Perceptual learning for a familiar category under inversion: An analogue of face inversion?

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Abstract

This study investigated the link between expertise for a prototype-defined category and the face inversion effect (which refers to the decline in performance in recognising faces that are inverted compared to the recognition of faces in their normal upright orientation; e.g., Yin, 1969). We aimed to demonstrate an analogous effect in chequerboards drawn from a familiar category such that participants had acquired a certain expertise with that category. Participants in this study were first presented with a categorisation task in which they were asked to sort a number of chequerboards (in an upright orientation) into two categories. This increased their familiarity with these categories. Then, in the next (study) phase, participants were presented with a set of chequerboards which included exemplars (some upright, some inverted) from one of the two categories that participants were familiar with, plus exemplars (also upright or inverted) from a novel category. Following this, participants were presented with an old/new recognition task that included exemplars seen in the study phase plus new exemplars of the same (familiar and novel) categories in both orientations (upright and inverted). We succeeded in obtaining the same pattern of effects reported in McLaren (1997), i.e. a significant inversion effect for stimuli drawn from the familiar category, but with standard recognition procedures. We interpret the results in terms of McLaren and Mackintosh's (2000) theory of representation development.

Keywords: Inversion; perceptual learning; expertise; faces; recognition; chequerboards; categorization; latent inhibition.

Introduction

The face inversion effect proper refers to the greater decline in performance in recognizing faces that are inverted compared to the recognition of faces in their normal upright orientation when contrasted with similar manipulations using other stimuli such as pictures of houses (Yin, 1969). On the basis of this effect it had been believed that faces were processed in our brain in a different way to other kinds of stimuli. The assumption that facial stimuli are special can be challenged by the demonstration that the inversion effect in recognition memory can be as strong with images of dogs as with faces when the subjects are experts in specific dog breeds (Diamond & Carey, 1986). Thus, this suggests that the face inversion effect may not be due to the fact that facial stimuli are separately processed by the brain, but instead that there are other factors, such as expertise, which give rise to this effect. Back in 1997 McLaren demonstrated that we can obtain a significant inversion effect analogous to that in faces with chequerboards drawn from a familiar category as long as they possess the appropriate stimulus structure. Subjects were exposed to a set of chequerboards and were asked to categorise them into two different prototype-defined categories. This was followed by a *discrimination task* which included two pairs of chequerboards (one pair in an upright and the other pair in an inverted orientation) from a familiar category, plus two control pairs of chequerboards from a novel category (again one pair upright the other inverted). The results showed that familiarity with a category defined by a prototype gave subjects an enhanced ability to discriminate between exemplars of that category in an upright orientation. This benefit was lost when the stimuli were inverted, to the extent that learning of the discrimination involving inverted familiar exemplars was worse than for appropriate controls. No inversion effect was found for exemplars taken from a novel category of chequerboards, or for chequerboards that were taken from a familiar category that was not prototype-based. In the same study McLaren (1997) tried to extend those results in a *delayed matching task*. Each trial of the delayed matching task involved a category exemplar being presented for 1 sec in either an upright or inverted orientation, and finally a second exemplar drawn from the same category and with the same orientation as the first. Subjects had to decide whether the second chequerboard was the same as or different from the first as rapidly as possible by pressing one of two keys. Trials were randomized with the constraint that half were positive (same) trials and half negative (different). Results showed that subjects presented with exemplars from a familiar category were significantly better at judging whether upright exemplars were the same or different than at making the same decision for the inverted exemplars. Finally performance on the familiar upright exemplars was significantly better than that for novel controls. Thus, experience with a category leads to a significant inversion effect in a matching task confirming the results obtained in the discrimination task. However this time performance on inverted familiar exemplars was not significantly worse than that on inverted novel exemplars. In the present study we aimed to replicate McLaren's (1997) findings using a standard *face recognition paradigm*, but with chequerboards as stimuli rather than faces. The prediction was that expertise with members of a familiar, prototype-defined category would lead to an improved ability in distinguishing and recognising these members; an improvement that would be lost on inversion. Finally, as McLaren (1997) showed that inversion of familiar exemplars may incur some cost in discriminating those exemplars, we investigated whether there may be some cost when recognising inverted familiar exemplars.

Experiment 1a

Experiment 1a aimed to find a significant inversion effect in an artificial prototype-defined category that participants became familiar with during the experiment.

Materials

The stimuli were 16 x 16 chequerboards containing roughly half black and half white squares. Four prototypes were generated at random but with the constraint that they shared 50% of their squares with any of the other prototypes. Exemplars were generated from these prototypes by changing squares at random as described in Figure 1.

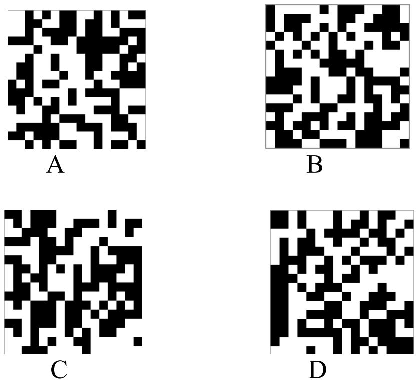


Figure 1: The prototypes for categories A, B, C and D. On average, 48 of the squares were set at random to generate each exemplar, thus, on average, 24 squares would be expected to alter from black to white or white to black. There was no special relationship between exemplars generated from each prototype.

Participants

32 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced by splitting participants into 8 groups.

Procedure

The study consisted of a ‘categorisation phase’ a ‘study phase’ and an old/new recognition ‘test phase’. In the categorisation phase, the subjects were instructed that once they pressed any key on the keyboard, a set of chequerboard stimuli would appear on the screen, one at a time in random order. Their task was to sort these stimuli into two categories by pressing one of the two keys (“x” or “.”), and they would get immediate feedback as to whether their response was correct or not. If they did not respond within 4seconds, they would be timed out. The set of chequerboard stimuli included 128 exemplars of two different categories, with 64 in each category. Subjects were encouraged to scan the whole of each chequerboard before categorising it. In order to counterbalance our stimuli, we used 8 participant groups. The first 4 of those were presented, during the categorisation task, with 64 exemplars drawn from category A and 64 exemplars drawn from category B. The second 4 were presented with 64 exemplars drawn from each of the C and D categories. After the categorisation phase was concluded participants proceeded to the study phase. For each subject, the task was to look at a number of new exemplars from one of the two familiar categories seen in the categorisation task, plus an equal number of novel exemplars from a category not previously seen. Thus, for example, participant group 1 was presented with a set of stimuli that included 32 exemplars (16 upright and 16 inverted) drawn from category A (familiar) and 32 exemplars (16 in both orientations) drawn from category C which was novel for them. To counterbalance this participant group 5 was presented with 32 exemplars (16 upright and 16 inverted) drawn from category C (familiar) and 32 exemplars (16 in both orientations) drawn from category A which was novel for that group. Thus, in the study phase each participant was shown 4 types of exemplar each containing 16 stimuli giving a total of 64 exemplars. These were presented one at a time in a random order for 3 seconds. The exemplar types were: 1-Familiar Inverted exemplars (1FI); 2-Familiar Upright exemplars (1FU); 3-Novel Inverted exemplars(1NI) and 4-Novel Upright exemplars (1NU). Following the study phase subjects were given an old/new recognition task. This involved the 64 exemplars seen in the study phase (32 in an upright and 32 in an inverted orientation, as presented in the study phase), plus 64 new exemplars (32 in an upright and 32 in an inverted orientation) split across the same four exemplar types shown in the study phase. The unstudied exemplar types were: 5-Familiar Inverted exemplars (2FI); 6-Familiar Upright exemplars (2FU); 7- Novel Inverted exemplars(2NI) and 8-Novel Upright exemplars (2NU). Each exemplar had a unique identifying number, to make sure that an individual exemplar never appeared in more than one condition at a time during the experiment. To simplify their use in the experiment, the stimuli available were divided into sets of 16 giving 8 sets of stimuli, and each participant group was shown a different combination of the 8 sets as shown in Table 1 below. Subjects in the test phase were asked to press “.” on the computer keyboard if they had seen the chequerboard before in the study phase, or “x” if they had not seen it and had 4 seconds in which to do so. Data was collected on accuracy and latency in recognition performance across the test recognition phase. At the end of the study subjects were debriefed about the purpose of the experiment.

Exemp. type	Subject Group1	Subject Group2	Subject Group3	Subject Group4	Subject Group5	Subject Group6	Subject Group7	Subject Group8
1(1FI)	A 65-80	A 81-96	A 97-112	A 113-128	C 65-80	C 81-96	C 97-112	C 113-128
2(1FU)	A 81-96	A 65-80	A 113-128	A 97-112	C 81-96	C 65-80	C 113-128	C 97-112
3(1NI)	C 97-112	C 113-128	C 65-80	C 81-96	A 97-112	A 113-128	A 65-80	A 81-96
4(1NU)	C 113-128	C 97-112	C 81-96	C 65-80	A 113-128	A 97-112	A 81-96	A 65-80
5(2FI)	A 97-112	A 113-128	A 65-80	A 81-96	C 97-112	C 113-128	C 65-80	C 81-96
6(2FU)	A 113-128	A 97-112	A 81-96	A 65-80	C 113-128	C 97-112	C 81-96	C 65-80
7(2NI)	C 65-80	C 81-96	C 97-112	C 113-128	A 65-80	A 81-96	A 97-112	A 113-128
8(2NU)	C 81-96	C 65-80	C 113-128	C 97-112	A 81-96	A 65-80	A 113-128	A 97-112

Table 1: Combinations of the stimuli presented to each participant group. Exemplars used in the study phase and the test phase were numbers 64 to128. The first 4 stimulus groups were the ones seen both in the study phase and in the test. The latter 4 were seen only during the test phase.

Results

The data from all 32 subjects was used for the signal detection analysis. In the categorization phase, the mean percentage correct was 64%. Figure 2 gives the results from the test phase for the signal detection measure *d'* by category type. Following McLaren (1997) we expected an inversion effect (higher score for upright than for inverted) for the familiar category, no inversion effect for the novel category, and a significant difference between the effects of inversion for familiar and novel categories. Planned contrasts were used to examine whether these effects were reliable. As expected, a significant difference in *d'* was found for the upright versus inverted familiar category exemplars, F(1,31)=3.59, p<.05 one-tail. No significant inversion effect was found for novel category exemplars, F(1,31)=-1.16, p=ns.

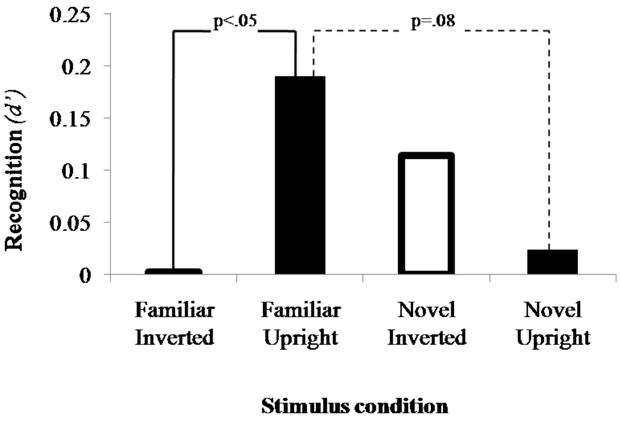


Figure 2: the X axis gives the four different stimulus conditions, whereas the Y axis shows the mean *d'* for the old/new recognition phase in Experiment 1a.

There was also a significant interaction between category type and orientation, F(1,31)=3.63, p<.05 one-tail. The effect of category type and orientation on recognition was also analyzed by means of planned comparisons on *d'* scores. Familiar upright exemplars were not recognized significantly better than unfamiliar upright exemplars, F(1,31)=2.07, p=.08, though there was a clear trend in that direction. There was also a non-significant trend for familiar inverted exemplars to be worse than novel ones, F(1,31)=0.92, p= .17.

Discussion

We have replicated the original effect with chequerboards, but this time using exactly the same recognition paradigm as is normally used for face recognition studies. There is a significant inversion effect for the familiar category of chequerboards, but no inversion effect for novel chequerboards. An explanation consistent with the results obtained in Experiment 1a is that stimulus pre-exposure leads to perceptual learning. The familiar chequerboards benefit from this and, hence, subjects are better able to recognize upright exemplars of that category. But an individual's performance declines when presented with exemplars of that ostensibly familiar category in an inverted orientation because they are not actually familiar with the stimuli in that orientation (McLaren, Kaye and Mackintosh, 1989; McLaren & Mackintosh, 2000). This leads to the inversion effect observed with the familiar category, but this effect is not seen for the novel chequerboards as here there is no perceptual learning to be lost on inversion. One issue for this account of Experiment 1a's results, however, is that the mechanism described predicts such an effect only for categories defined in terms of a prototype, but we have no direct evidence for this in these experiments as yet.

Experiment 1b

In Experiment 1b we addressed this issue. The same procedure was used again but this time there was an alteration in the method used to generate the stimuli. We used a variant on the procedure for generating 'shuffled' stimuli outlined in McLaren (1997), as this produced stimuli that were as easy to classify as prototype-defined stimuli, but they did not average to the base pattern used to generate them and so did not, as a class, possess a prototype themselves. Exemplars were constructed by shuffling rows, a random permutation of 3 randomly chosen horizontal rows of a base pattern (we used the base patterns from Experiment 1a) constituting an exemplar of that category. We only shuffled three rows, to keep the number of squares that (on average) changed the same as in Experiment 1a (this was far fewer than the number shuffled in 1997). The procedure was that two rows were identified at random and swapped, then a new row was identified, and swapped with one of the previous two. The result is that, on average, half the squares in each of the three rows will be altered making 24 in all. Thus, this experiment is, in some sense the control for Experiment 1a, though as will become apparent, the ease of classification produced by using these materials more nearly matched that of Experiment 2. We predicted no inversion effect for either familiar or novel category exemplars in this experiment.

Participants

32 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiments 1 and 2, by splitting participants into 8 groups.

Results

The data from all 32 subjects was, as for Experiments1a, used for the analysis.. In the categorisation phase, the mean percentage correct was 77%. Thus, as we predicted the stimuli were at least as easy to categorize as stimuli in Experiment 1a. However as Figure 3 suggests there was no significant difference in d-prime means for familiar category exemplars or for novel category exemplars, confirming our predictions. The crucial interaction, however, is not that within Experiment 1b, but emerges when we compare the results of Experiment 1b with those of Experiment 1a. In McLaren (1997) a similar comparison showed that the inversion effect, defined as the familiarity by orientation interaction, obtained with exemplars drawn from a prototype-defined category was significantly greater than that obtained with exemplars drawn from a category that was not defined by a prototype. If we compute the Experiment by Familiarity by Orientation interaction for Experiments 1a and 1b we find F(1,31)=5.15, p=.013 (one-tail), confirming that this is the case here. Thus we have the necessary evidence to state that the inversion effect depends on both the category being familiar and its being prototype based.

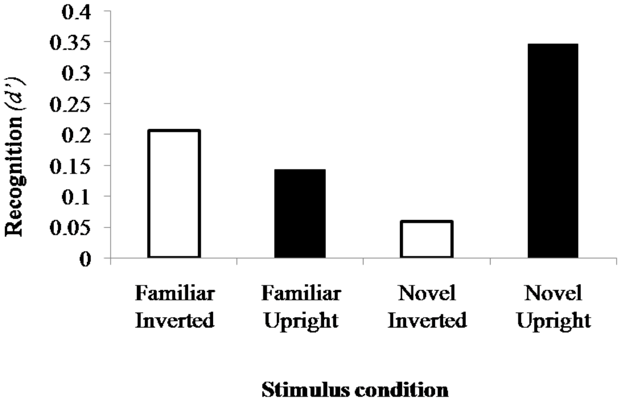


Figure 3: The X axis shows the four different stimulus conditions, whereas the Y axis shows the average number of accurate responses (out of 32) for each of the four conditions in the test phase of Experiment 1b.

Discussion

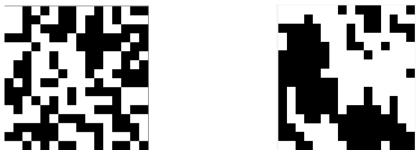
Experiment 1b supported our explanation of the inversion effect, in particular that the inversion effect would only arise for a category of stimuli based on a prototype. Being able to categorize stimuli that were not defined by a prototype did not give the subjects any advantage in recognising exemplars of that category in their upright orientation, and did not produce any of the effects observed in Experiment 1a. However, our inversion effect in Experiment 1a is not as substantial as we would like. This may be because participants found it too hard to recognize the chequerboards. Experiment 2 aimed to address this issue.

Experiment 2

Experiment 2 was a replication of Experiment 1a but this time we tried to make the chequerboards more "clumpy", with the intention of making the stimuli easier to recognize. We hoped to obtain a stronger inversion effect for familiar chequerboards than the one obtained in Experiment 1a.

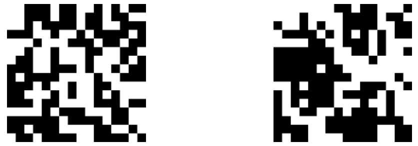
Materials

In this experiment a randomly chosen 96 squares (up from 48 in Experiment 1a) were set at random to generate each exemplar, and the prototypes themselves had stronger differentiation into black and white areas (see Figure 4).



Prototype A Experiment 1

Prototype A Experiment 2



Exemplar A65 Experiment 1

Exemplar A65 Experiment 2

Figure 4: The prototypes and example exemplars for category A in Experiment 1 and for category A in Experiment 2.

Participants

32 psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 1, by splitting participants into 8 groups.

Procedure

This was exactly the same as that used in Experiment 1a.

Results

The data from all 32 subjects was used for the analysis. In the categorisation phase, the mean percentage correct was 77%, indicating that our manipulation of the stimuli had made them easier to classify at least. Figure 5 gives the results for the mean *d*' score by category type. Planned comparisons were used to examine whether or not there was a significant inversion effect for familiar category exemplars. A reliable difference in *d*' emerged for the upright versus the inverted familiar category exemplars, F(1,31)=8.09, p<.01 one-tail. There was also a significant interaction between category type and orientation, F(1,31)=4.12, p<.03 one-tail. To explore this further the effect of category type on the recognition of upright exemplars was also analyzed. Familiar upright exemplars were not recognized significantly better than unfamiliar upright exemplars, F(1,31)=.96, p=.17, but novel inverted exemplars were recognized significantly better than familiar inverted exemplars, F(1,31)=4.11, p<.03 one tail.

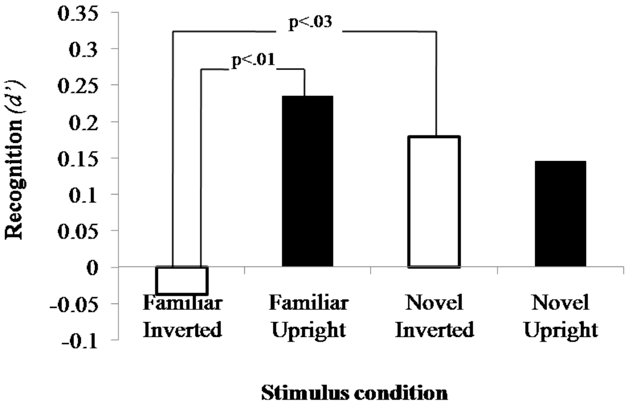


Figure 5:The X axis shows the four different stimulus' conditions, whereas the Y axis shows the mean discrimination in *d*-prime (out of 32) for the old/new recognition phase in Experiment 2.

Discussion

Experiment 2 replicated and strengthened the findings obtained in Experiment 1a.We were able to increase the inversion effect for chequerboards by making them easier to recognize. Thus, our results confirm that an inversion effect can be induced by familiarizing participants with a category. We are now also able to comment further on the basis for this effect. The trend for familiar upright exemplars to be better recognized than novel upright exemplars was not itself significant (though the effect was numerically in the right direction), but this time inverted familiar exemplars were significantly worse recognized than novel inverted exemplars. This replicates the finding in McLaren (1997), and indicates that the inversion effect may be as much to do with a disadvantage for inverted familiar exemplars as it is with an advantage for upright familiar exemplars. We return to this point in the General Discussion.

General Discussion

Experiments 1a, 1b and 2 support the hypothesis that expertise with a category defined by a prototype leads to an inversion effect in standard recognition paradigms with stimuli drawn from that category, and this does not happen after experience with a category that cannot be defined in terms of a prototype. Before accepting this assertion, however, we must establish that the pattern of performance seen in Experiment 1b was not simply a floor effect when compared to Experiment 1a. In fact, the data argue against this interpretation. Performance overall in Experiment 1a was only marginally better than chance F(1,31)=2.64, p=.057, confirming that our participants found the task very difficult. Overall performance in Experiment 1b was significantly above chance, F(1,31)=8.00, p<.005, however, so if anything the task with the shuffled chequerboards was easier, as the categorization results also suggest. It is unlikely, therefore, that the lack of an inversion effect with the shuffled chequerboards is due to a floor effect.

There is one aspect of the stimulus construction used this time in the case of the shuffled chequerboards that does require further discussion. In the McLaren (1997) experiments, the rows were shuffled a great deal, and as such the likelihood of any given row remaining in its base position was rather low. This meant that the average of all the shuffled patterns was a set of vertical bands of varying degrees of grey (depending on the proportion of black squares in any given column), and this average was not actually a chequerboard, and so could not be considered as a prototype of the category. In these experiments we only shuffle three rows, to equate the number of squares changed (on average) in Experiments 1 a and 1b, and this means that the chance of a row not being changed from its base position is rather high. Given this, the average of all the shuffled exemplars will now approximate a (slightly blurry) chequerboard, and the claim that this is no longer a prototype-defined category is harder to sustain. Nevertheless, there is no doubt that our procedures with these stimuli lead to a quite different set of results to those obtained with the standard prototype + noise stimuli used in Experiments 1a and 2. A more detailed application of the MKM (McLaren, Kaye and Mackintosh, 1989; further developed in McLaren and Mackintosh, 2000) model to these stimuli helps make it clear why this should be so.

Take the stimuli of Experiments 1a and 2 first. Starting with a base pattern (the prototype), 48 squares are randomly chosen and then set to black or white at random to create each exemplar that will, on average, differ by 24 squares from the prototype. Consider a typical changed square in the middle of the stimulus. It will be surrounded by 8 squares that will mostly be those of the base pattern (on average 0.75 of a square of these 8 will have changed). As a consequence of category pre-exposure, the MKM model tells us that the elements of a stimulus associate to one another, and that this allows them to predict one another, reduce their error scores, and as a consequence their salience decreases. But, for a changed square the predictions from the surrounding elements (which as near neighbours will be important predictors of this square) will be wrong, and so the square will have a very high salience because of it's very high error score. This facilitates discrimination and recognition based on these changed features (which define the exemplars). In the case of the shuffled stimuli in Experiment 1b, because a row is moved as a whole, the squares either side of a changed square will be the same as usual for that square and are the best predictors of that square, even though its location in the stimulus has altered. The predictions of the other surrounding squares (on average 5.75 will be unchanged) will be less important. The essential difference captured by this analysis is that shuffling rows makes the squares in a row the best predictors of one another independent of where that row is in the stimulus, and this acts in opposition to any salience increase that would be gained from location specific prediction effects. Thus category pre-exposure will not be expected to be so beneficial in the shuffled case.

The basis of the inversion effect obtained with prototype-defined categories seems to be in part due to some advantage for the upright exemplars from the familiar category. This was significant in McLaren (1997), and though not independently significant in the studies reported here, if we assess Experiments 1a and 2 in combination by deriving the Z-scores based on their probabilities (1.41 and 0.96), summing them and dividing by $\sqrt{2}$ to get a final Z we have Z=1.67, $p<.05$. The explanation of an advantage for the upright exemplars drawn from the familiar category has already been given but bears some repetition. During categorization, the prototypical elements common to the exemplars of a given category will be routinely exposed, and so will lose salience according to the MKM model (McLaren and Mackintosh, 2000). By way of contrast, the elements unique to each exemplar (which the subjects will have less exposure to), will still have relatively high salience. Hence, the structure of this prototype-defined category will ensure that differential latent inhibition of common and unique elements can happen. This differential latent inhibition as a consequence of categorization leads to perceptual learning, which leads to an improved ability to recognize upright exemplars of the familiar category because this depends on using the unique elements of exemplars rather than the ones they share in common. This advantage would be lost on inversion because subjects are not familiar with those exemplars in an inverted orientation, and hence the unique elements of an exemplar would no longer enjoy a salience advantage over the elements common to most exemplars and the prototype. On the other hand, when subjects are presented with exemplars of a novel category that they have not been pre-exposed to, no mechanisms for latent inhibition and hence perceptual learning can apply (at least not straight away) so there will not be any benefit in recognizing exemplars of that novel category in their upright orientation. Thus, no significant inversion effect would be expected, because an inverted novel chequerboard is just another novel chequerboard.

This leaves us with the evidence that we now have from two studies that familiarity with a prototype-defined category will lead to inverted members of that category being less easily discriminated (McLaren, 1997) or recognized (Experiment 2 of this paper) than novel controls. The implications of this finding are far-reaching, because they suggest that inversion effects, including those with faces, could depend on a disadvantage for familiar inverted stimuli as much as on an advantage for familiar upright stimuli. In fact, it is only experiments of the type reported here which can reveal this possibility, as the baseline for standard face inversion experiments is hard to establish. McLaren (1997) speculates on the possible basis of such a component to the inversion effect if it were to be established that such a component exists. We believe that we have now succeeded in demonstrating that this effect is real, but the explanation of the disadvantage brought about by inversion will have to wait for further research.

Acknowledgments

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