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SHORT TERM DECAY OF ODOR ASSOCIATES

by

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B.A.

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THE REQUIREMENTS FOR THE DEGREE OF

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ABSTRACT

Short term recall of the ordinal position of odors in a sequence was tested using an incidental memory procedure. Subjects rated the intensity of 8 odorants after which they were presented with three of them and asked to point to their position in the sequence. Recall performance was not better than expected by chance, but subjects' errors were negatively correlated with the ordinal position of the first test stimulus presented. A second version of the experiment was run, differing only in the use of words as stimuli and an "orientation identification" distractor task, which produced essentially the same results. The findings indicate that time decay is a major factor in the loss of positional information associated to odors.

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A. Short Term Decay of Odor Associates

Unlike memory for visual and auditory stimuli, olfactory recall is a functionally primitive process because the perceptual experience is not readily retrieved. Thus, it is not possible to study odor memory directly using recall measures of the information stored, but it is amenable to indirect experimental study in which the recall of associates to a set of odors is used (e.g., the "name" of the odor, whether it was pleasant or unpleasant, etc.), or in which recall is studied through recognition tests.[1]

The latter approach is represented in the literature by a set of experiments by Engen et al. (1973; a, b) who found imperfect acquisition of odors (averaging between 70-85%), but relatively little loss over periods of time ranging from 3 seconds to 30 days. This forgetting function contrasts sharply with results generally found in other modalities. For example, Shepard (1976) found recognition memory for pictures decayed from 100% to near chance performance over four months. However, Lawless (1978) showed that this difference is not strictly due to the difference between modalities, but rather depends on the type of stimuli used in making the comparison. By employing line drawings of irregular shapes he found a nearly parallel forgetting function with that for a set of common household odors where the functions only differed by approximately 5% in initial recognition performance, decreasing to a difference of nearly 0% over 3 months. As he observes,

> "Given the flexibility of the visual system, it is not surprising that stimuli could be constructed which show similar forgetting curves to those typical of odors. Other similarities exist for recognition memory for odors and simple figures; namely independence from verbal coding and little or no effect of time in short term tasks."

Thus, recognition performance with olfactory stimuli appears to be subject to limitations which might, but do not necessarily, apply in other modalities. It has been suggested (Lawless, 1978; Davis, 1977; Engen & Ross, 1973) that this apparent limitation on the acquisition of odor memories, as well as their durability over time, is due to their being encoded in a holistic, or unitary fashion (i.e., they will not support partial learning).

The use of associates to study odor memory has been employed by Davis (1977) who used a paired-associate task. Subjects learned to associate digit responses to either abstract figures or odors and retention was compared after 7 days. He found that equivalently learned responses in the two modalities were equally well retained. Thus, whatever limitation might exist for encoding of the olfactory stimulus in memory does not seem to influence retrieval of associated responses.

The present study was designed to investigate whether this difference in retention between recognition performance for odors and recall of associates holds for short term tasks. Since Engen et al.'s (1973) study clearly demonstrated the durability of recognition performance over short time periods, the present experiment focused on the recall of incidentally formed odor associates which represented information about the ordinal position of odorants in a sequence. Presumably these associates involve temporal and/or spatial information about stimulus position (see, e.g., Healy, 1975). Reasoning from Davis' results, it was hypothesized that these odor associates would be subject to a short-term decrement in recall.

An incidental testing procedure was employed to prevent subjects from generating verbal codes for the odors.[2] After rating a set of odors for their perceived intensity, subjects were presented with three of these stimuli, consecutively, and asked to point to their positions in the inspection sequence. It was expected that correct responses would be more frequent for odors later in the sequence, as is usually found in the serial position effect under conditions of free recall (e.g., Postman & Phillips, 1965), and that errors would be smaller for later items. Because this type of short term incidental procedure is not common in memory studies, another group of subjects was tested using words as stimuli. In order to approximate the limitations hypothesized to exist for odors, the words were all seven letters long and began with "QU", thus decreasing the number of discriminable features between them. The distractor task required subjects to find the target word on a page containing words in different orientations and then to indicate the target's orientation on a separate response sheet.

B. Method

Subjects

27 male and 45 female graduate and undergraduate university students participated in Experiment I; 23 males and 49 females in Experiment II. They were told they would be involved in a 5-10 minute experiment either in rating the intensity of a small set of odors, or as part of a pilot study for identifying words shown in various orientations.

Stimuli

The eight odorants were ionone, eugenol, vanillin, pinacolone, indole, citral, n-butyl ether, and p-acetoxy phenyl butanone. They were selected by the experimenter primarily for ease of discrimination, but also to represent both pleasant and unpleasant odors. The inspection set was presented in 2 dram, screw-top vials wrapped in opaque paper to prevent subjects from seeing the contents prior to rating.

The eight words were QUADRAT, QUANTIC, QUARTAN, QUINARY, QUINOID, QUINTAL, QUITTOR, and QUANDAM. Each word was presented initially on white 21.6 cm x 27.9 cm paper with 14 distractors, all in various orientations but none of which were completely reversed (see Appendix A). All words were presented individually on 8.3 cm x 18.8 cm yellow cards, also typeset in capital letters approximately 1.5 cm high.

Procedure

Experiment I

Subjects were seated at a table with the eight odorants arranged in a row in front of them. An instruction sheet at their seat read as follows:

> Rating Instructions
>
> In front of you is a set of odours arranged in an irregular order, left to right. Your task is to tell how <u>intense</u> they seem by checking the appropriate category in the list below.
>
> We have generally found that results are most consistent if you don't spend much time in making your rating - first impressions seem to give us the most information. This is the procedure we'd like you to follow:
>
> Beginning with the vial on your left, unscrew the top, close your eyes, and try to get a good impression of the general quality and intensity of the odor. Replace the cap and quickly write down your rating. It is very important that you do not spend a lot of time with any one odor, so as soon as you have made your rating, go on to the next odor in the series until they have all been assessed.

Places for twelve ratings were included on the sheet where subjects could indicate that the odor was very weak, weak, moderate, strong, very strong, or no odour at all.

The experiment was conducted in a screened-off section of hallway approximately 5 feet from a door leading outside. The experimenter sat acrcss a table from the subject with her back to the door. A fan and a timer were also on the table; the fan blowing out the open doorway. The timer was set to emit an audible tone every fifteen seconds. The three test vials were arranged behind the fan, out of the subject's sight. After the subject had read the above instructions, the experimenter added the following:

> Your ratings will be timed to ensure that each odor gets equal consideration. I will turn on the timer now to show you how we want the ratings done. After I tell you to start, take the first vial on your left and wait for the first tone from the timer. Then open it, take a sniff, replace the cap, and make your rating. Then replace the vial in the same position and take the next one. Do not open it until you hear the next tone.

The experimenter then demonstrated the procedure with two empty vials and asked the subject if she had any questions. When the experimenter was satisfied that the subject understood the instructions, the ratings were begun. As soon as the ratings were completed, the experimenter took the subject's rating sheet, brought out the test vials, and added the following instruction:

> I have three more vials here which have the same smell as three of the vials in the set you just rated. When I give you one, wait for the first tone, open it, and take a sniff. Then point to the position you think the odor was in. You will be given each odor to smell when you hear the tone.

The recall instructions were timed so that the first test vial was inspected approximately 30 seconds following presentation of the last odorant in the initial sequence. The test vials were then presented to the subject prior to each successive tone. The experimenter recorded each subject's responses.

Experiment II

Essentially the same procedure was followed as in the earlier study. The vials were replaced with eight cardboard folders arranged in a sequence from left to right, and the written instructions were as follows:

Instructions

> In front of you are eight folders. Inside each folder is a sheet with a number of words on it. The beeping you hear is a timer. Your task is, on the beep, to open the folder and find a <u>seven</u> letter word that begins with QU. When you have <u>found</u> it <u>close</u> the folder and draw a line on the blank page in front of you indicating in what orientation the word was on the sheet. Put the folder back in its original position on the desk, pick up the next folder and wait for the next beep. Then on the beep go through the above procedure again. Do this until you come to the end of the folders. Before beginning I will demonstrate the procedure for you.

After the demonstration subjects were cautioned to count the number of letters in the word since there may be other words beginning with QU. When the "orientation task" was completed, the experimenter told the subject that he would be presented with three of the words used as targets and that he should point to the folder he thought it had appeared in. The words were then shown to the subject on each tone of the timer as above.

Design and Analysis

Apart from the differences in stimuli used, the inspection sequences and test orders for Experiments I and II were identical.

Each subject was tested for recall of the position of 3 stimuli. This provided two different ways to assess retention: as a function of the position of the test stimulus in the inspection sequence and of the time between the last item in the inspection sequence and presentation of a given test stimulus. A design providing for a complete counterbalancing of stimuli, position and test order would have required 64 different inspection set-test combinations. To achieve 9 observations per cell, 576 subjects would therefore have been required.

Instead, 72 different sequences of stimuli were generated. Because the study was primarily concerned with how recall varies as a function of the position in the sequence being tested and of the time since the last item in the inspection sequence, the positions tested were completely counterbalanced with respect to test sequence; each position was tested 9 times in the first, second and third tests. Each of the 8 stimuli occurred 9 times in each position of the inspection sequence and consecutive testing of consecutive positions in the inspection set was avoided, occurring once for 8 of the subjects.

Counterbalancing of position in the inspection sequence and test order with 9 observations per cell meant that, for any given test, each odorant could not be presented an equal number of times in each position. The confounding of odorants and positions being tested was reduced to a minimum within each test by having each odorant appear once in seven different positions and twice in one position. No two odorants appeared twice in the same position within a test and the same organization of odorants and positions was employed for each test. To control for any possible effects due to the ordering of specific odorants in the inspection set, an attempt was made to equalize the number of times any two odorants appeared consecutively. Of the 56 possible pairs, 48 occurred 9 times and 2 pairs each occurred 7, 8, 10 and 11 times.

The testing of each subject at only three of the 24 combinations of position and test order restricted the type of analysis which could be employed. Subjects were treated as a fixed factor[3] with 72 levels in a four-way factorial design (Subjects x Stimulus x Position x Test) which included the two-way interactions between Stimulus, Position and Test factors. The main dependent variable was based on the absolute value of the difference between the position the test stimulus had actually appeared in, and the subject's response. A correction for chance was applied to this difference since the average distance of their responses from the correct response, due to chance, would depend on the position being tested. Therefore this measure of subjects' errors was divided by the average distance between the correct response and all other alternatives.

In addition to the analysis of variance, Kendall's Tau was calculated for the degree of association between the dependent variable and the ordinal position being tested.

C. Results and Discussion

Table 1 shows the number of correct responses for each position on each test and Figure 1 represents the proportion of correct responses at each position, pooled over all three tests[4], for both experiments. Giving each correct response a value of "1" and each incorrect response a value of "0", none of the main effects or interactions reached a level of significance in either experiment when the ANOVA model used for this design was applied.

Insert Table 1 and Figure 1 about here

While the effects did not reach significance, it is clear that, with one exception, the tendency in the data is in the hypothesized direction; correct rsponses in both experiments were most frequent when the test stimulus had appeared in the last position of the inspection sequence, and in Experiment II the total number of correct responses declined over the three tests - especially between the first and second. The reason for the reversal in this latter pattern over tests for the odorants is not clear. Engen et al. (1973) found the hit rate in their short-term recognition study increased over 12 seconds following presentation of the memory set, but this (nonsignificant) effect had disappeared for tests at a retention interval of 30 seconds, approximately when the first test of the present study was begun.

The trend in the data toward a recency effect is also somewhat unusual in light of earlier studies on free recall of word lists. Delays of as little as 15 seconds, during which rehearsal was prevented, have been sufficient to make the effect disappear (e.g., Postman & Phillips, 1965; Glanzer & Cunitz, 1966).

Subject's responses were not evenly distributed over the 8 available choices. Table 2 shows the number of responses given for each position in the sequence and Figure 2 shows the ratio of correct resposes to the total number of responses given for each position.

Insert Table 2 and Figure 2 about here

It would appear that although subjects did not correctly identify the position of stimuli which had been presented in the first position more than would be expected by chance, they tended to avoid giving this response unless they were reasonably confident that it was the correct response.

The average corrected error rates for Tests and Positions are shown in Table 3. The average errors for males and females responding to odors were 0.77 and 0.84, respectively; for responses to words, they were 0.70 and 0.83.

Insert Table 3 about here

When the ANOVA model was applied to the main dependent variable, only two main effects (Position in Experiment I and Subjects in Experiment II) reached a level of statistical significance. None of the interactions were significant (see Table 4). The failure to find a significant main effect for Position in Experiment II suggests that the ANOVA model requred by the design did not possess sufficient power to demonstrate all of the factors which influenced subjects' responses.

Insert Table 4 about here

It is possible, however, that the use of an incidental test of recall also contributed measurably to the error variability in the data. Nevertheless, given the grounds for doubt about the power of the test employed, and the small values of the F ratios for the interaction terms in Experiment I, it seems likely that the main effect for Position found in the first experiment is real (see Figure 3).

Insert Figure 3 about here

The failure to find an effect for Stimulus is consistent with earlier findings. Thus, Engen & Ross (1973) failed to find any significant difference in either the familiarity or preference ratings of stimuli which were recognized and stimuli which were missed. Lawless (1978), using common household odors, found no significant differences in recognition performance from that obtained in a earlier experiment (Lawless & Cain, 1975) which employed single chemicals.[5] Excluding Stimulus from the present design increases its power and reveals a significant effect for Position in Experiment II (see Table 5). Excluding Stimulus from the analysis of the dichotomized data failed to produce any change in the significance of the remaining terms.

Insert Table 5 about here

One final observation of interest on the error data is the apparent presence of a primacy effect in Experiment II, as indicated by the lower error rate for the first position compared with the second position, which is absent in Experiment I. It may be that this reflects some difference in the ability or tendency of subjects to employ rehearsal in the two experiments, but the comparably low hit rates for the two stimuli make this type of explanation seem unlikely. It may be that whatever positional isolation is conferred on words appearing in the first position, is ineffective for increasing recall of associates to odorants.

The decay of information about the correct position of the tested stimuli indicated by these findings is further supported by the calculations of Tau for the association between subjects' errors and the position tested (see Table 6). The existence of a significant negative measure of association for the first test stimulus clearly suggests that positional information about both the odors and words was lost over the course of the inspection portion of the experiments but that some information still remained at the time of the first test.

Insert Table 6 about here

The low value of this measure of association, the fact that Tau failed to reach significance for the two remaining tests and the low number of correct responses for the last items in the inspection sequence all support the experimental hypothesis by indicating that very little positional information remained by the time of the first test and that what little was present was quickly lost over the course of the subsequent tests.

Because odor perceptions are not readily retrieved, it is not possible to directly compare recall of odor information with the present findings. However no evidence exists to suggest that recognition performance does not reflect the pattern of results which would be found with a recall task. Assuming that recognition performance does parallel what a recall task would generate, specifically, Engen et al.'s (1973) findings of no decrement in recognition performance for odors in short term tasks, then the present study confirms the pattern of results obtained by Davis (1977): that information associated to odors and odor information are not maintained and retrieved in the same manner. This raises the question of what associates of odors are responsible for the durability of recognition performance over time.

As Lawless (1977) has observed, the absence of an effect on recognition performance due to familiarity or preference, suggests that background associations between odors are less important in mediating this performance than associations within the experimental context. However, the results of the present study indicate that incidentally formed associations which would facilitate performance on a recall task are quickly lost. This suggests that recognition performance is mediated not by associations <u>within</u> the experimental setting, but rather by association <u>to</u> the experimental setting itself. Changing the setting between presentation of the memory set and test stimuli in a long-term recognition task might prove interesting in demonstrating the effect of this association.

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FOOTNOTES

1. Recognition performance, too, is presumably mediated by associates to odors which identify them as having been part of an initial memory set or discrete perceptual event.

2. Lawless & Engen (1977) found that labels for odorants could be generated fast enough to be used by subjects as mediators in a paired-associate task. In a sequence reproduction task run as part of a pilot for the present study, subjects, who were aware that a subsequent memory test would occur, were found who employed idiosyncratic verbal mediators for the ordering of the odorants.

3. Though the treatment of subjects as a fixed factor technically restricts the generalization of the findings to those participating in the two experiments, this is perhaps mitigated by the number of subjects employed.

4. The bounded region in Figure 1 corresponds to an estimate of the chance level of correct responses. The lower limit represents the number of correct responses due to chance on the first stimulus tested (1/8). If subjects actually knew their first two responses were correct, the number of correct responses expected due to chance on the final test would be represented by the upper limit (1/6).

5. Common household odors generally involve a mixture of several different molecules, in contrast to the use of single chemical substances. Since odor quality is presumably a consequence of some molecular attribute(s), the failure to find any difference in memorability between single chemical substances and mixtures again suggests that encoding of odor quality is "holistic" in nature.

TABLE I

Positional Distribution of Correct Responses

Experiment I: Odorants

	Position								
Test	1	2	3	4	5	6	7	8	Total
1	-	2	1	-	-	1	2	4	10
2	2	1	2	4	2	3	-	3	17
3	2	1	1	2	1	3	2	4	16
Total	4	4	4	6	3	7	4	11	
Proportion Correct	.15	.15	.15	.22	.11	.26	.15	.41	

Experiment II: Words

	Position								
Test	1	2	3	4	5	6	7	8	Total
1	1	1	2	2	1	5	1	5	18
2	-	2	-	1	3	1	1	2	10
3	2	1	-	1	-	-	2	3	9
Total	3	4	2	4	4	6	4	10	
Proportion Correct	.11	.15	.07	.15	.15	.22	.15	.37	

TABLE 2
NUMBER OF RESPONSES FOR EACH POSITION

Stimulus		Position 1	2	3	4	5	6	7	8
Odorants	*n*	10	17	24	25	42	38	30	30
	Proportion	.05	.08	.11	.12	.19	.18	.14	.14
Words	*n*	10	28	36	25	30	35	24	28
	Proportion	.05	.13	.17	.12	.14	.16	.11	.13

TABLE 3

POSITIONAL DISTRIBUTION OF MEAN CORRECTED RESPONSE ERRORS

Experiment I: Odorants

	Position								
Test	1	2	3	4	5	6	7	8	Mean
1	1.30	.73	1.14	.94	1.00	.59	.44	.60	.84
2	.86	1.09	.94	.39	.67	.79	.85	.41	.73
3	1.08	1.17	.69	.72	1.00	.74	.65	.70	.84
Mean	1.08	1.00	.92	.68	.89	.71	.65	.57	.81

Experiment II: Words

	Position								
Test	1	2	3	4	5	6	7	8	Mean
1	.79	1.25	.99	.61	.55	.39	.61	.35	.68
2	.92	.52	.84	.83	.56	.84	1.05	.67	.73
3	.76	1.25	.94	.89	1.17	.84	.56	.67	.87
Mean	.83	1.01	.92	.78	.76	.69	.74	.56	.75

TABLE 4

ANALYSIS OF VARIANCE OF CORRECTED RESPONSE ERRORS

Experiment I: Odorants

Source	*df*	*MS*	*F*	*p*
Mean	1	121.97	272.85	
Subjects	71	.45	1.01	
Test	2	.21	.48	
Position	7	.97	2.17	.05
Stimulus	7	.26	.59	
Test × Position	14	.20	.44	
Test × Stimulus	14	.12	.27	
Position × Stimulus	49	.36	.81	
Error	51	.44		

Experiment II: Words

Source	*df*	*MS*	*F*	*p*
Mean	1	112.07	404.28	
Subjects	71	.46	1.66	<.05
Test	2	.66	2.38	
Position	7	.51	1.85	
Stimulus	7	.15	.54	
Test × Position	14	.36	1.31	
Test × Stimulus	14	.20	.71	
Position × Stimulus	49	.25	.91	
Error	51	.28		

TABLE 5

ANALYSIS OF VARIANCE OF CORRECTED RESPONSE ERRORS WITHOUT STIMULUS FACTOR

Experiment I: Odorants

Source	*df*	*MS*	*F*	*p*
Mean	1	142.49	392.43	
Subjects	71	.47	1.29	
Test	2	.21	.59	
Position	7	1.10	3.04	<.01
Test × Position	14	.22	.62	
Error	121	.36		

Experiment II: Words

Source	*df*	*MS*	*F*	*p*
Mean	1	[illegible]3.41	532.83	
Subjects	71	.49	1.95	<.001
Test	2	.66	2.64	
Position	7	.52	2.09	.05
Test × Position	14	.40	1.58	
Error	121	.25		

TABLE 6

ASSOCIATION[1] BETWEEN RESPONSE ERRORS AND POSITION

	Test		
Stimulus	1	2	3
Odorants	- .30*	- .14	- .14
Words	- .28**	.03	- .16

*$p < .001$ **$p < .005$

[1] The measure of association used is Kendall's Tau.

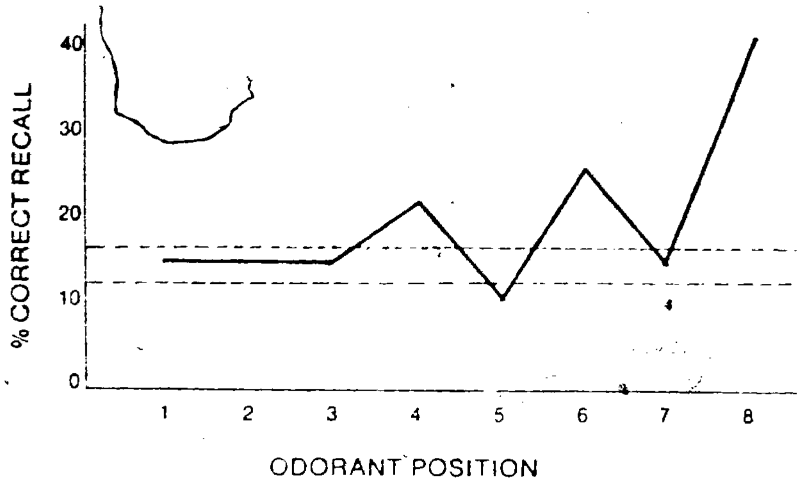

FIG. 1.(a) Mean percent correct recall of odorant positions.

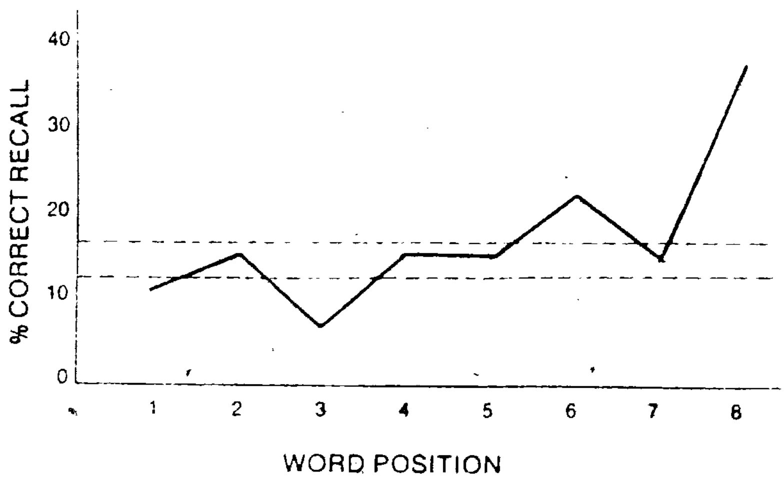

FIG. 1.(b) Mean percent correct recall of word positions.

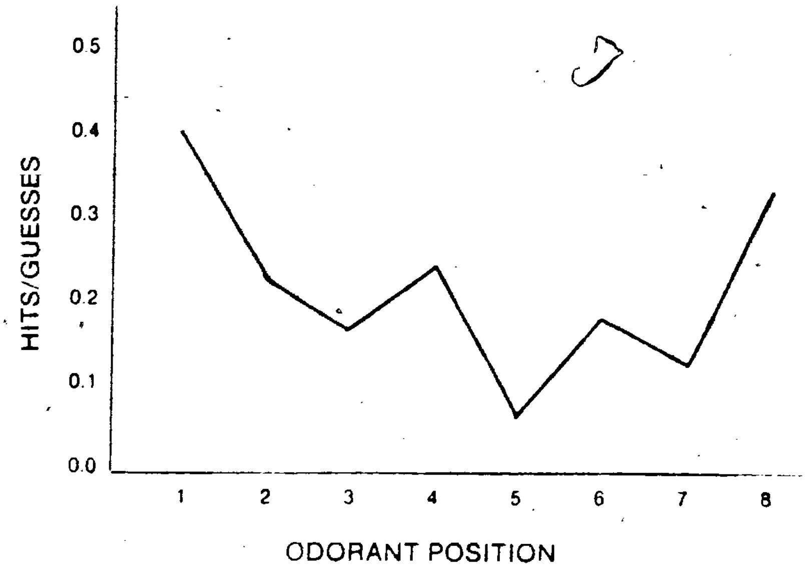

FIG. 2.(a) Proportion of correct responses to the total number of responses (Hits/Guesses) for odorants over all positions.

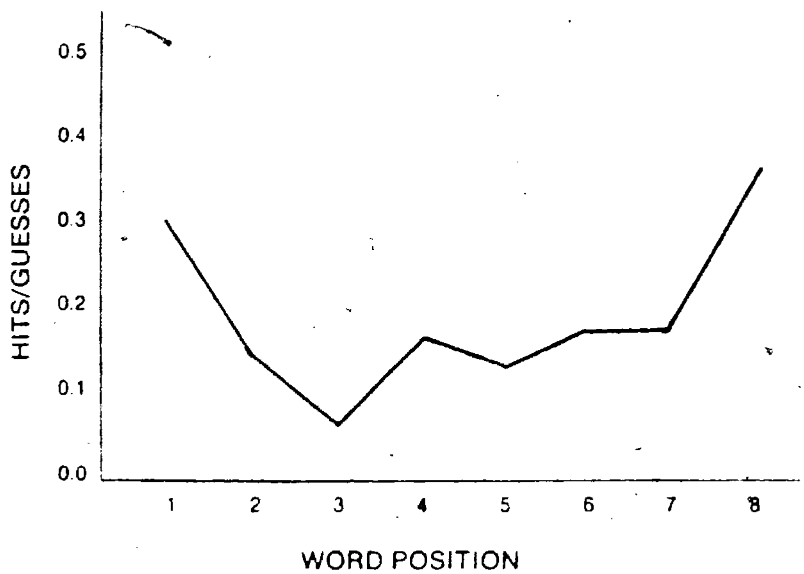

FIG. 2.(b) Proportion of correct responses to the total number of responses (Hits/Guesses) for words over all positions.

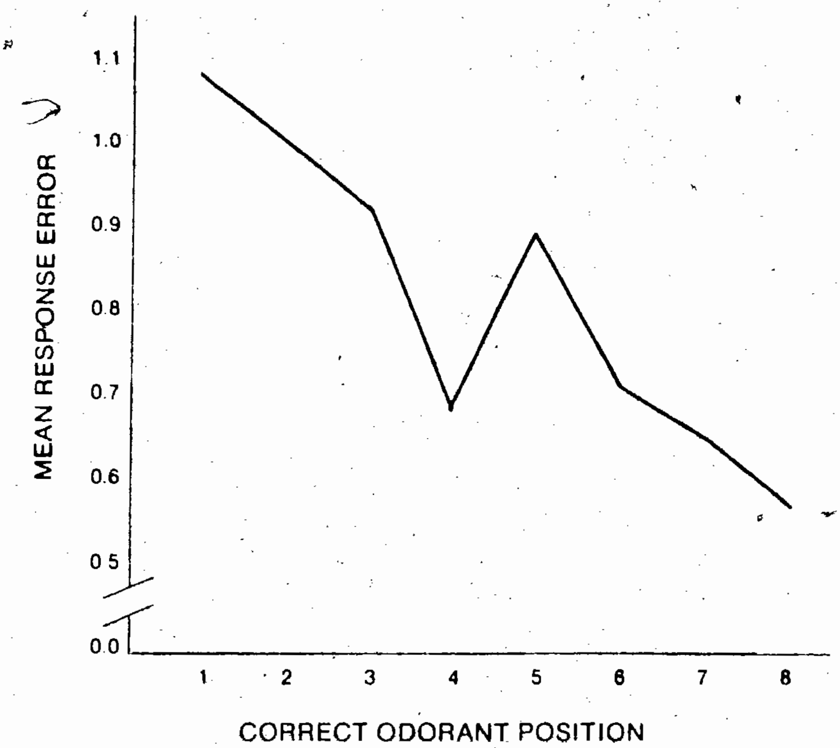

FIG. 3.(a) Mean corrected response error for odorant positions.

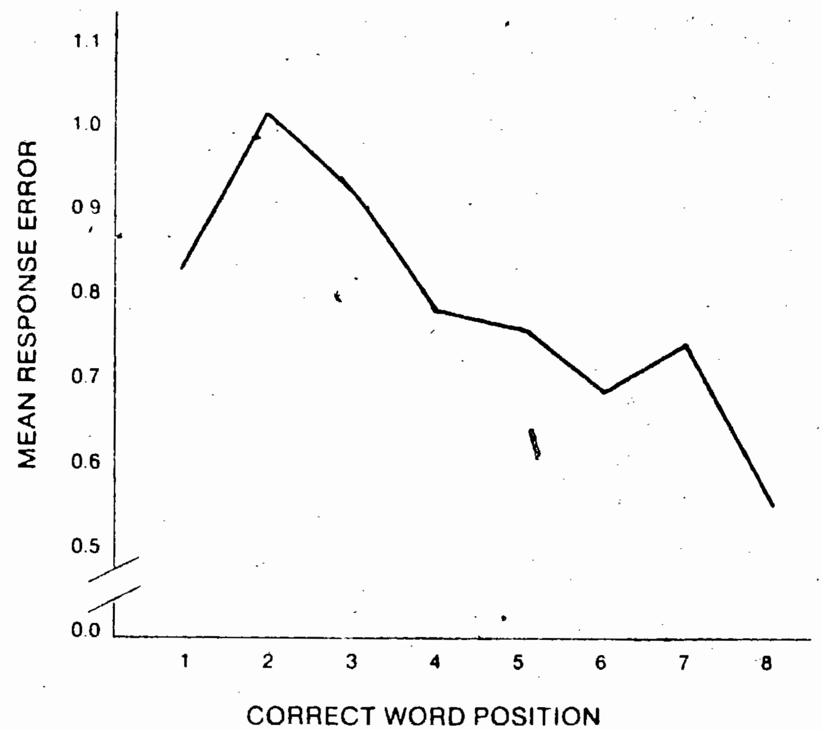

FIG. 3.(b) Mean corrected response error for word positions.

Appendix A

Stimulus Array Used in

Experiment II

BRADAWL

GREIGE

QUADRIVIAL

GUTTAPERCHA

FUMARIC

FUTTOCK

SULFONAL

BUTYRIN

CUSPIDATE

DUPERY

QUADRAT

DURMAST

QUATERNION

HUFFISH

CUTWORK