Title
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The Role of Feedback in Categorisation

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Abstract

The most popular theories of associative learning require some kind of external teaching signal, whether it be feedback on category membership or the presence of a US to determine whether a trial has been successful. However, under some circumstances (Bersted, Brown & Evans, 1969; Evans & Arnoult, 1967; Estes, 1994), it appears that such a signal is not required to produce accurate categorical decisions. The work presented here was motivated by Wills & McLaren (1998), which looked at Free Classification and demonstrated that human participants could accurately extract category structure with no feedback during the task. The current experiments compare performance on a generalisation task after training using one of a number of different conditions including Free Classification, allowing a comparison with participants who have had a teaching signal during training. The results seem to indicate that under some conditions, it is not feedback during training, rather the need for a decision to be made which is critical. The data also shows that there is no difference in accuracy between the ability of the groups to generalise, no matter what their initial training, rather the differences are manifested in the reactions times.

Introduction

There has been little work done on directly comparing performance on tasks where one group of participants receives feedback and another does not, as it seems intuitively obvious that if there is some external feedback, then this will aid rather than retard learning. The familiar notion that consistent feedback always produces the best performance (Homa & Cultice, 1984) can be challenged, however, with data showing that a teaching signal may not provide any advantage. Real world scenarios, where feedback may be absent, and theories of natural categorisation (Rosch & Mervis, 1975) seem to be in line with this idea. If we allow that reliable feedback is not always the key to success, then there must be other factors which participants are only able to take advantage of in some circumstances. Estes (1994) provides an experiment where two different types of feedback are compared. Observational training is the same as the Label condition described later in this report, where a label is provided with the stimulus and denotes which category it belongs to, with no decision being made by the participant.

This is compared to standard training, which has corrective feedback after a decision has been made about the category membership of a given stimulus by the participant. In Estes' study, the observational training was found to be more effective than the standard training on test, and it was deduced that the observational training was more consistent with the participants' perception of the categories. Both these types of training were included in the current experiment, as well as a free classification condition, and two other conditions designed to control for potential effects of response practice.

Experiment 1

Participants and Apparatus

The participants were 60 adults, aged between 18 and 35, who were paid for their participation. All were graduate or undergraduate students from the Cambridge area. Participants were tested individually in the same quiet experimental cubicle. The room contained an Acorn RISC PC600 microcomputer connected to a 14 inch colour monitor, model AKF60. Responses were made using a standard keyboard. Participants sat about one metre away from the screen which was approximately at eye level.

Stimuli

Each stimulus was a 16×16 array of black and white squares. These "chequerboards" measured 2.5 cm on a side and were presented on the centre left of the screen against a mid grey background. In some experimental conditions, a label for the chequerboard, either the letter 'A' or 'B' was presented in white on the centre right of the screen. The label was approximately the same size as the stimulus. For each participant, a new master pattern was created, and this was used as one of the prototypes during the experiment. The master pattern was a chequerboard of 128 white and 128 black squares randomly arranged, hereafter chequerboard A. A second prototype was created from the master pattern by selecting 120 of the squares (60 black and 60 white) and reversing the shade of those squares (black to white or vice versa), hereafter chequerboard B. The examples that were actually shown to the participants depended upon the phase of the experiment. During training the stimuli shown were created from the prototypes by subjecting each square to a small independent chance ($p = 0.05$) of reversing its colour. On test all stimuli were created from the master pattern and had a set number of squares reversed in colour, ranging from 0 to 120 in steps of 10, covering the artificial continuum between the prototypes. Each test stimulus reversed the colour of a different, randomly selected set of squares, depending on its position along the continuum between the prototypes. For example if a stimulus was in position 4 out of 12, then 40 of the master pattern squares would be changed to be the same as those in the second prototype. Another stimulus at position 4 would have a different set of 40 squares reversed in colour so as to match those in the other prototype.

Design

The experiment incorporated one of five different training conditions, all followed by an identical test session.

Labelled

Participants were presented with the training chequerboards accompanied by a consistent label, either A or B during training. No response was required and the participants were asked to try to learn what features made a pattern either an A or a B.

Free Classification

Participants were presented with the training chequerboards, but without a label being present. They were asked to divide the stimuli that they were being shown into two groups, in any way which they saw fit, by pressing one of the appropriate keys. No feedback was given throughout.

Corrective Feedback

Participants were presented with the training chequerboards alone and had to learn which of the two keys to press when they saw a given chequerboard. Corrective feedback in the form of a beep from the computer indicated when the participant had pressed the wrong key. No label was presented.

Mental Decision

Participants were given similar instructions to the Free Classification group, except no response was required in this condition. All the participants had to do was decide to which one of the two groups the pattern belonged. No label was presented.

Matching to Label

Participants were given similar instructions to the Labelled condition, except that they were required to make a keypress once the chequerboard had disappeared. The key they pressed simply corresponded to the label that was presented with the stimulus. This same key assignment was carried over into the generalisation phase.

Procedure

Each participant was asked to read the general experimental description which was displayed on the computer screen. This included a brief description of the whole experiment, more detailed instructions about the training phase and an example stimulus, with a label if appropriate. Participants were told to try to learn as much as they could in the first part of the experiment, as they would need this information for the final part. Once the participant had read the instructions, the experimenter verified that they had understood them, and then left the room for the remainder of the experiment. Participants started the training phase by pressing the 'Y' key at the top of the keyboard, and then proceeded through the 60 training trials in a fashion determined by the experimental condition.

During training, the stimuli (and label if appropriate) were displayed for 5 seconds before disappearing from the screen. If a response was required, then participants were allowed to press an appropriate key, either the 'x' or the '>' key, once the stimulus had gone from the screen. If no response was required during training, then there was a two second inter-stimulus interval. Training consisted of 30 presentations of A and 30 of B in a random order. All participants were told that the chequerboards that they were to be shown could be divided into two groups, and that this was their task.

After the final training trial, the instructions concerning the test phase were displayed. The test phase was identical for all participants regardless of their training condition and consisted of 130 trials which displayed a chequerboard on its own. The instructions asked each participant to continue placing the stimuli into two groups in the same way as before, but were informed that there would now be no label, if there had been one before, and that a response was required for each chequerboard. In conditions where a label had been presented to the participants a key mapping was provided, for example, "Press 'x' if it's an A". If no label had been present during training, participants were simply asked to carry on placing the chequerboards into the most relevant group. The instructions for the Mental Decision group required them to make an arbitrary assignment of the groups they had formed during training to the keys to be used during the test phase. Once a response to a test stimulus had been made, it was immediately replaced by another stimulus. If any other key apart from the two that were designated was pressed, the computer beeped, and another response was required. Participants were asked to focus more on accuracy rather than speed in this part of the experiment, and there was no explicit time-out procedure, so participants cannot be considered to be under any time pressure.

The design of the test phase was such that participants were shown stimuli along the continuum from the master pattern (A) to the second prototype (B). Each test stimulus had a multiple of 10 squares changed from A, to make it more like B. As A and B differed by 120 squares, there are 13 steps along such a continuum and with each point being sampled 10 times, this gives 130 test trials. The 10 stimuli for any given point on the continuum were all different, and generated as described above.

At the end of the experiment the computer automatically recorded responses and reaction times from the training phase where possible, and from the test phase in a data file. Each participant was paid for their time and thanked for their participation.

Results

The two measures of performance recorded during the generalisation test phase were response and reaction time, and they are dealt with separately. The independent measure on the plots in this section is distance along the

Table 1: Factors in Experiment 1

	Information	No Information
Keypress	Match to Label	Free Classification
No Keypress	Label	Mental Decision

B-A continuum, with B at one end and A the other, and the intermediate values being examples of B with ($10 \times$ distance) squares changed to make the stimulus more like A. Data was analysed firstly by comparison of the groups using ANOVA. A factorial design was also used, as illustrated below (Table 1). The conditions included in the experiment have tried to control for possible effects of making a response interacting with the presence of accurate information about category membership.

Responses

A single mixed design analysis of variance (ANOVA), with one within-subject variable (continuum position, 13 levels) and one between subjects variable (training condition, 5 levels) was performed on the mean number of B responses at each point on the continuum for each participant. This failed to reveal any significant difference between the groups $F(4,55) = 2.25$, $p<0.1$ or any interaction between the groups and the position along the continuum $F(48,660) = 0.647$, $p>0.9$. There was a significant main effect of position along the B-A continuum $F(12,660) = 6.88$, $p<0.001$. No further analyses were carried out on the response data, as there was no clear difference between the groups at this stage. The mean responses for each group at each point along the continuum are plotted in Figure 1. A mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and two between subject variables (the presence or absence of consistent information about category membership and the requirement to make a keypress) was performed. The

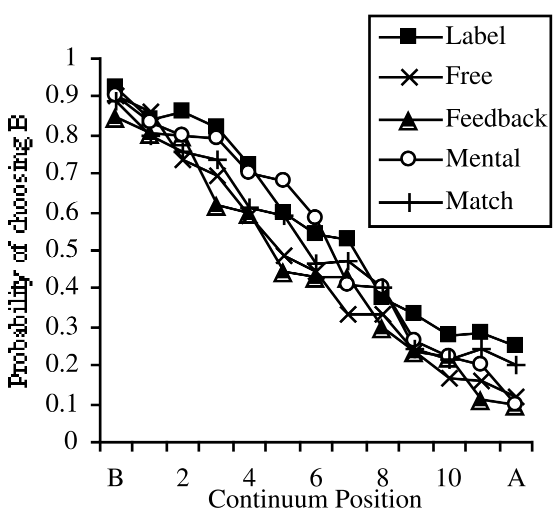

Figure 1: Response Data for All Groups in Experiment 1

analysis yielded a significant main effect of both the requirement to make a keypress, $F(1,44) = 4.76$, $p < 0.05$ and of continuum position, $F(12,528) = 99.45$, $p < 0.001$. No other effects approached significance in this analysis, $p > 0.15$. The mean responses for each level at each point along the continuum are plotted in Figure 2.

Reaction Times

Participants were not considered to be under any time pressure, so the reaction times provide a secondary performance measure. The mean reaction times for each group are plotted against the distance from B along the B-A continuum in Figure 3. ANOVAs were performed on the mean reaction times for each participant. A single mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and one between subjects variable (training, 5 levels) revealed a significant main effect of group, $F(4,55) = 5.00$, $p<0.01$, and of position along the continuum, $F(12,660) = 6.28$, $p<0.001$. There was no significant interaction between the two factors, $F(48,660) = 1.18$, $p > 0.15$.

A Tukey HSD test performed on the group factor revealed that each of the Free Classification, Mental Decision and Feedback conditions were significantly faster than the Label condition, all $p< 0.05$, with no other comparisons reaching significance. Pairwise analysis of the conditions reveals a significant quadratic interaction between the Label and Free Classification conditions, $F(1,22) = 5.84$, $p < 0.05$, and the Matching to Label and Free Classification conditions, $F(1,22) = 7.05$, $p < 0.05$, no other comparison of quadratic trends reached significance, $p > 0.1$.

A mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and two between subject variables (the presence or absence of consistent information about category membership and the require-

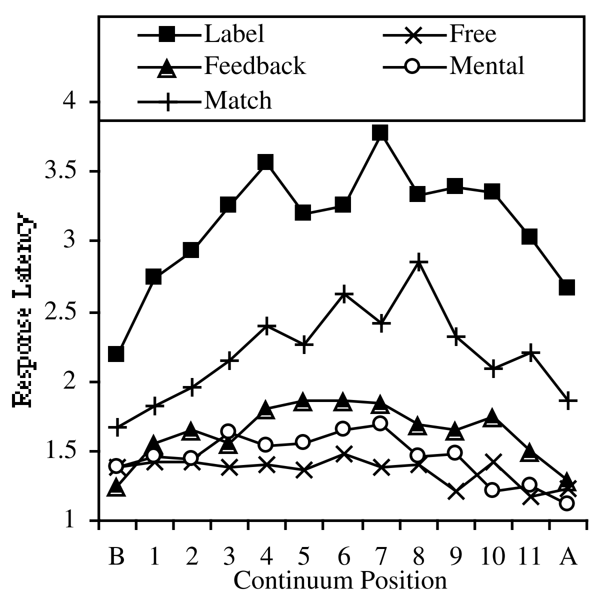

Figure 3: Reaction Times for All Groups in Experiment 1

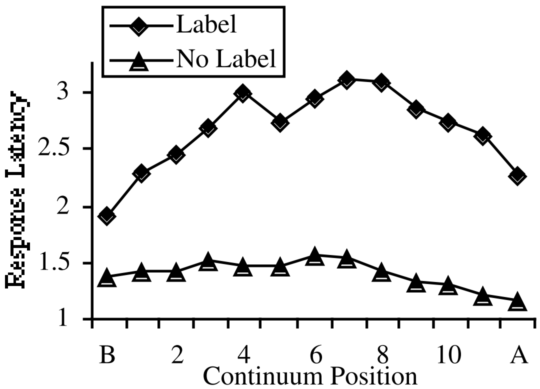

Figure 4: Effect of Label in Experiment 1

ment to make a keypress) was performed. This revealed a significant effect of information, $F(1,44) = 13.67$, $p = 0.001$, the expected main effect of continuum position, $F(12,528) = 4.83$, $p < 0.001$ and an interaction between these two factors $F(12,528) = 2.77$, $p < 0.05$. No other effects approached significance in this analysis, $p > 0.25$. The mean reaction times for each level at each point along the continuum are plotted in Figure 4.

Discussion

Experiment 1 provides evidence for a number of novel results with respect to the effect of feedback on categorisation. Whilst there is no significant observable effect of training condition on response performance, there is a significant effect on the reaction time data collected. Initially surprising is the fact that groups trained with a completely errorless teaching signal (Labelled and Match to Label) recorded the slowest reaction times. Two other groups received no feedback (Free Classification and Mental Decision), and both are found to be significantly faster than the Labelled condition. The response curves show that this speed advantage cannot be due to speed-accuracy trade off, and so there must be some other explanation for the deficit in performance observed in groups which intuitively should be the best at the task.

The main effect of labelling in the factorial analysis for the reaction time data confirms this finding, with the presence of a category label causing an increase in response time on generalisation. The effect of making a keypress can be seen in the response analysis, but can be regarded as relatively uninteresting as there is no sign of an interaction which might point to the task having been learnt better, causing one group to have a more step-like function.

The most obvious reason for the speed advantage seen for those groups who do not have a consistent piece of information relating to category membership is that they are required to make a decision about category membership during the training phase. This seemingly essential part of training is not present when a label is provided, as the stimulus and its category name are presented simultaneously. In the Feedback condition, even though there is consistent category information, a decision must be made before this feedback can be received and integrated. In the conditions where no feedback it present, a decision made internally about previous stimuli is the only information available when deciding to which group subsequent stimuli should be assigned. The similarity of the generalisation functions implies that all groups have learnt how to differentiate between the two categories to the same extent. However it may be that the application of this knowledge is mediated by a response mechanism which is yet to be set up by those groups which are not required to make a decision as to category membership during training. This leads to the difference seen between the relatively flat reaction time curves for the three conditions where decisions are required in training and the inverted U-shaped reaction time curves produced by those participants who are presented with the label during training. The inverted U-shaped curves are typical of those produced during generalisation along a continuum using these procedures (Jones, Wills & McLaren, 1998). The centre point of the continuum is no more like an A than a B, so any response made to these stimuli must be indeterminate, and hence produces a longer latency than those responses to items which are more like those in training.

Despite the potentially simple explanations for the differences observed between the groups, it is still an interesting result to have the Free Classification and Feedback conditions indistinguishable from one another even with the supposed added advantage of corrective feedback. This may be due to some motivational factor, as participants in the Free Classification group are never told that they are wrong, however with feedback, participants may be relatively sure that the stimulus that they are seeing is an A, but in fact turns out to be a B, which may disrupt their representation of the conditions for category membership. The feedback that they get may be consistent within the framework of the experiment, but may be inconsistent internally, and this may be part of the reason for the lack of benefit for the Feedback condition.

The reason the Label condition is so slow may be because it takes time to learn, and then to use, the response mapping. It cannot be entirely due to motor learning as although there is some advantage for the Matching to Label group over the Label group, there is still a difference between the Matching condition and the three where a decision was made during training. The results from the Mental Decision group also tend to discount this line of reasoning as they were not required to form a key mapping before the test phase but their responses are indistinguishable from the Feedback and Free Classification.

Experiment 2

Experiment 2 was designed in a factorial fashion to investigate the effect of both feedback and consistent label-

Table 2: Factorial Design of Experiment 2

	Feedback	No Feedback
Label	Match to Label (FB)	Match to Label (NFB)
No Label	Corrective Feedback	Free Classification

ling of the stimuli. In this respect it was similar to Experiment 1, but attempted to control for the formation of response mappings during training. Experiment 2 forced all participants to adopt a key mapping during training, so that any effect on test would be due to the actual training rather than differences in procedure. All participants were forced to make their responses to the stimuli within two seconds of the stimulus disappearing using the same keys as before.

Stimuli and Apparatus

These were identical to those in Experiment 1.

Participants and Design

Forty-eight Cambridge University students took part in the experiment. All were aged between 18 and 25. The experiment was designed to test the effect of two factors when learning an artificial categorisation problem. These were the presence and absence of feedback on the responses that were made during training, and the presence or absence of a consistent category label during training The design was similar to Experiment 1, with the test phase being identical, and is shown in Table 2.

Procedure

The procedure was similar to Experiment 1. The only differences were during training. All groups were presented with a stimulus and asked to respond within two seconds to that stimulus once it had disappeared. The training differed from Experiment 1 by presenting the label, if necessary, before the stimulus rather than concurrently. For those conditions without a label, a '#' symbol was presented before each stimulus, whether it was nominally an A or a B, in place of the label to equate the training time. The appropriate label or '#' was displayed for five seconds before the five second presentation of the stimulus. The instructions were identical to those from Experiment 1 apart from detailing the separate presentation of the label or '#' and the stimulus and informing the participants of their two second time limit.

Results

As with Experiment 1, there were two dependent variables, response selection and reaction time, and as a time limit had been imposed, the reaction times can be considered a more informative performance indicator. The data were analysed using an appropriate ANOVA. The performance of individual groups was analysed along with the effect of the factors built into the experiment.

Responses

A single mixed design analysis of variance (ANOVA), with one within-subject variable (continuum position, 13 levels) and one between subjects variable (training condition, 4 levels) was performed on the mean number of A responses at each point on the continuum for each participant. This failed to reveal any significant difference between the groups $F(3,44) = 0.76$, $p>0.5$ or any interaction between the groups and the position along the continuum

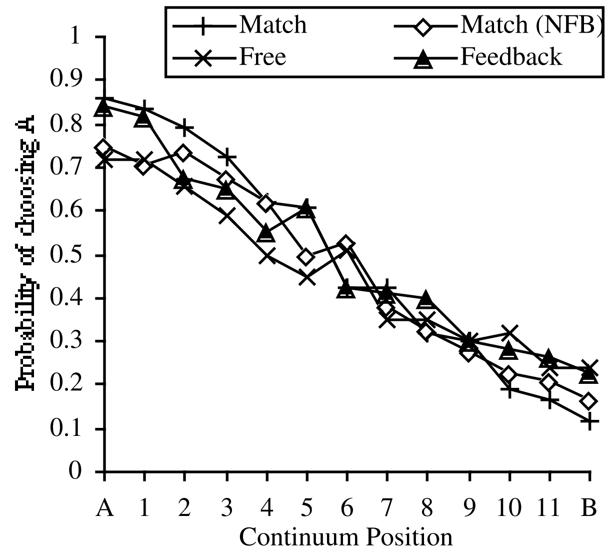

Figure 5: Response Data for All Groups in Experiment 2

$F(36,528) = 0.65$, $p>0.5$. There was a significant main effect of position along the A-B continuum $F(12,528) = 55.73$, $p<0.001$. No further analyses were carried out on the response data, as there was no clear difference between the groups at this stage. The mean responses for each group at each point along the continuum are plotted in Figure 5.

A mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and two between subject variables (the presence or absence of consistent information about category membership presence of feedback) was performed. The analysis yielded only a significant main effect of continuum position, $F(12,528) = 55.73$, $p < 0.001$. No other effects approached significance in this analysis, $p > 0.15$.

Reaction Times

The mean reaction times for each group are plotted against the distance from A along the A-B continuum in Figure 6. ANOVAs were performed on the mean reaction times for each participant.

A single mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and one between subjects variable (training, 4 levels) revealed a significant main effect of group, $F(3,44) = 3.38$, $p = 0.026$, and of position along the continuum, $F(12,528) = 5.64$, $p < 0.001$. There was no significant interaction between the two factors, $F(36,528) = .90$, $p > 0.6$. A Tukey HSD test performed on the group factor revealed that the Match to Label condition with feedback was found to be significantly slower than the Free Classification condition, $p < 0.05$. A mixed design ANOVA, with one within subject variable (continuum position, 13 levels) and two between subject variables (the presence or absence of category membership information and the presence of feedback) was performed. This revealed a significant effect of category information, $F(1,44) = 4.54$, $p = 0.039$, with the label conditions showing the longer mean

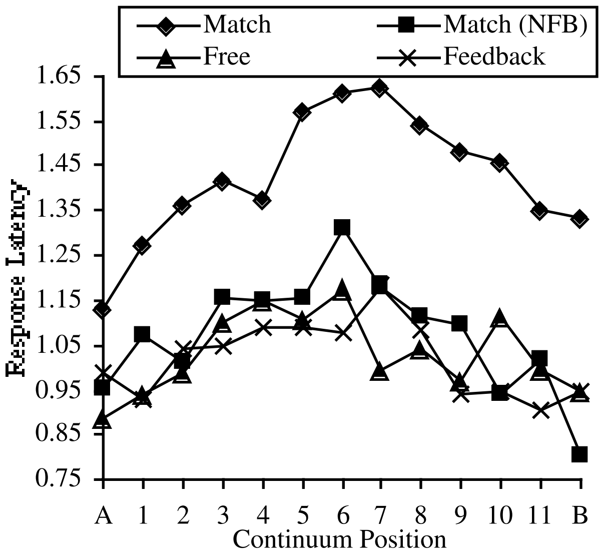

Figure 6: Reaction Time Data for All Groups in Experiment 2

reaction times, and the expected main effect of continuum position, $F(12,528) = 5.64$, $p < 0.001$. No other effects were significant in this analysis, $p > 0.09$.

General Discussion

The results from Experiment 2 are broadly in line with those obtained in Experiment 1. The inclusion of a consistent category label appears to have a detrimental effect when compared with the requirement to make an active decision about category membership. However, there appears to be a speed-accuracy trade off present in the results. Whilst the Match to Label with feedback (MFB) group are slowest, they also show the greatest difference between the ends of the generalisation gradients. Although this difference is not significant it would be difficult to conclude anything definite on the basis of this alone. However, taken with the results from Experiment 1, it seems clear that the fact that feedback is not present does not seem to have a detrimental effect on the performance shown by participants. Instead it seems that, in some cases, providing an entirely consistent label for the stimuli during training causes participants to perform worse. This is not what would be predicted from Homa & Cultice (1984), and is at odds with the results from Estes (1994) who showed that a condition analogous to the Label condition in Experiment 1 gave better performance on test than when participants were trained using a corrective feedback approach. It may be that the real advantage lies in being able to make active (i.e. self-generated) decisions during training rather than simply being exposed to the stimuli and the appropriate category information (Figure 4). Thus it may be the case that different processes are at work

Conclusion

It seems likely that the most successful approach to modelling such data will come form simple self-organising systems (Rumelhart & Zipser, 1986; Saksida, 1999) which are able to extract the necessary information from the stimuli encountered to form coherent categories through exposure to the stimuli alone. It may be the case that all that is needed is exposure to stimuli in order to extract information about them, and this raises the interesting question of what exactly feedback does if it does not always aid decision making.

References

Bersted, C.T., Brown, B.R. & Evans, S.H. (1969). Free sorting with stimuli in a multidimensional attribute space. *Perception and Psychophysics, 6B,* 409-413.

Estes, W.K. (1994). *Classification and Cognition.* Oxford: Oxford University Press.

Evans, S.H. & Arnoult, M.D. (1967). Schematic concept formation: Demonstration in a free sorting task. *Psychonomic Science, 9(4)*, 221-222.

Homa, D., & Cultice, J. (1984). Role of Feedback, Category Size, and Stimulus Distortion on the Acquisition and Utilization of Ill-Defined Categories. *Journal of Experimental Psychology: Learning, Memory and Cognition, 10,* 83-94.

Jones, F.W., Wills, A.J. & McLaren, I.P.L. (1998). Perceptual Categorisation: Connectionist modelling and decision rules. *Quarterly Journal of Experimental Psychology, 51(B),* 33-58.

Rosch, E., & Mervis, C.B. (1975). Family resemblance: Studies in the internal structure of categories. *Cognitive Psychology, 7,* 573-605.

Rumelhart, D.E., & Zipser, D. (1986). Feature discovery by competitive learning. In D.E. Rumelhart, J.L. McClelland, & The PDP research group. *Parallel Distributed Processing: Explorations in the microstructure of cognition.* Cambridge, MA: MIT Press.

Saksida, L.M.(1999). Effects of similarity and experience on discrimination learning: A nonassociative connectionist model of perceptual learning. *Journal of Experimental Psychology: Animal Behavior Processes*, *25*, 308-323.

Wills, A.J. & McLaren, I.P.L. (1998). Perceptual Learning and Free Classification. *Quarterly Journal of Experimental Psychology, 51(B),* 235-270.