not included in the analysis of SCR. Subtracting S's E(SCR) from his O(SCR) score yields a measure of SCR corrected for random responding. Thus, for each S there were six corrected SCR scores, one for each trial. From these measures, the group's mean O(SCR) - E(SCR) score was derived for each trial. These mean group scores are listed in Table 2 along with the *t* values resulting from comparisons of the group's mean O(SCR) vs mean E(SCR) scores for each trial. The *t* scores in Table 2 indicate that the general increase in amount of O(SCR) - E(SCR) over trials ($F = 4.01$, $df = 5/75$, $p < .005$) was due to greater-than-chance clustering on Trials 4, 5, and 6.

Given reliable category clustering, the nature of the intrusion errors assumes additional importance. As Deese & Hulse (1967, p. 272) point out, if items arouse a common superordinate which, in turn, mediates clustered recall, then imported items should also be category members. The present results support such a prediction. Of the 73 intrusion errors committed, 56 items, or 77% of the total, were words which rhymed with the list items (e.g., BLACK, TWIRL, FED, FLEW). Nine of these 56 rhymed intrusions were also associates to the list items (e.g., CURL, WHIRL). The remaining 17 intrusions, while not rhymes, were phonemically similar to list words (e.g., PECK for PACK, FURROW for FURL) and none of these 17 appear as free associates to the stimulus items listed in Table 1.

In short, the present findings that words which rhyme but which do not elicit one another as free associates occurred together in free recall, and that intrusions shared category membership but not, by and large, associative relationships with list items support the contention that at least one instance of category clustering does exist as a phenomenon separate from associative clustering.

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NOTE

1. The assistance of Mrs. Cheri Schwartz in preparing materials, testing Ss, and aiding in the scoring of the data is gratefully acknowledged.

Table 2
Mean Item Recall and O(SCR)-E(SCR) Scores for Each Trial

Score	Measure	Trials					
		1	2	3	4	5	6
Item Recall	M	5.50	7.62	8.94	9.00	9.44	10.00
	SD	1.15	1.26	1.06	1.97	1.63	1.71
O(SCR)-E(SCR)	M	.22	.19	.33	1.01	.91	1.58
	SD	.71	.93	.97	1.57	1.50	2.12
	<i>t</i>	1.22	.83	1.38	2.59*	2.39*	2.98**

** $p < .01$

* $p < .025$

The effect of information feedback and reference tones on d' and L_x : A further analysis of Nash and Adamson's data

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A signal detection theory analysis of the data reported by Nash and Adamson leads to somewhat different conclusions. For example, sensory sensitivity (d') is not altered by feedback in the no-anchor condition. The analysis also reveals that Ss chose a conservative response criterion (large value of L_x) when confronted with a combination of no feedback and no anchor stimuli.

A recent study by Nash and Adamson (1968) is of considerable interest since it appears to be the first in which the effect of both knowledge of results and of anchor (reference) stimuli on detection thresholds have been studied simultaneously. Ss were required to distinguish tone plus white noise from white noise alone. Separate analyses of the resulting hit and false affirmative rates led the authors to conclude that feedback improved performance under all anchor conditions (none, weak, and strong). They also found better discriminability with the strong-anchor ("suprathreshold") accessory

stimulus than with the no-anchor (control) and weak-anchor ("subthreshold") stimuli. The weak anchor, in fact, was held to be without effect on sensory performance. The purpose of the present paper is to demonstrate that these conclusions may be extended and must be modified when the data are treated by signal detection theory.

The data of Nash and Adamson are valuable because they report both hit and false affirmative rates. This procedure makes it possible to determine when the experimental conditions influenced S's sensory sensitivity (d'), and when they influenced his response criterion (L_x). Signal detection theory (Green & Swets, 1966) treats S as a statistical decision maker who chooses a value of the likelihood-ratio criterion (L_x) to distinguish sensation from noise. The criterion reflects the psychological components of the traditional threshold, including the values and costs of right and wrong responses. Collection of these nonsensory factors in the form of the criterion measure makes it possible to isolate a relatively pure measure of sensory sensitivity, d' , which indexes Ss' accuracy, that is, ability to distinguish noise from signal-plus-noise. This method of analysis is

essential in experiments in which the variables under study may influence either the response criterion or sensory sensitivity. Although it is clear that signal detection theory nourished the thinking and guided the data collection procedures of Nash and Adamson, they stopped just short of computing values of d' and L_x .¹

The origins of the threshold changes associated with information feedback and with the presence of an anchor stimulus have been debated separately within the context of signal detection theory. Information feedback is commonly thought to improve sensory performance. However, Schoeffler (1965) argues that, according to the signal detection model, when feedback is provided it will occasionally conflict with S's observation causing him repeatedly to adjust his criterion; since greater criterion variability decreases d' , information feedback would impair performance. Examination of a number of studies in which the influence of an accessory or anchor stimulus on a test stimulus was investigated has led Treisman (1964) to surmise that alterations in S's response criterion (L_x) rather than changes in sensitivity are responsible for the threshold changes observed. This brief survey of the different views concerning the relative influence of sensory sensitivity and response criterion on S's threshold performance illustrates the need to interpret the data of Nash and Adamson in terms of d' and L_x .

RESULTS AND DISCUSSION

Table 1 shows the hit and false affirmative rates determined from Figs. 1 and 2 of Nash and Adamson's report. These response rates were used to estimate the values of sensory sensitivity (d') and likelihood-ratio criteria (L_x) which appear in Table 2. Since their results were averaged over Ss and statistical analyses were not presented, the following reinterpretation of their findings must be regarded as suggestive rather than final. Nash and Adamson concluded that information feedback improved performance over all three anchor stimulus conditions because in each case the hit rate increased. However, signal-detection analysis reveals that sensory sensitivity (d') was not increased with feedback in the no-anchor condition (Table 2) and that the increased hit (and false affirmative) rate was caused instead by a decrease in the value of S's likelihood-ratio criterion. The failure of feedback to influence d' when anchor stimuli are absent agrees with the results of Campbell (1965) and Clark and Rubin;² the latter found that feedback failed to alter the detection threshold for thermal stimuli in either 32 normal Ss or 32 psychiatric patients. The conclusion of Nash and Adamson that the performance of the strong-anchor group exceeds both the

Table 1
Response Data Read from Nash and Adamson's Figs. 1 and 2

Anchor	No Feedback		Feedback	
	Hits	False Alarms	Hits	False Alarms
None	.56	.24	.64	.30
Weak	.59	.31	.67	.27
Strong	.70	.20	.77	.19

Table 2
Signal Detection Theory Analysis of Data in Table 1

Anchor	No Feedback		Feedback	
	d'	L_x	d'	L_x
None	.9	1.3	.9	1.1
Weak	.7	1.1	1.1	1.1
Strong	1.4	1.2	1.6	1.1

control and weak-anchor groups is confirmed by the d' analysis. However, contrary to their conclusions the control and weak-anchor groups do not appear to be similar. There is some evidence that the weak-anchor stimulus without feedback decreases sensory sensitivity (d') relative to the no-anchor control, while with feedback it increases sensory sensitivity. An interaction between feedback and test stimulus intensity in the absence of anchor stimuli has also been found by Carterette, Friedman, & Wyman (1966), who showed that while feedback decreased sensitivity (d') for easily detectable stimuli, it increased d' for weak stimuli. These are interesting results, for it is not often that a presumably nonsensory variable (feedback) is found to interact with sensory variables.

In Table 2 it is apparent that S's response criterion (L_x) is largest in the no-anchor/no-feedback condition, and is also slightly increased in the strong-anchor/no-feedback condition. With feedback, L_x remains small and unvarying. The likelihood ratio for an ideal O in this experiment is $L_x = 1.0$, since the a priori probabilities of stimulus and blank are equal and the payoff matrix sums to zero. As is commonly found (Swets, Tanner, & Birdsall, 1961), the Ss in this experiment tended to set a conservative criterion under all conditions which reduced the proportion of yes responses, perhaps because the subjective cost of a false affirmative was too high. Under the feedback condition Ss tended to adopt a somewhat more liberal criterion (smaller values of L_x). Since Clark (1966) and Clark, Brown, and Rutschmann (1967) found that if S is relaxed and believes that he is performing well, he will lower his likelihood-ratio criterion, it seems likely that the feedback in the present experiment produced a reassuring effect. The finding that the most conservative criterion ($L_x = 1.3$) appears in the experimental condition

containing the least amount of both sensory and feedback information agrees with this analysis. The results obtained under the no-feedback condition are relevant to the conclusion of Treisman (1964) that anchor stimuli influence L_x rather than d' . The present results confirm the change in the response criterion. In addition, however, the results suggest that a "subthreshold" anchor may decrease sensitivity (d') to the test stimulus, while a "suprathreshold" anchor may increase sensitivity.

This reanalysis of Nash and Adamson's data demonstrates that, although collection of false affirmative responses in addition to hits represents a marked improvement over traditional psychophysical procedures, it is still necessary to compute values of d' and L_x . Only a signal detection theory analysis will reveal the subtle interplay between sensory and attitudinal variables which may occur when the intensity of the anchor stimuli and knowledge of results are varied simultaneously.

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NOTES

1. Correspondence with Nash reveals that values of d' and L_x were computed, but were not presented because the authors were concerned that certain assumptions of signal detection theory had not been met. Although this view may be justified, the present analysis based on hit and false affirmative rates which have been averaged over Ss seems reasonable. This approach illustrates the advantages of signal detection theory, but of course does not permit statistical evaluation of the differences in d' and L_x .

2. Unpublished manuscript.

3. This paper was supported in part by Grant No. FR05650-03.