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THE USE OF CUING IN TRAINING TASKS: PHASE III

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ABSTRACT

A review of the literature on the effects of training on the efficiency of sonar cue judgments shows that there are important gaps in our knowledge, particularly with reference to the effects of training on signals masked by noise.

The present study investigates three potentially trainable discriminations, the relative pitch, intensity and duration of pairs of signals embedded in noise. These are relevant to the active sonar cues for doppler, echo strength and echo length respectively. It is emphasised that no statement on trainability can be final until all methods reasonably likely to be successful have been investigated.

Following our previous work the present study compares three methods, (a) cuing, in which the trainee is informed just before each pair of signals what the correct response should be, (b) knowledge of results in which he gets the same information just after hearing the signals and making his responses, and (c) a mixed cuing/knowledge of results condition in which training begins with cuing and later transfers to knowledge of results. This last is of special interest because it has been suggested that cuing may be best in the early stages of practice and knowledge of results best later in training when the probability of correct responses is higher.

In previous work we have found differences between cuing and knowledge of results which could be attributed to changes in response criterion rather than real improvements in the trainees' sensitivity to signals. A method aimed at eliminating response criterion effects was used.

The results show that all three methods are effective for pitch and intensity judgments but that none is effective for judgements of relative duration. Training effects, although significant, are generally small and occur early in practice.

The results confirm the suggestion that previously found differences between cuing and knowledge of results are due to manipulation of response criterion rather than differential effects on sensitivity and they confirm the view that learning in these cases is best described by a simple associative model rather than a stimulus-response reinforcement model.

FOREWORD

Purpose

This is the third phase of an on-going program of research which is investigating means to improve the training of operational sonar personnel. The first three phases experimented with the techniques of cuing and knowledge of results (KR) on a range of auditory detection and discrimination tasks.

In the first phase of this program (Annett and Clarkson, 1964), cuing was found to be more effective than KR in an auditory signal detection task. However, this finding was not confirmed in the second phase (Annett and Paterson, 1966), in which KR resulted in a greater, though insignificant, increase in detections. The finding that cuing and KR result in different response effects was observed in both previous phases. That is, KR led to a more lax response criterion, resulting in an increase of false positives, whereas cuing resulted in more cautious behavior, shown by a decrease in errors (false positives).

In this, the third phase of the program, experiments were conducted on three variables believed to be important for sonar operators, namely, pitch discrimination, intensity discrimination and duration discrimination.

Results

Among the results discussed in detail in the report are the following:

1. Each of the three techniques of training, namely, cuing, knowledge of results and a combination of cuing and KR, resulted in improvement (over a control group using practice alone) for pitch discrimination and intensity discrimination.

2. None of the three training techniques improved duration discrimination.

3. All three training techniques resulted in essentially equal performance.

Implications

The results of this study are not yet applicable to sonar training. It is still necessary to continue this program of research using real sonar sounds.

This study has demonstrated that of the "trainable factors" in sonar operator performance (Gavin, Parker and Mackie, 1959), pitch discrimination and intensity discrimination are trainable. The lack of improvement from training in duration discrimination suggests that different training approaches for this variable (which is relevant to the sonar cue of echo length) should be investigated.

Since practice alone did not result in improvement on the tasks used in this study, while KR, cuing or a mixture brought about essentially equal improvement, it appears that information about the stimuli is needed during training but that its timing shortly before (cuing) or after (KR) is not crucial.

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1. INTRODUCTION

1.1 Trainable Factors.

In a report "Trainable Factors in Sonar Performance" Gavin, Parker and Mackie (1959) identify nine types of discrimination believed to be basic to sonar performance and the first three of these are pitch, intensity and duration. These are particularly relevant to the active sonar cues, as doppler, echo strength and echo length. Gavin et al. comment that all these discriminations are commonly made against a background of noise and that very little was known, at that time, about the effects of training on these discriminations under characteristically noisy conditions. Basic experimental work was therefore required on the noise-masked differential thresholds for pitch, intensity and duration.

In a more recent review "Accuracy and Consistency of Judging Active Sonar Classification Cues" (Abrams and Klipple, 1965) the authors refer to the "continuing need for further study on the trainability of cue judgments" ..... "It is doubted whether much improvement in the proficiency levels of audio cue judgment can be attained using the present methods of training. A need for research on training methods is apparent."

The present authors have recently reviewed the literature on training for various kinds of auditory detection and discrimination (Annett and Paterson, 1966) but a few additional studies have appeared since that report went to press, hence a brief resume updating that review is in order.

1.2 Pitch.

This is the most studied dimension and doppler, its equivalent in sonar is probably the most studied sonar cue (see Abrams and Klipple) also (Lawson, 1965). In the last year's review we noted the earlier work already summarised by Gibson (1953). Although there are many difficulties in interpreting the earlier work due to recent changes in approach to discrimination and detection problems the evidence was that pitch discrimination was trainable if some form of feedback was used. Campbell and Small (1963) in a recent study produced improvement with knowledge of results (KR) but found that KR was not particularly helpful given early in practice (a point taken up in our experiments). Heimer and Tatz (1966) followed up this and improved on the procedure used by Campbell and Small finding significant effects of training but with KR not significantly superior to simple unaided practice. Training was highly specific to the standard frequency used and some negative transfer was found between different frequencies. Heimer and Tatz correctly point out that work so far has failed to throw appreciable light on the nature of the learning processes underlying this "sensitisation" resulting from practice.

In their review Abrams and Klipple summarise findings on doppler, a **principal** component of which is pitch discrimination. Doppler judgments are not generally subject to marked training improvements. In a second report on active cue judgments, Klipple and Abrams (1965) suggest that the accuracy of doppler judgments might be improved by training for better definition of response category boundaries. Lau (1966) has recently found substantial improvement in doppler judgments as a result of 7 hours drill with interspersed summary KR. The simulated signals used included variations in intensity as well as frequency. O'Hanlon, Schmidt and Baker (1965) in an investigation of the effects of prolonged watchkeeping on doppler discrimination used a device for providing knowledge of results as an "alertness indicator." They found no decrement, contrary to earlier findings, and found that with the "indicator" detections were 16% higher and even improved during the watch.

1.3 Intensity.

The study by Annett and Paterson (1966) seems to be the only recent contribution to this topic. Early work by Knudsen (1923) and Riesz (1928) is summarised by Licklider (1951). Annett and Paterson found a highly significant improvement in intensity discrimination with four hours of practice with KR. Klipple and Abrams in the report, referred to above, devoted "a small amount of time" to training echo strength cue discrimination. Accuracy did not improve with training given and this was also true of echo length.

1.4 Duration.

Although there is an extensive literature on time discrimination (Woodrow, 1951) there seems to be little if anything directly relevant to the trainability of differential thresholds for the duration of pairs of signals. Duration is, of course, involved in the echo-length cue.

1.5 Trainability.

Our previous report also contained a fairly long discussion of the question of trainability referring especially to the limited varieties of training techniques used. Two points worth re-emphasising are that a negative result may simply reflect the use of an inadequate method and that by submitting the training variables to closer scrutiny one would hope to achieve both useful practical procedures and some insight into the mechanisms of learning. In the present study we are concerned, as before, with two techniques, cuing and knowledge of results. In the present experiments we have attempted to reduce these to the minimum essential differences, that is, whether the trainee gets information before or after he hears the signal. We have deliberately aimed to exclude all other complicating conditions which might lead to differences in training performance.

The state of the literature has not much improved since the report by Gavin et al. (1959).

Frequency discrimination has been fairly extensively studied both in "laboratory" form and as doppler and improvements have been found but the mechanism of learning is still obscure. In the two most relevant studies KR has not come out quite as well as might have been expected. Intensity discrimination has been subject to little study but there has been one positive finding with KR. Finally there is virtually nothing on the improvability of judgements of the duration of auditory signals. Thus there is ample room for further investigation along the lines suggested by Gavin et al.

The report describes three experiments, one concerned with each of the three discriminations, pitch, intensity and duration. In each experiment three training conditions are compared.

In previous work (Annett and Clarkson; 1964, Annett and Paterson, 1966) we have found systematic differences between these training methods for both detection and discrimination tasks, which could be interpreted as changes in response criterion rather than sensitivity. In detection tasks where the subject is allowed to respond at any time and as often as he likes, KR serves to increase detection mainly by increasing response rate, and hence the false positive rate, whilst cuing increased detection without increasing response rate or false positive rate. In a discrimination experiment, subjects allowed a middle (no difference) category, tended to use this less after KR and more after cuing training. In the present experiments we have attempted to eliminate these factors by using a fixed response rate and a two-alternative forced-choice technique. Then the only remaining difference between cuing and KR is whether information about the correct response precedes or follows the response.

2. THREE EXPERIMENTS ON DISCRIMINATION TRAINING

2.1 Choice of Stimuli.

For each of the three discriminations there is a wide choice of stimuli which might be used. Reasons for choosing these particular stimuli need, therefore, to be given.

All stimuli are presented in pairs, a standard followed by a variable stimulus. The stimuli are 0.5 sec. pulses of pure tone separated by a 0.5 sec. empty interval. These are suitable for discrimination experiments and at the same time bear some resemblance to the ping and echo of active sonar. There are no reverberations present.

Stimulus levels are in the 50 db range but, in accordance with the aims of the project, are heavily masked with white noise. We chose levels of noise in which the pairs of signals were perfectly detectable but the noise was loud enough to affect discrimination compared with noise-free signals and loud enough to be a prominent subjective feature of the task without getting too uncomfortable.

Next there was the choice of the range of signals. Harris (1948) has shown that little is lost by using 5 instead of 7 values of the variable in establishing differential thresholds. For these experiments we used only 4 values, two above and two below the standard. We were not interested in establishing complete threshold curves but only in demonstrating changes in the discrimination of near-threshold differences. By reducing the number of values of the variable to a minimum, we were able to collect more data on potentially improvable discriminations and this seemed an economical procedure.

2.2 Choice of Method.

We chose the frequency method. The method of limits used by Heimer and Tatz (1966) for pitch discrimination is less efficient and special steps have to be taken to control for serial effects. Pairs of stimuli are presented the second being higher or lower in pitch, louder or softer, or longer or shorter than the first (in experiments I, II and III respectively). The order of presentation is randomised within each 100 pairs, each of the four differences being represented 25 times.

For responses we chose the two-alternative forced-choice technique. In our previous report on intensity discrimination we had used a middle category (same) and found that one group (cuing) tended to use this increasingly. That is to say they appeared to get progressively more cautious as a result of training. Since this would obscure any genuine "sensitisation" which might occur, we eliminated this response category in these experiments and in this way eliminated the variable of risk and caution which appeared to contribute to differences between training groups.

2.3 Response Recording.

Responses were recorded on a modified Pressey punch board. A sheet containing a matrix with rows representing item numbers and columns representing the two alternative choices was attached to an aluminium sheet in which holes had been bored. Subjects pressed with a ball-point pen at a point indicating their choice for a given item (e.g. higher or lower) and in the case of a correct choice the pen pierced the paper. This provided knowledge of results and a complete record of performance during training and testing. Under test conditions both choices were bored out so that a record was left without giving subjects KR. Subjects recorded their judgements within a few seconds of hearing the stimulus pair thus KR was almost immediate.

For the cuing condition advance information was given by the simple expedient of having subjects work one trial ahead. They were required to make a random guess in the interval between pairs of signals and from the result learned the direction of the difference between the two signals they would hear next. This was done a few seconds before each signal pair.

The records thus obtained were translated first to a standard form and later to punched tape for processing.

2.4 Procedures for Obtaining Training and Test Material.

All sounds used were generated electronically, the white noise by a Dawe white noise generator and the signals by a specially gated Marconi AF oscillator. All outputs were monitored on a Marconi sensitive valve voltmeter. The gating and pulse shaping s achieved by the use of a square wave generator on which the A.C. signal was imposed, the D.C. component being later removed. This eliminated transients and gave negligible rise and fall times. Three Racal Counter Timers were used to trigger the signal generator, giving the three precisely measured intervals (two signals and one interval). These instruments are accurate to ± one millisecond when used as timers. One of these instruments was also used as a frequency meter to monitor the oscillator output to an accuracy of ± 0.1 Hz.

The signals were recorded on a Tandberg two channel recorder with signals on one track and noise on the alternate track. The signal and noise levels to be used in each experiment were selected by trials with a small number of subjects. First the noise level was set at a not-too-uncomfortable level about 50 db. Next, signals were introduced and increased in strength until each pair could be reliably distinguished against the masking noise. Third, differences between standard and variable were varied to obtain levels at which performance was slightly better than chance. In general, subjects began training with a performance level of between 50% and 60% correct. All signal levels were monitored on the sensitive valve voltmeter both during recording and playback.

2.5 Training and Testing Schedules.

For each experiment enough tapes were prepared for one ½ hour pretest and three hour-long training and testing sessions. Signals were presented at the rate of 400 per hour in four blocks of 100, each block being subdivided into blocks of ten. Within a block of 10 subjects received a pair of signals at intervals of seven seconds. This was quite a fast rate of work, in fact almost twice the rate used in the comparable experiment previously reported. However, we found subjects could keep up and were happy working at this rate. A longer interval was introduced between blocks of 10 and the block number was announced. This eliminated the necessity for identifying each item verbally and in fact nobody lost their place or missed a signal with this technique. Since KR was provided by the punchboard tape time was saved by not having verbal announcements after presentation. Between blocks of 100 there were longer rest pauses and subjects could remove or readjust their headsets. Blocks of 100 alternated training and testing. The pretest also constituted one block of 100. Each of the three subsequent one-hour sessions consisted of 100 training, 100 test, 100 training and 100 test presentations.

For condition (1) KR and (2) cuing training was carried out as appropriate. For condition (3) day 1 training was as for cuing, day 2 consisted of 2 blocks of 50 and one block consisted of 50 cuing and the other 50 KR trials (interspersed with testing) and day 3 of training by KR. These conditions held for all three experiments, the only difference being the nature of the stimulus material and the nature of the discrimination required.

2.6 Experimental Setup and Subjects.

Three subje s at a time were tested in an acoustically shielded room, three separate outputs having been provided for the tape recorder. The experimenter (L.P.) was present throughout all training and testing sessions to provide instructions and to monitor the equipment and the subjects' performance. It was particularly necessary to ensure that under KR and cuing subjects used their punchboards correctly. This was ensured by demonstration and by constant monitoring. No confusion was detected and subjects, having made the first response fall into line with the rhythm of the experiment and did not depart from the required procedure.

Subjects were all volunteers from the student body and from a similar group of pupils at Kingston High School. They were paid at the rate of 7/6d. per hour. Before the pretest all subjects were screened for hearing loss on a Peters audiometer. Those with a loss greater than 5 db were rejected and in some cases referred for medical advice.

2.7 Training Conditions.

For all three discriminations we were primarily interested in three training conditions, (1) knowledge of results in which subjects listen, record their judgment and are immediately given KR by means of the Pressey punch-board, (2) cuing, identical to the first except that by working one step ahead on the punch board, subjects know a few seconds in advance the direction of the difference they will hear (whether for pitch, intensity or duration) and (3) a mixture of these two conditions in which the early stages of training are conducted by cuing, in the middle KR and cuing alternate and in the final stages KR alone is given.

The choice of the first two conditions is partially justified in our earlier reports where we have found systematic differences between cuing and KR. In the present series of experiments, however, we are specifically trying to eliminate the differences we have found, by manipulating the variables which we believe contribute to these differences. In short we are hoping to demonstrate that the differences are in a sense procedural artifacts and that auxilliary information given at or near the time of the signals to be discriminated will have a training effect.

In the detection experiments, it will be recalled, KR led to an apparent relaxation of response criterion which might be due to the necessity for frequent (positive) response <u>in order to obtain information</u>. Thus it might be argued that the difference between cuing and KR might be due to an enforced practice habit rather than directly to the nature of the information provided. In the intensity discrimination experiment when KR proved superior to cuing systematic performance changes were found in the opposite direction for the two conditions whilst the net result was that under KR subjects improved and under cuing they did not. This appeared to be due to the increased use of the middle category by subjects under cuing and the reverse under KR. Again this could be a difference in style of performance rather than a genuine difference in sensitivity. For the present experiments, therefore, we have specifically chosen a technique which eliminates these differences. Response rate is, of course, completely controlled and the middle response category is excluded by the two alternative forced choice technique. We have thus reduced the difference between cuing and KR to the only essential distinguishing characteristic, namely whether the subsidiary information is provided <u>before</u> or <u>after</u> the presentation of stimuli and the subject's response.

According to R.B. Miller (1953) and other writers this is the essential difference since learning in the latter case takes place by reinforcement of unaided correct responses whilst in the former case cuing can act as a crutch to performance and the subject may learn nothing. Our basic hypothesis is that reinforcement does not adequately describe the mechanism of perceptual learning and that the simple pairing of stimuli with subsidiary information concerning their nature is enough to ensure that whatever learning can occur will occur. True we have found differences between cuing and KR but these are not crucial to the basic hypothesis. We therefore predict that when the difference between these conditions is reduced to "before or after" with close contiguity of stimuli and associated information in both cases (a) subjects will learn and (b) there will be no difference in rate or extent of learning.

The third (mixed C/KR) condition was added for different reasons. Supposing our hypothesis to be wrong and that corrected guessing on the reinforcement model to be the actual mechanism of learning, it could be argued that KR in the initial stages of training is not too effective, if only because the subject is wrong much of the time (in our case about 45% of the time). This has been suggested by Campbell and Small (1963) to account for the unsatisfactory performance of subjects receiving KR early in training in their experiments. Going back to early studies of guidance vs. trial and error learning in the rat (Carr (1930), Waters (1930)) it has been shown that a small amount of guidance (analogous to cuing) early in training is beneficial but that guidance continued too long is detrimental. Thus an optimal training technique could be guidance (or cuing) followed by KR. For this reason it was highly desirable to try out this technique, cuing followed by KR, which could potentially give a better result than either alone. In the previous report we have criticised earlier work concluding that auditory discriminations are not trainable on the grounds that not enough potentially effective techniques have been tried. Thus the mixed C/KR condition is an important addition to our experiments.

2.8 Control Groups.

Our first hypothesis, that there is no difference between KR and cuing training where the number of responses is fixed and a 2-alternative forced choice procedure is employed, may be tested by a simple comparison of these two conditions. The second hypothesis that the mixed KR/cuing procedure is not superior to either, requires only another simple comparison. In the event of significant differences being found between any of the conditions, no further controls are needed (Case 1). In the event that all three methods are equally ineffective again, no further control is needed (Case 2). However, in the event that all three methods give a significant training effect but there are no differences between methods one would require some additional reassurance that this effect was due to the training methods and not simply to some general effect such as habitat to the experimental conditions (Case 3). As it turned out one of our experiments (duration) resulted in no training effects (Case 2), and two (pitch and intensity) resulted in equivalent training effects for the three methods (Case 3), so we subsequently ran some subjects under a fourth "control" condition in which they were exposed to the stimuli and made responses in the normal way, but did not receive training in the form of cuing or KR. We did not include these controls in the original design since in two of the three possible outcomes of the experiment this would have been an unnecessary waste of subjects and experimental time. The second consideration was that the "no training" control procedure was likely to be extremely boring for the subjects and there was some danger that training effects might be masked by vigilance decrement.

3. EXPERIMENTAL RESULTS

3.1 Pitch - Experiment I.

Stimulus materials were devised as described in an earlier section. As a result of preliminary experimentation it was decided to use two values of the variable ± 2 Hz and ± 3 Hz with the standard at 1000 Hz. These values at a sound pressure level around 50 db gave initial accuracy scores of just better than 50% for ± 2 Hz and nearly 60% for ± 3 Hz.

60 subjects drawn from the student body were used, 20 being allocated at random to each of the three training conditions. Subjects attended for 3 days in succession at the same time each day having taken the pretest some days before. Following the main experiment 9 further subjects were tested in a control condition, responding actively but without benefit of KR or cuing.

3.1.1 Results.

Table 1(a) shows mean % correct judgements for the three training groups (cuing, KR and C/KR) and the control group. Each cell for the three training groups, represents 100 responses from each of 20 subjects, and for the control group, 100 responses from each of 9 subjects. The first column shows the pretest score taken some days before training and column 1.1 etc. represents the first test on day 1 and so on. Column 3.2 the second test on the third day, is taken as a posttest and the final column shows the pretest-posttest gain.

On the pretest, all groups were performing a little better than chance and the gain over 3 days training is about 10% for the 3 training groups and about 2% for the control group. Tables 1(b) and 1(c) break down the result of the 3 training groups by size of the stimulus difference. Tables 1(d) and 1(e) give another breakdown by direction of the stimulus difference. Table 1(f) shows the results of a 4 factor analysis of variance (Winer 1962) carried out on the 3 training groups. Factor A, treatments, is not significant. Factor B shows a highly significant improvement with practice. Table 1(g) further breaks down the improvement with practice using the Newman-Keuls test for difference between all possible pairs of trials. The cells show difference in totals for all possible comparisons, and those marked asterisk are significant at $p < .01$. With one exception (1.2 to 2.1) successive tests show significant improvements up to the second test on day 2 and thereafter no further improvement.

Factor C, table 1(f), shows a significant effect of the size or the difference between standard and variable stimuli, 3 Hz being more correctly judged than 2 Hz. Factor D, direction of the difference i.e. the variable stimulus higher or lower pitched than the standard, is insignificant showing that there was no response bias.

Interactions are insignificant with the exception of B (practice) x D (discrimination of difference). When the variable is of lower pitch than the standard, improvement with practice is slightly greater.

Since all three training methods are equally effective, it is necessary to be sure that the training effects are not due to some single common factor such as repeated exposure to the material. In table 1(a) the mean gain for the no-training control group is much smaller than that of the other groups.

An analysis of variance in table 1(h) on all four groups, shows that the over-all differences between groups are not quite significant. However there is a significant interaction between training group and practice and this supports the assumption that the control group learned less effectively. An analysis of variance of subjects x practice for the control group alone, table 1(i), confirms that the slight improvement was insignificant. We can therefore attribute improvements in the three main groups to the training treatments and not to any common factor shared by the control group.

3.1.2 Summary of Results for Pitch.

(a) Training involving the use of supplementary information effectively improves noise-masked pitch discrimination.

(b) Exposure to the training materials, making responses but not receiving supplementary information does not in itself improve discrimination.

(c) The three means of presenting supplementary information, cuing, KR and mixed cuing KR are effectively equivalent.

(d) Effects of training occur early in practice.

(e) There is a tendency for judgements of stimuli of lower pitch than the standard to improve more.

3.2 Intensity - Experiment II.

As a result of preliminary experimentation the four values of the variable chosen were ± 0.2 db and ± 1.2 db in relation to the standard. As shown in **tables 2(a,b and c) these gave an initial accuracy of 54% for ± 0.2 db and 66% for ± 1.2 db, an over-all level of about 60%.**

Thirty subjects drawn from the same population were used in this experiment, 10 in each of the three training conditions. A further 6 subjects were later run on a no-training control group.

3.2.1 Results.

Table 2(a) summarises the results for the three training conditions and no-training control for the pretest and 2 tests on each of 3 subsequent days. The final column shows the mean gain between the pretest and the second test on day 3. Each cell represents 100 responses from each of 10 subjects in the training conditions and 6 subjects in the control condition. All groups score about 60% on pretest and the 3 training groups gain between 5.6% and 7.2% whilst the control group gain only 2.5%. The practice curve is somewhat irregular tending to peak at trial 1.2 test declining to about pretest level on trial 2.2 and rising again on trials 3.1 and 3.2. Tables 2(b) and 2(c) show the results for the 3 training conditions broken down for the small (± 0.2 db) and the large (± 1.2 db) differences between standard and variable. Tables 2(d) and 2(e) show the results for the variable more and less intense than the standard respectively. Table 2(f) shows the results of a 4 factor analysis and variance (Winer, 1962) on the 3 training conditions. Factor A, treatments, is insignificant. Table 2(g) further analyses the test results showing significant difference between pairs of scores. The asterisk designates differences significant at $p < .01$. Trial by trial improvement is irregular. A significant improvement over pretest level is reached by trial 1.2 and this is followed by a decline on trials 2.1 and 2.2 to the pretest level. A further improvement follows on day 3 to a level significantly above the pretest. In table 2(f) factor C is significant, the larger difference being discriminated better than the smaller. Factor D, the direction of the difference, is not significant showing no consistent bias towards judgments of "louder" or "softer". There is a quite complex pattern of interactions involving all four factors. B x C and C x D, A x C x D and B x C x D are all significant. The B x C interaction suggests that improvement is more marked with the larger than with the smaller stimulus differences. The C x D interaction indicates that correct judgments of "louder" are more frequent with larger differences and correct judgments of "softer" are more frequent with smaller differences. This is not so much a response bias as a tendency to confuse a bigger difference (in either direction) with the variable louder and small differences (in either direction) with the variable softer. The second order interactions A x C x D and B x C x D further complicates the picture. The subjects' tendency to substitute "louder" for "bigger" and "softer" for "smaller", is most marked in the KR condition. In the cuing condition, we get confusion of "louder" with "bigger" but not "softer" with "smaller" and for the mixed cuing / KR condition, no systematic tendency in either direction is observed. The B x C x D interaction links the effect with certain tests. The tendency for larger differences to be judged correctly more often when they are louder is consistent over time, but the tendency for more correct judgements of "softer" for small differences varies from trial to trial. These interactions are difficult to interpret and even less easy to explain. In general, they seem to indicate a tendency to confuse the larger differences with "louder", irrespective of the direction of difference and to a lesser extent to confuse small differences with "softer". but these tendencies are modified by training groups and by test sessions. Analysis of variance comparing the three experimental groups and the control group shows a significant difference at the 5% level and a significant interaction between treatment group and practice. When the three experimental groups are combined $F = 61.13$, $p < .001$ indicating the control group is different from the others. Table 2(i) shows an insignificant F when pretest scores are compared. We may conclude that the control group, unlike the experimental groups, does not benefit from practice.

3.2.2 Summary of Results for Intensity.

(a) Training involving the use of supplementary information effectively improves noise-masked intensity discrimination.

(b) Exposure to training materials involving actual responses but not supplementary information does not in itself improve discrimination.

(c) The three methods of presenting supplementary information, cuing, KR and mixed cuing/KR are effectively equivalent.

(d) The practice curve was distinctly irregular showing peaks on the first day, and on the third day.

(e) Training groups, practice, size and direction of difference all interact in a complex way suggesting that under certain conditions subjects are inclined to treat bigger differences as indicating that the variable was louder than the standard and to a lesser extent, small difference is indicating that the variable was softer.

3.3 Duration - Experiment III.

For this experiment standard and variable are identical in frequency and amplitude to the standard signal used in the first two experiments but the variable signal can be longer or shorter than the standard. Preliminary experimentation led to the adoption of ± 10 milliseconds and ± 15 milliseconds as the four values of the variable. The standard was precisely 500 milliseconds. This degree of accuracy in naive subjects seemed to us remarkably good and we were surprised at the small values we had to use to approach the chance level of performance. Blakely (1933) found times around $\frac{1}{2}$ second to be most accurately judged but reported a j.n.d. of about 8%. Our value would obviously be somewhat lower but according to (Woodrow 1951) very low values are found from time to time with individual subjects.

Thirty subjects from the same population were randomly assigned to the three training groups as before.

3.3.1 Results.

Table 3(a) shows the mean % correct judgments for the three training groups (10 subjects in each group), over seven test sessions, the final column being the difference between pretest and trial 3.2 representing final gain.

Tables 3(b) and 3(c) show the results broken down by the size of the difference between standard and variable and Tables 3(d) and 3(e) show the results broken down by the direction of the difference.

Table 3(f) shows the four factor analysis of variance on these results. It can be seen at a glance that none of the main factors and no interactions are significant.

Since none of the three training methods effected an improvement in performance there was no justification for using a no-training control group.

4. DISCUSSION AND CONCLUSIONS

A series of three experiments was conducted to assess the trainability of three auditory discriminations, pitch, intensity and duration. These had been identified by Gavin, Parker and Mackie (1959) as three "trainable" factors basic to sonar performance and, with the possible exception of pitch there was very little information on how thresholds were affected by training under conditions of masking noise.

Bearing in mind that one has to explore all reasonable possibilities before pronouncing a particular discrimination "untrainable" we chose to concentrate on three training methods we felt had some possibility of being successful, knowledge of results, cuing and a mixed condition beginning with cuing and transferring to KR.

Apart from the practical value of developing suitable conditions of training the experiment also represented an attempt to illuminate the nature of the learning mechanism. Heimer and Tatz (1966) recently commented that there is no satisfactory theory to account for changes in apparent sensitivity as a result of practice and training. This consideration was the major determiner of the method we used.

Most investigators in the field have, for one reason or another concluded that KR represents the best possible form of training and that cuing, whilst possibly useful initially acts as a prop to performance and gives relatively poor transfer to the criterion task. Differences between cuing and KR in the expected direction have often been found and we have found differences in previous experiments (Annett and Paterson 1966). We suggest, nevertheless, that in this type of perceptual learning at least, what matters is that the subject shall be exposed to the relevant signals and shall know at or near the time of exposure the appropriate response, i.e. the name by which it is called or the difference, its direction and extent. The learning process is likened to the collection of a sample of instances and non-instances of the signal to be detected or the difference to be discriminated thus forming a store for future comparisons. This can be done equally well by cuing or KR techniques, provided the KR is not too delayed.

We attributed the difference we had earlier found between these techniques to what could be called an artifact. The requirement to respond <u>in order to get KR</u> effectively induced a lax response criterion. Cuing, with no requirement to respond induced a more strict criterion. In this way we thought that the negative result with cuing in the intensity discrimination last year (Annett and Paterson 1966) could be an artifact. By using the 2-alternative forced choice technique the subject was permitted no discretion in the use of response criterion. He had to make his judgement one way or the other. The equal number of responses eliminated the problem of KR increasing response rates. Thus we eliminated the major differences between cuing and KR and were left with the simple distinction that information could be received before or after the stimulus and the required response.

The simple punch board ensured that KR was immediate and, as predicted, KR and cuing were found to be of equivalent training value. This result tends to increase confidence that the simple learning mechanism hypothesised is correct. The result particularly when compared with our earlier results also demonstrates that positive results with KR cannot be taken at face value as confirming the alternative reinforcement mechanism. Our previous experiments have shown that part of the effect of KR has nothing at all to do with learning.

The third mixed training condition is one which has frequently been suggested in the literature and it was therefore important to try it. A combination of cuing and KR could, in theory, have proved superior to either technique alone. As a general result in these experiments the mixed condition was the most popular with trainees. They seemed to welcome the change and felt that they were doing well. However, as has been shown, this has no effect at all on their performance. Had the mixed condition proved superior to both of the simple conditions our basic hypothesis would have needed modification. Since, under these rather special conditions the two were equivalent, a difference would have been most puzzling. However this proved not to be the case.

One should perhaps point out that with other types of cuing and KR (the accepted definitions are fairly broad) a mixture might still be superior. Our result, therefore, should not be interpreted too generally for the reason that actual techniques often differ in ways other than those implied under a strict definition.

Concerning the empirical findings on the "trainability" of noise-masked pitch, intensity and durations thresholds, we can say that the first two appear moderately "trainable" by using a. of the three methods. The improvements do not appear to be simply the result of exposure to the stimulus material or habituation to the experimental conditions but genuine effects of training.

In the case of pitch, most of the learning occured early in practice but in the case of intensity performance went up, then down again and finally up. We cannot guarantee that it might not have gone down again had practice been continued, but our previous experiment over a longer training period (Annett and Paterson 1966), suggests that there would be a continued tendency to improve. We are unable to isolate the cause of the poor performance on day 2. Apparatus artifacts can be ruled out since signals were continuously monitored in a sensitive valve voltmeter and, in any case, subjects were tested at different times, day 2 was not a "black Friday" common to all subjects. The results suggest that the intensity discrimination has a characteristic not, apparently, shared by the frequency discrimination. The interactions suggest that, under certain conditions, there was a tendency to judge bigger differences "louder" irrespective of the direction of the differences and a tendency to judge smaller differences as softer. Subjects were most carefully instructed and it was clear from the significant C factor that larger differences were, on the whole, judged more correctly. Nevertheless this curious result suggests subjects find some slight difficulty in isolating the relevant sensory dimension. The tendency to confuse magnitude of difference with absolute magnitude (intensity) seems not entirely unreasonable. This occured most markedly under the KR conditions, the only fact which has emerged from this series of experiments to distinguish KR from cuing. Its significance, however, remains obscure.

The third experiment in which subjects judged whether the variable was longer or shorter than the standard produced quite different results. It would be too simple to say that the duration discrimination is untrainable. True, the methods used successfully for pitch and intensity failed here but one must seek possible alternative explanations for failure.

The first point to be made is that, even on pretest, these subjects were extremely accurate (cf. Woodrow, 1951). Prior to the experiment we ran a number of subjects in trials using differences ranging from 5 to 55 milliseconds and found better than chance performance in some subjects for differences as small as 7 milliseconds. Following our negative result we ran 10 more subjects using a modified method of limits in which we went from large to small difference and then small to large, randomising the direction of the difference, and obtained the following values:

	+ 8m.sec.	+ 12m.sec.	+ 24m.sec.	+ 45m.sec.
% correct	55.2%	61.0%	63.6%	70.2%

This result justified our choice of values at ± 10m.sec. and ± 15 m.sec., to give an initial performance of between 50% and 60%. In fact, our subjects in the main experiments averaged ir ' '-tle less than this but the size of the differences used could be considered to be in the threshold region.

It might be said of our pretest results either that the discrimination was too difficult to permit learning or that our subjects were already performing at an asymptotic level due to prior practice.

To take the first suggestion. Comparisons with the other two experiments show that the mean level for the pretest was a little lower.

Nevertheless many subjects in the other experiments were performing as badly initially and managed to improve. We carried out correlations between pretest score and gain for all three training conditions in all three experiments.

	KR	C	C/KR
F	0.03	-0.45*	-0.08
I	-0.7*	-0.46	-0.83**
D	-0.25	-0.84**	-0.87**

* = $p < .05$
** = $p < .01$

The correlations tend to be negative, that is to say that subjects with the lowest pretest scores tend to improve most. We are therefore inclined to reject the argument that duration discrimination did not improve simply because the initial level of difficulty was too great.

The argument that we find duration "untrainable" because subjects were already performing at an asymptotic level has some plausibility.

People rarely, if ever, have to judge small time differences as such, but these differences were important cues to auditory localisation, implying an efficient mechanism for temporal discrimination somewhere in the auditory system. This cue is, however, seldom used explicitly or consciously. Several of our subjects reported spontaneously that they had difficulty in attending to the time difference. The irrelevant dimensions of pitch and intensity (always constant for both standard and variable in the experiment), were more readily perceived and subjects sometimes remembered they had difficulty in isolating duration as such (despite their rather high standard of performance). We cannot, therefore, be definite about the reasons for failure to produce training effects with the discrimination of duration. It seems likely that when subjects can concentrate on the duration of the signals their performance is good, perhaps because small time differences are a constantly used cue to the nature of the auditory world. On the other hand, it is rather more difficult to isolate duration as an independent dimension of the auditory stimulus than it is to isolate and attend to pitch and intensity. Possibly the kind of training most relevant to this dimension is that which calls attention to the duration as an independent dimension of the auditory stimulus.

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APPENDIX A

Tables of results referred to in the text

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING, N = 20	54.35	59.50	61.65	60.45	64.50	63.65	64.70	10.35
KR, N = 20	56.75	64.30	64.60	66.90	67.20	67.65	67.05	10.30
C/KR, N = 20	58.15	60.75	64.85	64.60	66.25	66.45	67.75	9.60
CONTROL N = 9	55.0	56.56	58.78	55.22	57.56	52.89	57.00	2.0

Table 1(a)

% correct responses in judgments of noise-masked pitch differences over three days practice.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	52.8	57.2	60.2	59.3	60.4	61.4	62.4	9.6
KR	55.8	61.7	60.7	64.6	63.6	64.8	63.4	7.6
C/KR	55.9	57.7	64.3	61.9	62.8	63.1	64.9	9.0

Table 1(b)

% correct judgments of pitch differences ± 2 Hz.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	55.9	61.8	63.1	61.6	68.6	65.9	67.0	11.1
KR	57.7	66.9	68.5	69.2	70.8	70.5	70.7	13.0
C/KR	60.4	63.8	65.4	67.3	69.7	69.8	70.6	10.2

Table 1(c)

% correct judgments of pitch differences ± 3 Hz.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	56.3	59.1	62.7	62.9	64.2	60.9	64.4	8.1
KR	57.3	61.9	63.1	66.1	66.5	65.1	65.4	8.1
C/KR	56.9	62.9	70.0	68.0	67.0	66.9	69.8	12.9

Table 1(d)

% correct judgments of variable higher pitch than standard.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	52.4	59.9	60.6	58.0	64.7	66.4	65.0	12.6
KR	56.2	66.7	66.1	67.7	67.9	70.2	68.7	12.5
C/KR	59.4	58.6	59.7	61.2	65.5	66.0	65.7	6.3

Table 1(e)

% Correct judgments of variable lower pitch than standard.

Source	SS	df	MS	F	p
Between subjects					
A	266.0	2	133.0	<1	NS
Subjects within groups	10759.4	57	188.76		
Within subjects					
B	1122.8	6	187.1	22.01	<.001
AB	62.6	12	5.2	<1	NS
B x subjects within groups	2908.7	342	8.5		
C	662.5	1	662.5	53.91	<.001
AC	9.4	2	4.7	<1	NS
C x subjects within groups	700.5	57	12.29		
D	7.6	1	7.6	<1	NS
AD	169.0	2	84.5	2.30	NS
D x subjects within groups	2094.8	57	36.75		
BC	43.7	6	7.3	1.25	NS
ABC	40.2	12	3.3	<1	NS
BC x subjects within groups	1995.0	342	5.83		
BD	114.2	6	19.0	2.2	<.05
ABD	142.3	12	11.8	1.4	NS
BD x subjects within groups	2959.4	342	8.65		
CD	3.0	1	3.0	<1	NS
ACD	14.7	2	7.35	2.17	NS
CD x subjects within groups	193.2	57	3.39		
BCD	99.2	6	16.5	<1	NS
ABCD	2484.4	12	207.0	<1	NS
BCD x subjects within groups	424645.3	342	1241.6		

Table 1(f). Four factor Analysis of Variance. Judgments of Pitch Difference.

A = Treatment groups
B = Training trials
C = Size of difference
D = Direction of difference

		Pretest	1.1	1.2	2.1	2.2	3.1	3.2
		1	2	3	4	5	6	7
Pretest	1		306*	437*	454*	568*	570*	605*
1.1	2			131*	148*	262*	264*	299*
1.2	3				17	131*	133*	166*
2.1	4					114*	116*	151*
2.2	5						2	37
3.1	6							35
3.2	7							

Table 1(g)

Significant differences between pairs of trials

(total scores) * = $p < .01$.

Source	SS	df	MS	F	p
Between subjects A	5093.86	3	1697.95	2.41	$< .10$ (for $p < .05$, $F = 2.76$).
Subjects within groups	45828.3	65	705.05		
Within subjects B	2601.93	6	466.99	14.29	$< .001$
AB	1192.10	18	66.23	2.03	$< .10$ (for $p < .05$, $F = 2.17$).
B x subjects within groups	12744	390	32.68		

Table 1(h)

Analysis of variance for the three training groups

and one control group.

Source	SS	df	MS	F	p
Between subjects	2790.9	8			
Within subjects	1312.9	54			
Treatments	203.3	6	33.88	1.47	NS
Residual	1109.3	48	23.11		

Table 1(i)

Analysis of variance for control

group alone

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING N = 10	60.3	63.9	64.7	59.8	59.8	62.3	67.5	7.2
KR N = 10	60.4	60.7	68.3	61.4	58.8	63.7	66.0	5.6
C/KR N = 10	60.0	62.4	65.8	61.8	61.2	64.1	65.8	5.8
CONTROL N=6	59.0	57.7	59.5	59.3	59.7	58.8	61.5	2.5

Table 2(a)

% correct responses of judgments of noise-masked intensity differences over three days practice.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	54.2	50.8	59.8	54.8	49.4	55.0	58.6	4.4
KR	55.6	53.6	55.8	54.2	50.6	52.4	60.2	4.6
C/KR	54.4	53.8	58.8	53.8	50.4	56.0	57.8	3.4

Table 2(b)

% correct judgments of intensity differences, ± 0.2 db.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	66.6	70.6	76.8	68.0	68.2	72.4	73.4	6.8
KR	65.0	74.2	73.6	65.4	69.0	72.2	74.8	9.8
C/KR	65.6	71.0	72.8	69.8	72.0	72.2	73.8	8.4

Table 2(c)

% correct judgments of intensity differences, ± 1.2 db.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	60.0	63.2	64.4	61.6	58.6	61.8	66.2	6.2
KR	61.2	63.0	73.0	64.2	58.2	64.6	67.6	6.4
'KR	62.0	60.8	69.2	59.0	60.8	64.2	64.4	2.4

Table 2(d)

% correct judgments of variable louder than standard

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	60.6	64.6	65.0	58.0	61.0	62.8	68.8	8.2
KR	59.6	58.4	63.6	58.6	59.4	62.8	64.4	4.8
C/KR	58.0	64.0	62.4	64.6	61.6	64.0	67.2	9.2

Table 2(e)

% Correct judgments of [illegible]iable softer than standard

Source	SS	df	MS	F	p
Between subjects					
A	1.229	2	0.614	<1	NS
Subjects within groups	352.968	27	13.073		
Within subjects					
B	331.414	6	55.236	10.174	<.001
AB	49.271	12	4.106	<1	NS
B x subjects within groups	879.458	162	5.429		
C	3380.030	1	3380.030	324.467	<.001
AC	0.152	2	0.076	<1	
C x subjects within groups	281.282	27	10.418		
D	9.858	1	9.585	<1	NS
AD	48.467	2	24.233	<1	NS
D x subjects within groups	950.853	27	35.217		
BC	108.229	6	18.038	3.429	<.005
ABC	26.714	12	2.226	<1	
BC x subjects within groups	852.343	162	5.261		
BD	54.767	6	9.128	<1	NS
ABD	74.833	12	6.236	<1	NS
BD x subjects within groups	1582.971	162	9.77		
CD	156.867	1	156.867	36.754	<.001
ACD	29.515	2	14.757	3.458	<.05
CD x subjects within groups	115.225	27	4.267		
BCD	103.991	6	17.332	3.607	<.005
ABCD	54.752	12	4.563	1	
BCD x subjects within groups	778.400	162	4.805		

Table 2(f) Four factor Analysis of Variance.
Intensity Difference.

A = Treatment groups
B = Training trials
C = Size of difference
D = Direction of difference

		Pretest	1.1	1.2	2.1	2.2	3.1	3.2
		1	2	3	4	5	6	7
Pretest	1		63	181*	23	11	94*	186*
1.1	2			118*	40	74*	31	123*
1.2	3				158*	192*	87*	5
2.1	4					34	71*	163*
2.2	5						105*	197*
3.1	6							92*
3.2	7							

Table 2(g)

Significant differences between pairs of trials

(total scores) * = $p < .01$.

Source	SS	df	MS	F	p
Between subjects					
A	534.92	3	178.31	3.36	$<.05$
Subjects within groups	1696.7	32	53.02		
Within subjects					
B	392.68	6	65.44	2.94	$<.01$
AB	984.96	18	54.72	2.46	$<.05$
B x subjects within groups	4272.95	192	22.25		

Table 2(h)

Analysis of Variance for the three training

groups and one control group.

Source	SS	df	MS	F	p
Between groups	10.53	3	3.51	<1	NS
Within groups	1207.0	32	37.72		

Table 2(i)

Analysis of Variance of pretest scores for three

training and one control group.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	52.8	52.5	50.7	51.2	54.0	51.9	54.1	1.3
KR	53.4	50.3	53.9	54.3	55.1	53.4	51.9	-1.5
C/KR	53.8	54.8	52.3	54.3	55.9	53.5	55.2	1.4

Table 3(a)

% correct responses of judgments of noise-masked duration differences over three days practice.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	52.2	54.2	52.0	51.0	56.0	53.6	52.4	0.2
KR	53.6	51.2	53.2	52.2	54.6	52.8	52.6	-1.0
C/KR	54.6	53.8	53.4	49.4	53.0	51.4	52.8	-1.8

Table 3(b)

% correct judgments of duration differences, ± 10 milliseconds.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	53.4	50.8	49.4	51.4	52.0	50.2	55.8	2.4
KR	53.2	49.4	54.6	56.4	55.6	54.0	51.2	-2.0
C/KR	53.0	55.8	51.2	59.2	58.8	55.6	57.6	4.6

Table 3(c)

% correct judgments of duration differences, ± 15 milliseconds.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	52.6	55.6	53.8	52.4	56.1	55.0	55.6	3.0
KR	58.4	53.0	51.8	55.6	54.2	53.6	50.6	-7.8
C/KR	55.4	55.6	51.4	54.4	58.0	53.0	56.8	1.4

Table 3(d)

% correct judgments of variable
longer than standard.

	Pretest	1.1	1.2	2.1	2.2	3.1	3.2	Gain
CUING	53.0	49.4	47.6	50.0	51.6	48.8	52.6	-0.4
KR	48.4	47.6	56.0	53.0	56.0	53.2	53.2	4.8
C/KR	52.2	54.0	53.2	54.2	53.8	54.0	53.6	1.4

Table 3(e)

% correct judgments of variable
shorter than standard.

Source	SS	df	MS	F	p
Between subjects					
A	28.692	2	14.346	1.156	NS
Subjects within groups	335.047	27	12.409		
Within subjects					
B	36.017	6	6.003	1.052	NS
AB	49.391	12	4.116	<1	
B x subjects within groups	924.378	162	5.706		
C	10.296	1	10.296	1.525	NS
AC	43.994	2	21.997	3.257	NS
C x subjects within groups	182.318	27	6.753		
D	68.001	1	68.001	2.183	NS
AD	20.817	2	10.409		
D x subjects within groups	841.074	27	31.151		
BC	49.679	6	8.280	1.391	NS
ABC	63.656	12	5.305	<1	
BC x subjects within group	9[illegible].308	162	5.953		
BD	28.107	6	4.685	<1	
ABD	109.300	12	9.108	<1	
BD x subjects within groups	1552.950	162	9.586		
CD	0.145	1	0.145	<1	
ACD	14.372	2	7.186	<1	
CD x subjects within groups	257.804	27	9.548		
BCD	63.531	6	10.589	1.526	NS
ABCD	78.377	12	6.531	<1	
BCD x subjects within groups	1124.021	162	6.938		

Table 3(f)

Four factor Analysis of variance of judgments of duration differences.

A = Treatment groups
B = Training trials
C = Size of difference
D = Direction of difference

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12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

The present study investigates three potentially trainable discriminations, the relative pitch, intensity and duration of pairs of signals embedded in noise. These are relevant to the active sonar cues for doppler, echo strength and echo length respectively. It is emphasized that no statement on trainability can be final until all methods reasonably likely to be successful have been investigated.

This study compares three methods, (a) cuing, in which the trainee is informed just before each pair of signals what the correct response should be, (b) knowledge of results in which he gets the same information just after hearing the signals and making his responses and (c) a mixed cuing/KR condition in which training begins with cuing and later transfers to KR.

The results show that all three methods are effective for pitch and intensity judgments but that none is effective for judgments of relative duration. Training effects, although significant, are generally small and occur early in practice.

The results confirm the suggestion that previously found differences between cuing and KR are due to manipulation of response criterion rather than differential effects on sensitivity and they confirm the view that learning in these cases is best described by a simple associative model rather than an S-R reinforcement model.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
CUING FEEDBACK KNOWLEDGE OF RESULTS TRAINING AUDITORY DETECTION AUDITORY DISCRIMINATION						