasks, Os seem to become biased to say different as they forget the S stimulus. This bias would not be found in studies using "higher" and "lower" response alternatives.

The present experiments have shown that STRM for pitch is highly dependent on the nature of the retroactive stimulus filling the interval between the S and C tones. Furthermore, a blank interval between the S and C tones is sufficient to eliminate most of the effect of decreasing pitch discrimination as the I interval duration increases. This seems to indicate that if there is any pure decay of memory for perceptual stimuli, the rate of decay is very small (cf. Table 8). A decay theorist will quickly comment that the blank interval enables O to rehearse or reinstate the stimulus during the forgetting interval. However, the employment of three similar S tones in the present experiment makes it virtually impossible for O to rehearse the S tone such that his employment of the rehearsal will improve pitch discrimination relative to employing the perceptual trace of S tone. An experiment conducted in an undergraduate laboratory by Shirley Lui and John Moore indicated that Os given instructions to hum the S tone could perform no better than chance under all the I conditions of the memory task used in Experiment II. It is proposed that O in no way can increase the strength of the memory trace during a blank I interval. Furthermore, it may be that under a blank I interval condition the O may try to hum or rehearse the S tone. Since rehearsal seems to disrupt memory, any memory loss observed under a blank I interval condition might be due to an increased likelihood of O rehearsing the tone with longer I intervals.

Retroactive auditory stimuli do not only prevent rehearsal but actively interfere with the trace of the S tone. Pure decay effects require that the retroactive stimulus does not interfere with the perceptual trace, but only prevents O from reinstating the trace. The present experiments have shown that retroactive auditory stimuli do interact with the trace of the S tone and the amount of interference or facilitation is highly dependent on the nature of the I stimulus and the strategies of the O. Therefore, Wickelgren's (1966b) finding that STRM for pitch decreased over time with an I interval tone should be attributed to interference rather than pure decay.

In summary, two psychological processes underly STRM for pitch: storage and forgetting. We have seen how the strength of the trace stored can be dependent on retroactive stimuli. Also, whether psychophysically similar stimuli are interfering or facilitating the storage of the sensory perception is dependent upon the strategy of the O. Furthermore, the decrease of the sensory trace is highly dependent upon the nature of the retroactive stimulus. The I stimuli are doing more than just preventing the rehearsal of or attention to the S tone. Every stimulus in the I interval (except the blank interval) somehow actively interfered or facilitated the memory of the S tone. Under a blank condition, very little forgetting is found and might be attributed to a pure decay of memory strength.

The present experiments have demonstrated that studying pure decay effects of perceptual memory requires a "blank" interval. If the experimenter does not feel at ease with a blank interval and employs I stimuli he must then take into account the effects of the I stimulus on the perceptual trace.

SUMMARY

The present studies were carried out to investigate the effects of different retroactive stimuli on pitch discrimination in a short-term recognition memory task. Tones, Gaussian noise, and "blank" stimuli were employed in the retroactive (interference) interval. Tones in the interference interval can enhance memory for pitch if the observer (O) employs the interference stimulus as a point of reference. However, if the O tries to ignore the interference stimulus, tones will interfere with pitch discrimination relative to Gaussian noise in the interference interval. Blank interference intervals did not produce any significant forgetting. This result cannot be attributed to the fact that Os may have rehearsed or hummed the tone during the blank interference interval. Furthermore, auditory stimuli in the interference interval not only prevent rehearsal but also actively affect the trace of the tone to be remembered. Therefore, the decrease in accuracy of perceptual memory over time in the present studies was attributed to interference rather than decay. Operating characteristics and a posteriori probability functions indicated that a continuous memory system underlies recognition memory for pitch. Both a storage-forgetting model and a diffusion model or perceptual memory described the quantitative results accurately.

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APPENDIX I

Table 1

Analysis of Variance of d' Values in Experiment I

Source	SS	DF	MS	F*
O (observers)	32.85	3	10.95	
L (I duration)	8.23	2	4.12	
OL	10.26	6	1.71	
F (S frequency)	36.07	2	18.03	26.13
OF	4.14	6	.69	
I (I stimulus)	78.78	3	26.26	7.29
OI	32.37	9	3.60	
C (criterion value)	8.18	4	2.05	15.89
OC	1.55	12	.13	
LF	.20	4	.05	
OLF	3.71	12	.31	
LI	3.64	6	.61	
OLI	6.36	18	.35	
LC	.59	8	.07	
OLC	2.07	24	.09	
FI	1.75	6	.29	
OFI	11.59	18	.64	
FC	2.96	8	.37	10.57
OFC	.85	24	.04	
IC	8.19	12	.68	
OIC	8.75	36	.24	
LFI	3.16	12	.26	
OLFI	7.79	36	.22	
LFC	.67	16	.04	
OLFC	2.51	48	.05	
LIC	1.17	24	.05	
OLIC	3.96	72	.06	
FIC	1.07	24	.05	
OFIC	3.16	72	.04	
LFIC	2.27	48	.05	
OLFIC	7.53	144	.05	

*All F's significant at .05 level

Table 2

Analysis of Variance of Per Cent Same Responses in Experiment 1

Source	SS	DF	MS	F*
O (observers)	.23	3	.076	
L (I duration)	.35	2	.172	7.35
OL	.14	6	.024	
F (S frequency)	.48	2	.239	11.91
OF	.12	6	.020	
I (I stimulus)	9.43	3	3.144	77.99
OI	.36	9	.040	
LF	.05	4	.012	
OLF	.09	12	.007	
LI	.12	6	.020	
OLI	.37	18	.020	
FI	.05	6	.009	
OFI	.12	18	.006	
LFI	.06	12	.005	
OLFI	.11	36	.003	

*All F's significant at .05 level

Table 3

Analysis of Variance of d' Values in Experiment II

Source	SS	DF	MS	F*
G (group)	164.86	1	164.86	27.62
O(G)	286.50	48	5.97	
L (I duration)	39.75	2	19.87	54.64
GL	2.98	2	1.50	
OL(G)	34.91	96	.36	
I (I stimulus)	119.52	3	39.84	67.14
GI	14.60	3	4.87	
OI(G)	88.08	144	.61	
LI	1.58	6	.26	
GLI	1.40	6	.23	
OLI(G)	97.94	288	.34	

*All F's significant at .001 level

Table 4

Analysis of Variance of Per Cent Same Responses in Experiment II

Source	SS	DF	MS	F*
G (group)	2.56	1	2.56	10.38
O(G)	11.83	48	.25	
L (I duration)	1.69	2	.84	34.11
GL	.05	2	.03	
OL(G)	2.38	96	.02	
I (I stimulus)	12.27	3	4.09	60.70
GI	5.10	3	1.70	25.22
OI(G)	9.70	144	.07	
LI	2.11	6	.35	26.04
GLI	.09	6	.02	
OLI(G)	3.88	288	.01	

*All F's significant at .005 level