Expertise and the Inversion Effect

Lisa M. Thomas

Thesis submitted in fulfilment of the requirements for the award of Doctor of Philosophy

Department of Psychology
University of Surrey
2002
Abstract

It has often been argued that the processing of faces is 'special' relative to the processing of other objects and there is much evidence in support of this notion. One source of evidence is the inversion effect, which occurs when faces presented upright are recognised significantly better than faces presented upside down. This effect of stimulus inversion has been shown to impair face recognition to a greater extent than for any other object class. It is this disproportionate effect that has been given as one source of evidence that face processing is special.

However, other research has argued that effects of inversion can be found for non-face stimuli providing that there is sufficient development of expertise with them and that these stimuli can be defined by a common prototype. This thesis further explores this idea. Inversion effects were investigated for both prototypically and non-prototypically defined, abstract, chequerboard stimuli and compared with those for faces.

When subjects learned to categorise chequerboard stimuli that were defined by a common prototype equal size inversion effects were found to those observed for faces. However, inversion effects were not observed for category training with multiple exemplars of chequerboard stimuli that were not defined by a common prototype. Together the findings are consistent with the idea that inversion effects are a general phenomenon resulting from the acquisition of category expertise with any prototype defined stimulus category. They undermine the inversion effect as a source of evidence for the specialness of face processing.

Further, using a new Moving Windows technique, additional experiments investigated the underlying mechanisms responsible for the effects of inversion found for faces and chequerboards. These showed that the diagnostic image regions searched differ across the two stimulus classes. However, on the basis of the results, it is argued that the inversion effects found for both could result from impaired processing of second-order configural information.
Acknowledgements

During the four years of work on this thesis, many people have contributed to its progress in different ways. Some have aided the development of my thinking about theoretical issues, other have contributed to the success of the practical research and yet other have provided criticism, advice and encouragement.

I would particularly like to thank my supervisors, Paul Sowden and Ian Davies. Ian gave me the opportunity for doing this research in the first place, and was invaluable in his critical reading of this thesis. Paul’s supervision has been invaluable throughout and characterised by great skill and sensitivity. Discussions with Paul have significantly contributed to my understanding of the theoretical issues surrounding this thesis.

My family and friends have been extremely supportive throughout. I would particularly like to thank my parents and my sister, all of whom have supported me emotionally and financially throughout difficult periods. My friends have been invaluable sources of advice friendship and support, and I would like to mention particularly Nancy Robertson, Michelle Nuttall, Sarah Birch, Stephanie O’Keeffe and Tina Rothi. I would particularly like to thank Robert White, who on a practical level wrote a computer program to enable me to transpose some of the data. On a personal level handled me with encouragement and patience.
# Table of Contents

**CHAPTER 1**

1.1 Introduction: Face and object recognition .............................................. 1
1.2 Developmental Studies ................................................................................ 2
1.3 Prosopagnosia............................................................................................ 3
1.4 Neurophysiological Studies - Single cell recordings .............................. 5
1.5 Neurophysiological studies - Brain imaging ............................................. 6
1.6 Categorisation ............................................................................................ 8
1.7 Prototypes and prototype effects ............................................................. 11
1.8 Expertise....................................................................................................... 12
1.9 Face inversion .......................................................................................... 13
1.10 Configural processing. .................................................... 15
1.11 Summary ...................................................................................................... 18
1.12 Structure of thesis...................................................................................... 21

**CHAPTER 2**

2.1 General Introduction .................................................................................. 22

2.2 Experiment I ................................................................................................ 23
2.2.1 Introduction .................................................................................................. 23
2.2.2 Method .................................................................................................... 24
2.2.2.1 Overall Design ................................................................................. 24
2.2.2.2 Participants ..................................................................................... 24
2.2.2.3 Stimuli – construction and design ....................................................... 25
2.2.2.3.1 Learning / Categorisation Phase .................................................... 25
2.2.2.3.2 Discrimination phase ................................... 26
2.2.2.4 Procedure ........................................................................................ 28
2.2.2.4.1 Learning / Categorisation phase ..................................................... 28
2.2.2.4.2 Discrimination phase ..................................................... 29
2.2.3 Results ...................................................................... 31
2.2.3.1 Learning / Categorisation phase ........................................................ 31
2.2.3.2 Discrimination phase ........................................................................... 31
2.2.3.2.1 Accuracy ................................ 34
2.2.3.2.2 Response times ............................................................................ 34
2.2.3.3 Further analysis .................................................................................... 35
2.2.3.3.1 Development of expertise .................. 35
2.2.3.3.2 Regression analysis .......................................................................... 35
2.2.3.3.3 Termination of categorisation phase..... ......................................... 36
2.2.3.3.4 Expertise development and chance values  .................... 36
2.2.3.3.5 Time Out .............................................................................................. 37
2.2.3.3.6 Averages ............................................................................................. 38
2.2.4 Discussion ................................................................................................... 39
CHAPTER 3

3.1 General Introduction ................................................................. 79

3.2 Experiment 4 ........................................................................ 81
  3.2.1 Introduction .......................................................................... 81
  3.2.2 Method ................................................................................ 82
  3.2.2.1 Participants ................................................................. 82
  3.2.2.2 Stimuli ............................................................................. 82
  3.2.2.3 Overall design ............................................................... 84
  3.2.2.4 Procedure ......................................................................... 85
  3.2.2.4.1 Pre-exposure phase .................................................. 85
  3.2.2.4.2 Category learning phase .......................................... 85
  3.2.2.4.3 Test phase ................................................................. 87
  3.2.3 Results ................................................................................ 88
  3.2.3.1 Category learning phase ............................................. 88
  3.2.3.2 Test phase ..................................................................... 88
  3.2.4 Discussion ........................................................................... 91

3.3 Experiment 5 ........................................................................ 94
  3.3.1 Introduction .......................................................................... 94
  3.3.2 Method ................................................................................ 95
  3.3.2.1 Participants ................................................................. 95
  3.3.2.2 Stimuli ............................................................................. 95
  3.3.2.3 Overall Design ............................................................... 97
  3.3.2.4 Procedure ......................................................................... 98
  3.3.2.4.1 Pre-exposure, category learning phase and test phase ... 98
  3.3.3 Results ................................................................................ 99
  3.3.3.1 Category learning phase ............................................. 99
  3.3.3.2 Test phase ..................................................................... 99
  3.3.4 Discussion ........................................................................... 102

3.4 Chapter 3 – General Discussion ............................................. 105
CHAPTER 4 .............................................................................................................. 106
4.1 General Introduction ........................................................................................ 106

4.2 Experiment 6 .................................................................................................. 108
4.2.1 Introduction ............................................................................................... 108
4.2.2 Method ....................................................................................................... 109
4.2.2.1 Participants ........................................................................................... 109
4.2.2.2 Stimuli .................................................................................................. 109
4.2.2.3 Design .................................................................................................... 111
4.2.2.4 Procedure ............................................................................................ 111
4.2.2.4.1 Pre-exposure, category learning and test phase ....................... 111
4.2.3 Results ...................................................................................................... 112
4.2.3.1 Category learning phase .................................................................... 112
4.2.3.2 Test phase ........................................................................................... 112
4.2.4 Discussion ................................................................................................. 115

4.3 Experiment 7 .................................................................................................. 118
4.3.1 Introduction ............................................................................................... 118
4.3.2 Method ....................................................................................................... 120
4.3.2.1 Participants ........................................................................................... 120
4.3.2.2 Overall Design ...................................................................................... 120
4.3.2.3 Stimuli .................................................................................................... 120
4.3.2.4 Procedure ........................................................................................... 121
4.3.2.4.1 Pre-exposure, Category learning phase and Test Phase .......... 121
4.3.3 Results ...................................................................................................... 122
4.3.3.1 Category learning phase .................................................................... 122
4.3.3.2 Testing phase ........................................................................................ 122
4.3.4 Discussion ................................................................................................. 125

4.4 Experiment 8 .................................................................................................. 128
4.4.1 Introduction ............................................................................................... 128
4.4.2 Method ....................................................................................................... 129
4.4.2.1 Participants ........................................................................................... 129
4.4.2.2 Design .................................................................................................. 129
4.4.2.3 Stimuli .................................................................................................... 129
4.4.2.4 Procedure ............................................................................................ 130
4.4.2.4.1 Pre-exposure, category learning and test phase ....................... 130
4.4.3 Results ...................................................................................................... 131
4.4.3.1 Category learning phase .................................................................... 131
4.4.3.2 Test phase ........................................................................................... 131
4.4.4 Discussion ................................................................................................. 134

4.5 Chapter 4 – General Discussion ...................................................................... 135

VI
CHAPTER 5

5.1 General Introduction ................................................................. 139

5.2 Experiment 9 ................................................................................ 141
5.2.1 Introduction ............................................................................. 141
5.2.2 Method ................................................................................... 142
5.2.2.1 Participants ......................................................................... 142
5.2.2.2 Stimuli ............................................................................... 142
5.2.2.3 Overall Design ..................................................................... 144
5.2.2.4 Procedure ........................................................................... 144
5.2.2.4.1 Pre-exposure and category learning phase ......................... 144
5.2.2.4.2 Test Phase / old – new recognition .................................. 144
5.2.3 Results .................................................................................. 145
5.2.3.1 Category learning phase ..................................................... 145
5.2.3.2 Test phase .......................................................................... 145
5.2.4 Discussion .............................................................................. 148

5.3 Experiment 10 ........................................................................... 150
5.3.1 Introduction ............................................................................. 150
5.3.2 Method ................................................................................... 152
5.3.2.1 Participants ......................................................................... 152
5.3.2.2 Stimuli ............................................................................... 152
5.3.2.3 Overall design ..................................................................... 152
5.3.2.4 Procedure ........................................................................... 154
5.3.2.4.1 Pre-exposure phase ......................................................... 154
5.3.2.4.2 Category learning phase .................................................. 154
5.3.2.4.3 Test phase ....................................................................... 154
5.3.3 Results .................................................................................. 156
5.3.3.1 Category learning phase ..................................................... 156
5.3.3.2 Testing phase ................................................................. 157
5.3.3.2.1 Accuracy and response time data ...................................... 157
5.3.3.2.1.1 Faces ............................................................................ 157
5.3.3.2.1.2 Chequerboards ............................................................ 159
5.3.3.2.2 Accuracy and response time data – summary .................... 161
5.3.3.3 Sequence data ................................................................. 163
5.3.3.3.1 Number of iterations ..................................................... 163
5.3.3.3.2 Average position of window moves ................................. 164
5.3.3.3.3 Statistical examination .................................................. 168
5.3.3.4 Summary of findings for sequence data ............................. 173
5.3.4 Discussion .............................................................................. 174
5.3.4.3 Faces ............................................................................... 174
5.3.4.4 Chequerboards ................................................................. 174
5.3.4.5 Comparison of the faces and chequerboards ....................... 174

5.4 Chapter 5 – General Discussion .............................................. 177
CHAPTER 6

6 General Discussion ........................................................................ 179
6.1 Summary of chapters .................................................................. 179
6.1.1 Chapter 2 .................................................................................. 179
6.1.2 Chapter 3 .................................................................................. 180
6.1.3 Chapter 4 .................................................................................. 181
6.1.4 Chapter 5 .................................................................................. 183
6.2 Overall Conclusions ...................................................................... 184
6.3 Are faces special? ........................................................................ 185
6.4 Categorisation ............................................................................ 185
6.4.1 Expertise .................................................................................. 186
6.5 Comparison with McLaren's work .............................................. 188
6.6 Chequerboards ........................................................................ 188
6.7 Prototypes .................................................................................. 190
6.8 Configural processing ................................................................. 192
6.8.1 Composites ............................................................................ 193
6.8.2 Moving window ....................................................................... 194
6.9 Importance of face recognition .................................................. 196
6.10 Conclusions ............................................................................ 197
6.11 Further Analysis ....................................................................... 198

References ..................................................................................... 201
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>209</td>
</tr>
<tr>
<td>Figure 3</td>
<td>209</td>
</tr>
<tr>
<td>Figure 4</td>
<td>210</td>
</tr>
<tr>
<td>Figure 5</td>
<td>210</td>
</tr>
<tr>
<td>Elimination by regression</td>
<td>211</td>
</tr>
<tr>
<td>Termination of categorisation phase</td>
<td>211</td>
</tr>
<tr>
<td>Expertise and chance values</td>
<td>212</td>
</tr>
<tr>
<td>Time out</td>
<td>212</td>
</tr>
<tr>
<td>30 participants</td>
<td>213</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>214</td>
</tr>
<tr>
<td>Figure 6</td>
<td>214</td>
</tr>
<tr>
<td>Figure 7</td>
<td>215</td>
</tr>
<tr>
<td>Categorisation phase</td>
<td>215</td>
</tr>
<tr>
<td>Discrimination phase</td>
<td>216</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>219</td>
</tr>
<tr>
<td>Figure 10</td>
<td>219</td>
</tr>
<tr>
<td>Figure 11</td>
<td>220</td>
</tr>
<tr>
<td>Further analysis</td>
<td>220</td>
</tr>
<tr>
<td>Further analysis</td>
<td>221</td>
</tr>
<tr>
<td>Experiment 4</td>
<td>224</td>
</tr>
<tr>
<td>Figure 13</td>
<td>224</td>
</tr>
<tr>
<td>Figure 14</td>
<td>224</td>
</tr>
<tr>
<td>Experiment 5</td>
<td>225</td>
</tr>
<tr>
<td>Figure 16</td>
<td>225</td>
</tr>
<tr>
<td>Figure 17</td>
<td>225</td>
</tr>
<tr>
<td>Experiment 6</td>
<td>226</td>
</tr>
<tr>
<td>Figure 20</td>
<td>226</td>
</tr>
<tr>
<td>Figure 21</td>
<td>226</td>
</tr>
<tr>
<td>Experiment 7</td>
<td>227</td>
</tr>
<tr>
<td>Figure 24</td>
<td>227</td>
</tr>
<tr>
<td>Figure 25</td>
<td>227</td>
</tr>
<tr>
<td>Experiment 8</td>
<td>228</td>
</tr>
<tr>
<td>Figure 28</td>
<td>228</td>
</tr>
<tr>
<td>Figure 29</td>
<td>228</td>
</tr>
<tr>
<td>Experiment 9</td>
<td>229</td>
</tr>
<tr>
<td>Figure 31</td>
<td>229</td>
</tr>
<tr>
<td>Figure 32</td>
<td>229</td>
</tr>
<tr>
<td>Experiment 10</td>
<td>230</td>
</tr>
<tr>
<td>Figure 33</td>
<td>231</td>
</tr>
<tr>
<td>Figure 34</td>
<td>231</td>
</tr>
<tr>
<td>Figure 35</td>
<td>231</td>
</tr>
<tr>
<td>Figure 36</td>
<td>231</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1 - Categorisation phase stimuli: An example of two prototypes A and B, and four exemplars of each of these prototypes.................................................................26

Figure 2 - This shows a prototype used in the discrimination phase, two exemplars and two inverted exemplars. .....................................................................................27

Figure 3 - McLaren's accuracy figures for the upright and inverted stimuli for discrimination phase. ........................................................................................................32

Figure 4 - Accuracy for the upright and inverted stimuli for discrimination phase of experiment 1 .................................................................33

Figure 5 - Mean response times in milliseconds for the upright and inverted stimuli in the discrimination phase..........................................................33

Figure 6 - Mean percentage correct for familiar and novel upright and inverted stimuli during the discrimination phase .................................................49

Figure 7 - Mean response times in milliseconds for the familiar and novel upright and inverted stimuli during the discrimination phase. ..................49

Figure 8 - This shows four exemplars from the 'A' category and four from the 'B' category for the categorisation phase.........................................................61

Figure 9 - This shows an example of two of the faces used in the discrimination phase of the experiment, presented both upright and inverted.................65

Figure 10 - Accuracy data for the discrimination phase of the experiment ....67

Figure 11 - shows the mean response times for the discrimination phase ....68

Figure 12 - This diagram shows face stimuli from two categories with variations in the percentage of the noise face.................................................................83

Figure 13 - Accuracy for upright and inverted stimuli during the test phase. ....89

Figure 14 - Mean response times in milliseconds for upright and inverted stimuli during the test phase. .................................................................89

Figure 15 – Globally orientated chequerboards. The numbers indicating the number of rows changed from the prototype in order to create each exemplar.........96
Figure 16 - Accuracy for the upright and inverted stimuli in the test phase

Figure 17 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase

Figure 18 - shows a comparison of the size of the inversion effect for faces (experiment 4) and chequerboards (experiment 5)

Figure 19 - Non-prototypically defined, globally orientated chequerboards

Figure 20 - Accuracy for the upright and inverted stimuli of the test phase

Figure 21 - Mean response times in milliseconds for the upright and inverted stimuli of the test phase

Figure 22 - Accuracy comparison for experiments 5 & 6

Figure 23 - Stimuli from two chequerboard categories. Categories A and B are both defined by a prototype and are a sample of the multiple exemplars

Figure 24 - Accuracy for the upright and inverted stimuli in the test phase

Figure 25 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase

Figure 26 - Comparison of accuracy for experiment 5 and experiment 7

Figure 27 - Example stimuli from 2 categories of non-prototypically defined chequerboards

Figure 28 - Accuracy figures for the upright and inverted stimuli in the test phase

Figure 29 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase

Figure 30 - Chequerboard composites and non-composites (left and right)

Figure 31 - Average accuracy figures for the composite and non-composite chequerboards

Figure 32 - shows the mean response times in milliseconds for the composites and non-composites

Figure 33 - Accuracy figures for upright and inverted face stimuli for test phase
Figure 34 - shows the mean response times for the upright and inverted face stimuli in the testing phase

Figure 35 - Accuracy for the test phase with the chequerboard stimuli

Figure 36 - shows the mean response times for the upright and inverted chequerboard stimuli in the testing phase

Figure 37 - Inversion effects found in experiments 4 and here for the faces

Figure 38 - Upright and inverted, familiar and novel face moves. Shown as both intensity maps (left) and as 'masked' images (right)

Figure 39 - Upright and inverted, familiar and novel chequerboard moves. Shown as both intensity maps and as 'masked' images

Figure 40 - Intensity maps and 'masked' face images from 2 different participants

Figure 41 - Intensity maps and 'masked' images from 2 different participants

List of Tables

- Table 1 - Allocation of the prototype images, for the categorisation and discrimination phases of the experiment
- Table 2 - Averaged overall means for faces and chequerboards
- Table 3 - Face PCA results
- Table 4 - Chequerboard PCA results
CHAPTER 1

1.1 Introduction: Face and object recognition

In many ways it is hard to see why face and object recognition are seen as distinct. Whether the content of the image is a common object or a face, our visual system must create a representation that is invariant over at least a range of viewing conditions and yet discriminate among exemplars (Farah, 2000). Yet, there is an enormous volume of evidence that argues that face recognition is different from object recognition and that the face recognition process is in many ways special and distinct from that of objects (e.g. Valentine, 1998; Desimone, 1991, Johnson, Dziurawiel, Ellis and Morton, 1991). On the other hand there is also evidence that the two are processed by the same system and that the crucial difference between the two lies in the level of expertise (e.g. Gauthier, Tarr, Anderson, Skudlarski and Gore, 1999).

The ability to recognise faces is fundamental to social interaction and person identification. This social significance requires us to be ‘experts’ at face recognition. It may be that it is relative expertise that distinguishes face recognition from object recognition. There may be less requirement to become expert at object recognition, but when we do, object recognition has many of the characteristics of face recognition (e.g. Diamond and Carey, 1986 and Gauthier, Anderson, Tarr, Skudlaski and Gore, 1997). Thus, what is ‘special’ about face recognition may be that it
is simply an everyday example, and the most commonly encountered
case, of expert recognition. In the next sections the various sources of
evidence for the 'specialness' of face processing are reviewed together
with criticisms of this work.

1.2 Developmental Studies

It is important to emphasise how much infants depend upon the
recognition of faces of their caregivers in order to develop in the world.
Thus, from an evolutionary perspective it would be advantageous for
infants to come into the world knowing something about faces as an
important and distinct class of objects (Roth and Bruce, 1995). Face
recognition and developmental studies support this view.

Infants have been shown to pay increased attention to faces as well as
demonstrating the ability to recognise faces from a very early age
(Baylis, Rolls and Leonard, 1985). Goren, Sarty and Wu (1975) showed
that newborn infants would track schematic face-like patterns more than
control patterns with the same features rearranged. This result was
supported more recently by Johnson, Dziurawiel, Ellis and Morton (1991)
who suggest that human infants may come equipped with knowledge of
roughly what heads and faces look like. This innate knowledge may allow
them to attend selectively to such objects so that they can subsequently
learn more about the appearance of their own caregivers. They argue
that what is innate is in fact the ability to pay attention to faces and that
this attentional bias then acts to direct a different neural system to learn about individual characteristics of faces. The rapid learning of parental appearance within the first few days as demonstrated in experiments by Bushnell, Sai and Mullen (1989) is consistent with Johnson’s arguments that infants have innate knowledge of faces. Note that the foregoing argument essentially provides motivation for learning about faces. It says nothing about the processes underlying face recognition per se.

1.3 Prosopagnosia

Prosopagnosia is a neurological disorder in which patients cannot recognise faces and it provides the most compelling evidence for a specific mechanism for face processing (Whitely and Warrington, 1977). Face recognition impairments are often due to injury to the right cerebral hemisphere. Consistent with this, evidence from neuropsychological studies has shown that different areas of the brain are involved in face recognition and object recognition (Farah, Klein and Levinson, 1995). Young and Bruce (1991) studied brain injury patients with right hemisphere damage resulting in prosopagnosia. They found that the fusiform gyrus area of the brain was specifically responsible for the recognition of faces. Even more striking evidence comes from patients with preserved face recognition but impaired object recognition. For
instance, Moscovitch, Winocur and Behrmann (1997) reported a case with severe impairments in reading and object recognition but with completely normal face recognition (see also Humphreys and Rumiati, 1998).

Despite the double dissociation between object and face recognition (referred to above) there is also evidence that virtually all prosopagnosics have difficulties making at least some other within-category visual discriminations (Etcoff, Freeman and Cave, 1991). Etcoff, et. al. argue that prosopagnosia reflects a more generalised disorder of individuating members of a visually similar class of object or even that it is a general difficulty distinguishing objects that share the same global shape and that are visually complex stimuli.

Similarly, Gauthier, Behrmann and Tarr (1999) argue that the literature on prosopagnosia fails to demonstrate unequivocal evidence for a disproportionate impairment for faces as compared to non-face objects. They tested two prosopagnosic patients for the discrimination of objects from several categories, including faces, at different levels of categorisation (basic, subordinate and exemplar). Their findings showed that regardless of object category, the prosopagnosics were more affected by manipulations of the level of categorisation than normal controls.
1.4 Neurophysiological Studies - Single cell recordings

Studies measuring the activity of single cells in the temporal lobe have found cells that only respond to faces (e.g. Heywood and Cowry, 1992 and Rolls, 1992). Cells have also been found that respond exclusively to non-face objects (Baylis, Rolls and Leonard, 1987) although the selectivity and strength of such responses are weaker than for face cells.

Tanaka (1996) investigated whether the regions of the brain involved in acquiring visual expertise for non-face stimuli were the same as those involved in face recognition. He trained monkeys to discriminate between stimuli that were visually similar, and found neurones that selectively responded to stimuli from the trained set were found in the inferotemporal cortex after training in a greater proportion than those found before training. Responses to the trained stimuli and to faces were collected. No evidence was found that the cells responsive to the trained stimuli were responsive to faces. Indeed anatomical information suggested that these two areas were physically segregated. This suggests that distinct neural populations are involved in face recognition and in making expert discriminations within a non-face category.

Conversely, Logothetis, Pauls and Poggio (1995) demonstrated a similarity between the properties of the face cells and those of the ‘amoeba-selective’ neurones recorded from expert monkeys. These neurones show selectivity to complex configurations that cannot be
reduced without diminishing the cell's response to specific views. Face cells are sensitive to configuration of features and may be mediating the configural sensitivity that is a hallmark of upright face recognition (Young and Yamane, 1992). This evidence is consistent with the possibility that the responses of these cells are built from experience and adapted to the interactions of an animal with objects. In most cases, animals need to recognise most objects at a categorical level and faces at the exemplar level. However, if animals need to treat other objects like faces and discriminate visually similar exemplars, a number of cells may begin to represent the features that are best suited to this task (Gauthier and Logothetis, 2000).

1.5 Neurophysiological studies - Brain imaging

Functional brain imaging investigations of the normal human brain have complemented the evidence from the neuropsychology and single cell recordings. The activities of whole ensembles of cells are measured using brain imaging. Kanwisher, McDermott and Chun (1997) used functional magnetic resonance imaging (fMRI) and found an area in the fusiform gyrus that was activated at least twice as strongly for faces as for a wide variety of non-face stimuli. Kanwisher and colleagues concluded that this area is selectively involved in the perception of faces.
However, there is substantial evidence that the fusiform face area (FFA) may not be exclusively involved in face recognition, but may instead be involved in face detection (i.e. recognising a face is a face) (Tong, Nakayama, Moscovitch, Weinrib and Kanwisher, 2000). Gauthier, Williams, Tarr and Tanaka (1998) trained participants to be experts at identifying 'Greebles'. These, like faces, share a common spatial configuration and they found that the 'face area' (fusiform gyrus) of the brain became increasingly activated when discriminating amongst 'Greebles', thus indicating that the neurons in this area are not specific to the perception of faces.

Various other studies using fMRI have shown the 'face' area can respond to birds, cars and greebles when 'experts' view these categories. Notably, Gauthier, Skudlarski, Gore and Anderson (2000) tested bird and car experts with fMRI during tasks with faces, familiar objects, cars and birds. Their findings showed that homogeneous categories activated the FFA more than familiar objects and the right FFA showed significant expertise effects. This suggests that the level of categorisation and expertise, rather than superficial properties of objects, determine the specialisation of the FFA. Indeed, expertise seems to be one factor that leads to specialisation in the face area (Gauthier, Tarr, Anderson, Skudlarski and Gore, 1999).
1.6 Categorisation

Category learning often accompanies the acquisition of perceptual expertise. Gibson and Gibson (1955) suggested that simply through repeated exposure to the stimulus array, the process of perceptual expertise can be developed and can lead to an individual learning to differentiate finer and finer properties of the physical world. Similar learning processes have probably been involved in developing the ability to discriminate faces and possibly other objects.

The categorisation of natural objects is thought to involve many levels of processing. The law of ‘cognitive economy’ (Rosch, 1978) dictates that it is necessary to organise the world into stable units of information based on some principle rather than to treat every new instance as a new event. The process of ordering the world into categories i.e. categorisation, means that things with similar attributes become represented as equivalent. Having a series of organised categories means that everything encountered does not have to be dealt with as a unique event and it becomes possible to generate inferences. A fundamental question concerns how much of the level of structure of categories is predetermined and how much it emerges through learning (Schyns and Rodet, 1997).
Levels of categories. Most objects are recognised at what has been called a ‘basic’ level of abstraction e.g. bird or chair (e.g. Jolicoeur, Gluck and Kosslyn, 1984 and Tanaka and Taylor, 1991). However, all objects can be recognised at several different levels including more subordinate levels (robin, sparrow etc.). Objects in different basic level categories are distinguished from one another by the presence (or absence) of certain parts or configurations of parts (e.g. the presence of wings are diagnostic of a bird). Whereas, objects within the same basic-level category have the same parts and configuration of parts (e.g. wings on either side of a bird). Thus, to be able to discriminate objects at subordinate level we must rely on variations in the basic configuration of features (Diamond and Carey, 1986). It may be this ability to discriminate objects at a subordinate level that is enhanced during category learning, thus leading to the development of expertise.

Research using novel stimuli has investigated the effects of expertise and category learning. Many studies exploring expertise have used recognised experts, with a consequent lack of control over the training conditions. Gauthier, Williams, Tarr and Tanaka (1998) overcame this limitation with a series of experiments studying expert object recognition processes. They constructed categories of ‘Greebles’, novel objects that, like faces, share a common spatial configuration. Gauthier and her colleagues began by asking whether experienced perceivers employ the same mechanisms as novices in identifying the same object. To explore this they trained individuals to become ‘expert Greeble perceivers’ using
various categorisation and identification tasks. They concluded from their observations, that the nature of expertise is multi-faceted, and cannot be assessed by a single task or described by a single term. With respect to experts and novices they found that ‘Greeble experts’ were beginning to process ‘Greebles’ configurally and that the ability to use configural coding may develop slowly across time.

Another series of studies concerned with the acquisition of expertise through category learning were conducted by Schyns and Rodet (1997), using computer generated ‘Martian cell’ stimuli. Although they did not set out to study expert categorisation per se, they argued that the perceptual organisation of experts is very different from that of novices. The results showed that varying the order of category learning induced the creation of different ‘functional features’, effectively new holistically perceived features. These changed the perceptual appearance and featural representation of identical category exemplars. They maintain that features can be learned flexibly as a consequence of categorising and representing objects.
1.7 Prototypes and prototype effects

A prototype can be regarded as the original or most typical instance of a 
class or category of things (Rosch and Mervis, 1975). It can be seen as 
the way in which objects are represented in memory, an abstraction (not 
the original) based on shared features or functions of the members of the 
class. That is, the prototype is the best example that summarises the 
most common or typical exemplar of that category. For example, if the 
prototype is seen as the basic level – Dog, then a subordinate category 
exemplar would be – Labrador. Basic level objects are the first to be 
learned and are at the highest level in which the exemplars of the 
category share properties with members of other categories (Rosch, 
Mervis, Gray, Johnson and Boyes-Braem, 1976).

Distributed memory systems are capable of extracting the prototype from 
a series of exemplars while retaining information regarding the particular 
exemplars shown (McClelland and Rumelhart, 1985). A face prototype 
might be considered to be both the presence and arrangement of the 
eyes, nose and mouth. Bruce, Doyle, Dench and Burton (1991) created 
different versions of the same faces by changing the relative placement 
of the internal features, hence creating variations or exemplars of the 
category prototype. Their subjects saw the different versions (category 
exemplars) and were asked to rate them. They found that whilst
sensitivity to exemplars was retained, memory for those different faces operated in a way that enhanced responses to 'prototypical' configurations, even when they had not been studied. This indicates that the subjects were capable of extracting the prototype from the face exemplars.

Valentine and Bruce (1986c) suggest that a facial prototype may be an emergent property of overlaying many instances of face exemplars in a distributed memory network. Therefore, the extraction of facial prototype is not a face-specific process. The effects of face distinctiveness arise simply because faces form an expert's homogeneous category of which many exemplars are experienced. Therefore, the ability to extract a prototype from the category exemplars could be used as a criterion to define 'expertise' in discriminating within an object stimulus class.

1.8 Expertise

As a result of practice expertise is developed. This leads to quick and accurate performance as well as a degree of automaticity in accomplishing certain aspects of tasks (Shiffrin and Schneider, 1977).

The crucial property of expertise may be that it lowers (makes more specific) the basic level of recognition (e.g. Tanaka, 1996). The social importance of faces requires that we recognise individual faces, and the individual may be the basic level, as opposed to man / woman or young / old. With objects, much of the time, the object class level may be
sufficient (e.g. 'a tree', or even 'an oak tree') but rarely is it defined more specifically (e.g. a particular oak tree). However, if circumstances require more specific recognition of individual objects, they may be processed in the same way as faces (Gauthier, Skudlarski, Gore and Anderson, 2000 and Archaumbault, O'Donnell and Schyns, 1999). This implies that experts in particular domains of object recognition may show those characteristics of face processing, such as the inversion effect (e.g. Diamond and Carey, 1986).

As well as a shift in the basic level of categorisation, expertise may bring specific reliance on configural information (Kohler, 1940; Diamond and Carey, 1986 and Leder and Bruce, 2000). Inversion prevents the use of configural information, so that both experts and novices must rely on isolated features to recognise inverted stimuli.

1.9 Face inversion

Yin (1969) first reported a disproportionate effect on the ability to remember inverted faces when compared with other mono-orientated inverted objects. This effect has been replicated more recently with other objects such as aeroplanes, houses and outdoor scenes (e.g. Diamond and Carey, 1977; Diamond and Carey, 1986; Valentine and Bruce, 1986b; Yin, 1969, 1970). Valentine (1988) argues that this differential inversion effect provides a further indication that face recognition is
different from object recognition. This led to the suggestion that the
difficulty of looking at upside-down faces involves both a general factor of
familiarity with mono-orientated objects and a special factor only related
to faces (Yin, 1969).

However, the differential effect of inversion, found for faces and objects,
may be a function of degree of expertise required for recognition. For
example, Diamond and Carey (1986) studied memory for faces of dogs
in both lay persons and dog breeders and judges. They found that dog
experts were disproportionately affected by inversion of dog pictures
compared with the non-experts.

These results show pre-existing expertise with a specific stimulus domain
can produce a strong inversion effect. Indeed, Gauthier, Tarr, Anderson,
Skudlarksi and Gore (1999) showed that following training, to develop
sufficient expertise with their 'greeble' stimuli, inversion effects were
produced. Similarly, McLaren (1997) showed that inversion effects could
be induced following training with novel stimuli (random chequerboards)
provided that the category was defined by a prototype (developed further
in subsequent section). He argued that it is crucial to control the level of
expertise in investigating the nature of object recognition and it is the lack
of control that has led to faces being considered special, along with a
failure of appropriate comparison objects.
1.10 Configural processing

Adult’s expertise at recognising faces has been attributed to configural processing (e.g. Rhodes, Brake, Taylor and Tan, 1989). The term ‘configural processing’ has been used to refer to any phenomenon that involves perceiving relations among the features of a stimulus such as a face (Maurer, LeGrand and Mondloch, 2002). Configural processing of faces can be divided into three types: (1) First-order relations (local features), seeing that a stimulus is a face because of the arrangement of the internal features. (2) Holistic processing (global features), seeing the individual features as a gestalt. (3) Second-order relations, perceiving the spatial distances among internal features (relational processing).

Inversion has been said (Maurer, et al., 2002) to affect each type of configural processing although it has been typically attributed to second-order relations.

The ‘Thatcher illusion’ (Thompson, 1980) shows that the rotation of the eyes, nose and mouth make a face look grotesque. However, this grotesqueness is only apparent when the face is upright, it goes unnoticed when the face is inverted. This is taken as evidence that the configural processing of features that specify the first-order relations are disrupted by inversion.
Further, Young, Hellawell and Hay (1987) demonstrated the importance of 'holistic' configurational information in face perception and that configurations are only properly perceived in upright faces. They used facial composites, in which photographs of the top and bottom halves of different familiar faces fused to form unfamiliar faces when aligned with each other. The perception of a novel configuration in such composite stimuli was sufficiently convincing to interfere with identification of the constituent parts but this effect disappeared when the stimuli were inverted. This was taken as evidence that the effect of inversion is to prevent (holistic) configural processing.

Haig (1984) demonstrated the way in which small changes in the configuration of a constant set of facial features can alter a person's appearance. This second-order (relational) configural processing was further demonstrated more recently by Leder and Bruce (1998). Using face stimuli with different spatial relations between single features they found that this information proved to be crucial for facial recognition. Their experiments show the disruption of the processing of relational, rather than holistic, information determines the occurrence and size of the inversion effect.
Many experiments have shown that faces are processed as configurations of interacting features, not just as collections of isolated features and the importance of configural information in face perception has been widely accepted (e.g. Freire, Lee and Symons, 2000). However, as noted in a previous section, it is now clear that comparable inversion effects can be found for stimulus classes other than faces, provided that their members share similar appearances and that the perceiver is expert at differentiating them (e.g. Diamond and Carey, 1986; Gauthier, Williams, Tarr and Tanaka, 1998 and Gauthier, Skudlarski, Gore and Anderson, 2000). In other words, whilst face recognition may rely more heavily on processing of configural information than object recognition in general, an equally familiar and homogeneous stimulus class (i.e. one that is prototypically defined) might be expected to show similar dependence on the processing of configural properties.
Faces differ from other objects in several important respects. Firstly, faces are the earliest encountered case of visually important stimuli, this and the subsequent repeated exposure to faces over a lifetime leads to the development of face expertise. Secondly, it is often sufficient to identify common non-face objects at the basic level of categorisation without determining the specific exemplar of the category. For faces we usually proceed beyond the general category face to determine the identity of the particular individual. We probably also look to discriminate between faces more than any other class of visual stimuli. Thus, we are all face experts and it is possible that the mechanisms we use to process faces are not specialised for face processing per se but rather for making fine-grained discriminations between visually similar exemplars of any category.

There is a growing body of evidence that reflects the notion that faces are not a 'special' case and that it is the level of expertise which is gained for faces that is important. It may be that other object classes may show similar effects to those found with faces providing that the level of expertise with other non-face stimuli remains constant and is comparable with faces.
The face inversion effect has long been used as evidence that faces are ‘special’. However, inversion effects comparable with faces have been found for other object classes (e.g. Diamond and Carey, 1986) which challenge the ‘specialness’ argument. Indeed, it may be that providing the object class shares the same properties of the face, in that it can be defined by a prototype, and that sufficient expertise is gained with that object class, then comparable effects of inversion might be found with any non-face object class.

Much of the evidence for faces being ‘special’ reflects the notion that there are separate processing mechanisms operating for faces and objects (e.g. Valentine, 1998). This comes from studies on the inversion effect, and the distortion of facial features (Yin, 1969).

The work carried out by McLaren (1997) showed an analogue of the face inversion effect. He did a rather neat experiment that used chequerboard stimuli. These possess characteristics similar to those found in faces in that they are derived from a prototype and that the level of expertise gained with the stimuli was sufficient to produce an inversion effect comparable with faces. In his experiment participants were required to learn category membership of two sets of exemplars during a ‘categorisation phase’. Following this, in a discrimination phase, a selection of chequerboards that had been learnt in categorisation (familiar) together with a new set of chequerboards (novel) were presented in their upright and inverted orientations. In this discrimination
phase participants were required to track the position of stimuli which were displayed either to the left or right on a computer screen. However, the correct stimulus to choose, whilst being consistent over this phase of the experiment, was completely arbitrary. The results of his experiments showed an inversion effect with the chequerboards that was contingent upon familiarity with a category and on the category possessing a prototypical structure.

However, whilst the work of McLaren supports the view that faces are not 'special', and shows effects that are comparable with faces, he did not directly compare his chequerboard stimuli with faces. Neither did he explore any of the underlying mechanisms that might lead to comparable effects. Thus, in this thesis, chequerboard stimuli are used to investigate the nature of the inversion effect and indeed if this can be said to be comparable with faces.
1.12 Structure of thesis

The following chapters report experiments that investigate:

I. Expertise. As a starting point, chapter 2 describes attempts to replicate McLaren's findings before exploring in more detail their likely explanation. This, and the following chapter (3), then move on to investigate the importance of expertise for the occurrence of inversion effects with non-face objects. Note: - Expertise, in the current thesis, means learning to distinguish members of a category from members of another category as a result of category training. This is clearly different from the long-term expertise developed in tasks such as medical image perception where, multiple stimulus categories and variations have to be learned.

II. Prototypes. Chapter 4 investigates the nature of the stimuli that are capable of producing inversion effects and whether or not they are prototype derivatives. This chapter then moves on to address the issue of multiple versus limited stimulus training sets.

III. Processing mechanisms – configural versus local, feature based. Chapter 5 looks at how the inversion effect is produced, by exploring the nature of the processing and whether this is the same for objects that produce inversion effects as it is for faces.
CHAPTER 2

2.1 General Introduction

This chapter sets out to first replicate McLaren's (1997) experiment. It then leads on to investigate the nature of expertise, how expertise can be developed through category learning and ways in which the development of expertise can be demonstrated.

The experiments in this chapter start by using chequerboard stimuli, similar to those used in the experiments by McLaren (1997) and these chequerboards form categories. Chequerboards are very useful stimuli to work with. Here, they are 16 x 16 black and white square stimuli that are easily produced by computer generation which give them advantages over other more naturally occurring stimuli. A chequerboard prototype can give many category exemplars by adding 'noise' in the form of changing randomly selected squares from black to white and vice versa. These category exemplars can then be coded as deviations from the prototype and used in discrimination experiments as detailed here.
2.2 Experiment I

2.2.1 INTRODUCTION

This experiment was designed to investigate the claims that the inversion effects, reported for face perception, are dependent on expertise (e.g. McLaren, 1997). Diamond and Carey (1986) showed that stimulus inversion disproportionately affected recognition by experts in their expert stimulus domain, compared with non-experts, in the same domain. McLaren (1997) demonstrated inversion effects contingent upon expertise, analogous to those observed with faces, using simple chequerboard stimuli. He argued that demonstrating the same effect with qualitatively different stimuli from faces suggests that the underlying statistical structure shared between stimuli is what matters. This, he contends, is that they belong to a category defined in terms of a prototype.

Here McLaren's (1997) propositions about the importance of category expertise for inversion effects were tested. To this end, the experiment here replicated the one by McLaren using his chequerboard stimuli.
2.2.2 METHOD

2.2.2.1 Overall Design

Both the stimuli and the experimental design were replicated from the experiment as detailed by McLaren (1997). The stimuli were black and white chequerboards and were first presented individually in a category learning phase, where participants were required to learn the membership of two categories. This was followed by a discrimination phase where two chequerboards were presented together and participants were required to choose one of them. On half of these trials the chequerboards were from the two previously learned categories (familiar) and the remainder were from two novel categories. All of the chequerboards were presented both upright and inverted. Response times and accuracy data were collected.

2.2.2.2 Participants

Thirty participants completed this experiment. All participants were between the ages of 18 and 35 and had no previous experience with the stimuli.
2.2.2.3 Stimuli – construction and design

The stimuli were 2cm square chequerboards (see figure 1); each chequerboard contained 16 x 16 squares, with each square consisting of 4 x 4 pixels and were displayed on a computer screen with a resolution of 600 x 800 pixels.

2.2.2.3.1 Learning / Categorisation Phase

Four base stimuli were generated at random for each of the participants. This was done by randomly setting each 4 x 4 pixel square to either black or white. These base stimuli, or prototypes, defined four categories. From each of the four prototypes, a set of exemplars were generated (see figure 1). Two of the prototypes were used in the category learning phase and therefore formed two familiar categories. The other two formed two novel categories. The exemplars were created, from each prototype, by randomly replacing an entire row with a new randomly generated row. The process was repeated eight times and on each occasion all of the 16 rows were eligible for replacement. Thus, each exemplar shared roughly 80% of its squares with the category prototype.
2.2.2.3.2 Discrimination phase

Four pairs of stimuli were used in this phase of the experiment. Both stimuli in a pair were exemplars derived from the same category prototype. Stimuli were presented 0.5 cm apart on either side of a fixation cross, in the centre of the screen. The exemplars were constructed by first taking a category prototype, then for each exemplar in a pair two rows of the prototype were selected at random and replaced with two randomly generated rows. Each pair of exemplars could therefore differ in four rows (see Figure 2).
Figure 2 - This shows a prototype used in the discrimination phase, two exemplars and two inverted exemplars.

One pair of stimuli were exemplars drawn from one of the categories used in the participant’s initial categorisation phase and were presented in the upright orientation (familiar upright). A different pair of exemplars, drawn from the same category was displayed upside down (familiar inverted). This produced familiar upright and familiar inverted categories. The other two pairs of stimuli were taken from a category that was used by a different participant. Again, one of these pairs was presented in the
upright orientation and the other pair in the inverted orientation, giving both a novel upright and a novel inverted category. There were therefore two factors with two levels, Pre-exposure (familiar and novel) and Orientation (upright and inverted).

2.2.2.4 Procedure

2.2.2.4.1 Learning / Categorisation phase

Participants were given a set of instructions on the computer screen. They were told that once they pressed the ‘enter’ key the stimuli would appear on the screen one at a time. Their task was to sort the stimuli into one of two categories by pressing either the key labelled “x” or the key labelled “.”. They received immediate feedback. Participants were warned that initially the task would be ambiguous, although stimuli that belonged to a certain category would have features in common. However, no particular feature would be a reliable index of category membership. They were asked to scan the stimuli before making a decision and that the speed of their response was not as important as making an accurate choice.

Participants were informed that this phase of the experiment would be completed ‘when they were doing well enough’. This served to reinforce that accuracy was of the greatest importance. In reality, a minimum of 50 trials was required together with six correct responses in a row, including
the last response. If on the fiftieth trial the participant achieved this criterion then this phase of the experiment terminated. If criterion had not been achieved the experiment continued until they achieved six correct in a row.

Once the experiment began the trials were continuous. A fixation cross was presented for 1 second before each stimulus. A randomly selected stimulus was then presented individually in the centre of the computer screen until a response was made. Once a response was made feedback was given for 1 second. The feedback was either 'correct' or 'error' accompanied by a beep, then the next fixation cross appeared. Once criterion was met, the categorisation phase of the experiment ended and participants waited five minutes before progressing to the discrimination phase of the experiment.

2.2.2.4.2 Discrimination phase

Participants were asked to inspect the stimulus pairs and to make a choice of one of the stimuli. They were told that they would receive immediate feedback and that for a given pair one stimulus was always the correct one to choose. Although this was arbitrary, it was consistent throughout the experiment. Once the "enter" key was pushed a block of 16 trials began. A fixation cross was presented for 1 second followed by a pair of stimuli, which remained on the screen until a response was made. The participant responded by pushing either the "x" key to indicate the left stimulus or the "." to indicate the right. Feedback was then
received for 1 second, either 'correct' or 'error' accompanied by a beep and then the process repeated. Each pair of stimuli was presented four times in each block, twice in each spatial relation (either to the left or to the right of the centre of the screen) and there were four blocks in total. Thus there were 16 opportunities to classify each pair. At the end of each block participants received summary feedback indicating the number of errors and the mean reaction time for that block.
2.2.3 RESULTS

Throughout the thesis, unless otherwise stated, the standard p value required for statistical significance is < 0.05. Results of analyses can be found in the appendix section together with means and standard deviations.

2.2.3.1 Learning / Categorisation phase

The mean number of trials taken to complete this phase was 115.7, the mean percentage correct, excluding the last six trials was 56.9 percent and the mean response time, per trial, during the categorisation phase was 2252 msec.

2.2.3.2 Discrimination phase

Response times for each stimulus category were correlated with the numbers correct in that category. The correlations for each were between r=0.1 and r=0.3 and not significant. This indicated that there was no speed accuracy trade off taking place.

Figure 3 shows the accuracy results that McLaren (1997) obtained for the discrimination phase of his experiment. Performance on upright, familiar stimuli is greater than for the novel controls and the performance on familiar inverted stimuli is worse than for the novel inverted controls.
Figure 4 shows the accuracy results, obtained for the upright and inverted exemplars of the familiar and novel stimuli, in the discrimination phase of the experiment here. It can be seen that there is no interaction. In figure 5 the mean reaction times are graphically represented and no interaction can be seen. The familiar upright stimuli appear to have taken longer to identify than any of the other stimuli, although the error bars for these figures are large suggesting that there is no significant difference in these results.

![Figure 3](image)

**Figure 3** - McLaren's accuracy figures for the upright and inverted stimuli for discrimination phase. (McLaren did not give error bars).
Figure 4 - Accuracy for the upright and inverted stimuli for discrimination phase of experiment 1. Error bars show +/- 1 standard deviation.

Figure 5 - Mean response times in milliseconds for the upright and inverted stimuli in the discrimination phase (error bars show +/- 1 standard deviation).
Two way ANOVAs (Pre-exposure (2) – familiar vs. novel; Orientation (2) – upright vs. inverted) were carried out for both accuracy and the mean response times. In each case these tested the main effects: pre-exposure and orientation and the interaction between them.

2.2.3.2.1 Accuracy

The Pre-exposure X Orientation interaction was not significant, and no significant main effects of ether pre-exposure or orientation were found. Thus, whether the stimuli were familiar or novel, upright or inverted there was statistically no difference in the results found. Indicating that there was no effect of inversion on either the familiar or novel stimuli.

2.2.3.2.2 Response times

No interaction was found and no significant main effects of either pre-exposure or orientation. The response times therefore showed no effect of either familiarity or inversion.

The results found are in direct contrast to the work of McLaren (1997) who reported a significant effect of orientation on the familiar stimuli. He found that performance on familiar upright stimuli was significantly better than on familiar inverted stimuli and hence, showed an inversion effect. In order to account for this discrepancy between findings, further analysis of the present data was conducted.
2.2.3.3 Further analysis

2.2.3.3.1 Development of expertise

McLaren (1997), amongst others, argued that inversion effects are thought to be contingent upon expertise. If participants failed to develop expertise in the categorisation / learning phase of this experiment this could therefore account for the lack of an inversion effect. These analyses therefore centre on selecting out sub-groups of participants who show the strongest evidence of expertise development.

2.2.3.3.2 Regression analysis

The responses for the categorisation data were divided into blocks of ten trials and the number correct in each of the blocks was calculated. Regression analysis of these results was performed, in order to determine whether or not the participants had learned to effectively categorise and develop expertise or whether the termination of the categorisation phase of the experiment was chance. Further analysis was conducted on data from participants for whom the slope value exceeded $r = 0.7$. The figure 0.7 was chosen because firstly a positive slope indicates that performance improves over blocks, and also at this level it was possible to say with confidence that effective learning had
taken place. Those participants who did not achieve this level in the
categorisation phase were excluded from the analysis. This resulted in
only 7 participants remaining. Using only the data for these participants,
further 2 x 2 way ANOVAs were carried out on the discrimination data.
No significant effects of pre-exposure or orientation were found.

2.2.3.3.3 Termination of categorisation phase

By chance participants should achieve a score of 50% in the
categorisation phase. However, the percentage correct for each of the
participants was calculated and found to be between 30% and 85%.
Therefore all participants who fell below chance (50%) were eliminated
from the analysis. This resulted in 13 participants remaining. Two 2 x 2
way ANOVAs were conducted on the discrimination data for these
participants. No significant effects were found.

2.2.3.3.4 Expertise development and chance values

In McLaren's experiment, he found that the mean percentage correct for
the categorisation phase of the experiment was 63%, somewhat greater
than observed here. In these experiments the number of participants in
the data samples was manipulated until the percentage correct replicated
the results of McLaren. This resulted in 15 participants remaining. Again,
2 x 2 way ANOVAs was conducted on the discrimination data for these
participants and no significant effects were found.
2.2.3.3.5 Time Out

In the initial experiment conducted by McLaren, there was an enforced 'time out'. In that if the participants failed to respond to the stimulus, in either the categorisation phase or the discrimination phase, within 4.25 seconds then they were timed out and unable to respond to that stimulus. In the experiment reported here none of the participant's responses were subject to time constraints. If the results reported here were not significant due to a failure to develop expertise, it is possible that the lack of any time out may have contributed.

The data in the categorisation phase of the experiment were reviewed and all responses that were greater than 4.25 seconds were removed. This resulted in 6 participants being entirely eliminated, on the grounds that nearly all their responses were outside this time limit. Again, 2 x 2 way ANOVAs were conducted, they were not significant.

The data in the discrimination phase of the experiment were then reviewed and all responses outside the imposed time limit, of 4.25 seconds removed. All the participants remained in the data set for the 2 x 2 way ANOVA. No significant differences were found. Although it was noted that there were fewer correct responses in the novel data than the familiar data, this was not significant.
2.2.3.3.6 Averages

All the data were analysed using the mean, median and mode to calculate the average performance for each stimulus pair type. The results were the same for each of the analyses i.e. no clear development of expertise could be found for the learning / categorisation phase and for the discrimination phase no significant effects of pre-exposure or orientation were found.

Analysis of the results therefore concluded that no significant effects were found.
2.2.4 DISCUSSION

The results of the experiment showed that there were no significant correlations between speed of response and accuracy for the discrimination phase of the experiment. It was concluded that no speed accuracy trade off had taken place. No pre-exposure / orientation interaction was found and there were no significant main effects. This was true for both the accuracy and response time data. Further analysis found that only a few people had adequately learned to categorise and had developed expertise. Further criteria were used to reduce the data and to eliminate non-learning participants; none of the subsequent analysis gave significant findings. It is concluded that there was no effect of inversion on these stimuli, regardless of pre-exposure.

The experiment failed to replicate the work of McLaren (1997) who, in direct contrast, found that familiarisation with a category improves the ability to discriminate between exemplars of that category and that this advantage is lost by inversion, here no such effects were found.
Following category learning, recognition is impaired for transformed exemplars of the previously learned categories (McLaren, 1997). Here it is thought that perhaps the categorisation phase of the experiment was not an adequate base to support the learning of the categories. Thus, participants might not have developed the expertise required for any effects of transforming the exemplars to be significant. Consequently, modifications to the design of the experiment, coupled with more stringent criteria to create effective learning and the development of expertise shall be investigated in the next experiment.
2.3 Experiment 2

2.3.1 INTRODUCTION

This experiment is a modification of experiment one and was designed to facilitate effective learning, and thus development of expertise with the stimuli, so that the inversion effect might be found. The modifications to the design of experiment one are as follows:

1. The categorisation phase of the experiment previously required 6 correct responses in a row. A figure that McLaren did not explain the basis of. The probability of obtaining 6 correct in a row by chance is 1 in 64. Thus, the categorisation phase of the experiment would, on average, terminate by chance after 192 trials ((6 x 64) / 2). Whilst this number is greater than the average number of categorisation trials in experiment one, it is still likely that a significant number of participants moved onto the discrimination phase by chance. Thus, a more stringent criteria could be imposed that would give a reduced risk of the categorisation phase terminating by chance. The probability of obtaining ten correct responses in a row is 1 in 512 and thus, on average, it would take 2060 ((10 x 512) / 2) trials before the categorisation phase of the experiment terminated by chance. Therefore the number of correct responses required to terminate the categorisation phase shall be increased to 10 in a row.
2. To avoid participant fatigue, and to further reduce the risk of participants proceeding to the discrimination phase by chance, a maximum of 500 category learning trials shall be permitted. If participants have not achieved 10 correct responses in a row by trial 500 then the categorisation phase of the experiment will terminate and they will not proceed to the discrimination phase.

3. In research on perceptual learning a single prolonged presentation of a stimulus was found to be sufficient to initiate learning, that is, a single encounter enables an effect that Ahissar & Hochstein (1997) termed 'eureka'. Therefore, an example stimulus will be presented at the start of the experiment that serves to induce learning and familiarity with the nature of the stimuli.

4. A time limit of 4.25 seconds shall be imposed on the response times required for both the categorisation phase and the discrimination phase. McLaren's original experiment had this time limit. It is thought that since the participants failed to effectively learn to categorise, a time out may enforce this learning and familiarity with the category members. Therefore only 4.25 seconds will be permitted for a response, after which time the stimulus will disappear from the screen and a 'timed out' message will appear. Timed out responses will count as incorrect for the purposes of achieving the 10 correct in a row exit criterion.
5. McLaren (1997) rewarded his participants an undisclosed sum of money for participation. Therefore, all participants here shall be paid a basic sum of £2.50 for the categorisation phase of the experiment and a further 4 pence for every correct response in the discrimination phase. It is hoped that this performance related component will maximise participant motivation. Thus, all participants have the chance to earn a maximum of £5.06 in total.

6. The nature of the feedback will be changed such that the beep heard in experiment one for incorrect responses will be replaced by the sound of a coin dropping when a correct response is given.

7. A number of participants in the previous experiment indicated that the instructions were ambiguous. The instructions are to be modified to eliminate any ambiguity, remove any jargon and to ensure that participants are entirely familiar with the procedure.

Thus, in summary, a range of modifications were made to experiment one which may facilitate effective learning and thereby develop expertise so that the inversion effect might be found for the chequerboard stimuli.
2.3.2 METHOD

2.3.2.1 Overall Design

There were three phases to this experiment. Stage one of the experiment was an initial pre-exposure phase where participants viewed the stimuli on the screen for 3 minutes. The second stage was the categorisation phase and then the discrimination phase followed.

2.3.2.2 Participants

Thirty students between the ages of 18 and 35, with no previous experience of the stimuli were used in this experiment. All were paid for their participation.

2.3.2.3 Stimuli design and construction

As in experiment 1, the stimuli were 2cm square chequerboards. For both the categorisation phase and the discrimination phases the stimuli were designed in exactly the same way as described in experiment 1 and resulted in two factors with two levels, pre-exposure (familiar and novel) and orientation (upright and inverted).
2.3.2.4 Procedure

Initial instructions were presented on the screen. These informed participants that there would be three stages to the experiment.

2.3.2.4.1 Pre-exposure phase

They were told that for the first stage they would see examples of the chequerboard stimuli that would be in the rest of the experiment. They were not required to make any response only to view the chequerboards. Six exemplars from each group were then shown on the screen at the same time for 3 minutes. The six chequerboards on the left were from the 'A' group and were labelled as such and the six on the right were from the 'B' group and again were labelled as such. After 3 minutes the stimuli disappeared and another instruction page was shown.

2.3.2.4.2 Categorisation phase

Participants were asked to sort the chequerboards that they would be seeing into two groups by either pressing the key labelled "A" or the key labelled "B". These were in fact the x and the full stop keys with labels stuck on. They were told that they needed to get 10 correct responses in a row after completing a minimum number of trials (this was in fact 44 trials). They were also informed that they would be paid £2.50 for this phase of the experiment.
Once the experiment began the trials were continuous. On each trial a fixation cross was first presented for 1 second. Next an individual stimulus was displayed in the centre of the screen. The participant had a maximum of 4.25 seconds to respond. If they responded in this time then a feedback message was displayed for 1 second. This was either 'error' or 'correct' together with the sound of a coin dropping. This served as a reminder that every time they were obtaining correct responses they were earning money. If no response was made during the 4.25 seconds then they received a “timed out” message and this counted as an incorrect response. If after the 44th trial they obtained 10 correct responses in a row then this phase of the experiment terminated. Thus, it was possible to complete this phase of the experiment in a minimum of 54 trials. However, if they had not achieved this criterion then the experiment continued until 10 correct responses in a row was achieved. If this was not done by the 500th trial the experiment was terminated, they were paid £2.50 and thanked for their participation. Thus, only those people who had learned to categorise the chequerboards before the 500th trial moved forward to the discrimination phase.
2.3.2.4.3 Discrimination phase

Five minutes after the categorisation phase the discrimination phase began. Participants were again presented with on screen instructions. Participants were then asked whether they fully understood what was required of them. In order to facilitate understanding they were presented with four pieces of card, labelled “Bob” “Alice” “Mary” and “John”. These were shown to the participants in pairs, they were told they represented the chequerboards that they would be seeing. From the ‘Bob and Alice’ pair, they would always need to choose Bob whether he be on the left or the right, basically they needed to track his position. For ‘Mary and John’ they would always need to choose Mary and to track her position. Again understanding was checked, and any queries resolved.

Chequerboards were presented for a maximum of 4.25 seconds with feedback being the same as for the categorisation phase. Each pair of stimuli was presented 4 times in each block and each stimulus was presented twice in each spatial location. There were 4 blocks in total. Thus giving 16 opportunities to classify each pair. At the end of each block, summary feedback was given indicating the number correct, the mean response time and the amount of money that they had earned for that block.
2.3.3 RESULTS

2.3.3.1 Categorisation phase

From the 30 participants, 26 successfully completed the categorisation phase. The mean number of trials taken to complete this phase was 146.46. The mean response time, per trial, for these 26 participants during the categorisation phase was 1116.77 msec. The mean percentage correct, excluding the last 10 trials, was 57%.

2.3.3.2 Discrimination phase

The response times for each stimulus pair were correlated with the numbers correct in that category. Each of these correlations was not significant. This indicated that there was no speed accuracy trade off taking place.

Figure 6 shows a graphical representation of accuracy for the upright and inverted exemplars of the familiar and novel stimuli for the discrimination part of the experiment. It can be seen that there is no interaction. Indeed the familiar inverted stimulus has a slightly higher percentage correct than the familiar upright stimuli, although not significant. In figure 7 the mean reaction times for orientation are graphically represented. Again, there is no clear interaction effect.
Figure 6 - Mean percentage correct for familiar and novel upright and inverted stimuli during the discrimination phase with the error bars showing +/- 1 standard deviation.

Figure 7 - Mean response times in milliseconds for the familiar and novel upright and inverted stimuli during the discrimination phase. The error bars show +/- 1 standard deviation.
Two way ANOVAs (Pre-exposure (2) – familiar vs. novel; Orientation (2) – upright vs. inverted) were carried out on both the accuracy data and the mean response times for each of the four categories. In each case these tested the main effects of pre-exposure and orientation and also the interaction between them. The Pre-exposure x Orientation interaction was not significant, no significant main effect of either pre-exposure or orientation was found. Thus, whether the stimuli were familiar or novel, upright or inverted, there was statistically no difference in the results found. Indicating that there was no effect of inversion on either the familiar or novel stimuli.

These results are similar to those found in experiment one but are in direct contrast to the results found by McLaren (1997), who reported a significant effect of orientation on the familiar stimuli hence the inversion effect.

This experiment was a modification of experiment 1 where it was concluded that the participants did not learn to categorise the stimuli presented in the categorisation phase and that this was the reason that the inversion effect was not found in the discrimination phase. Here, modifications were made to ensure that effective learning took place during the categorisation phase. Therefore, further analysis of the present data, as detailed below, investigated whether effective learning occurred.
2.3.3.3 Further analysis

2.3.3.3.1 Categorisation phase

The mean response times and the mean percentage correct for all 30 participants, in the categorisation phase, were correlated and were found to be significant ($r = -0.366$ (p<0.05)). This negative correlation indicates that the higher the percentage correct, the lower and therefore the quicker the response times. This is the opposite of speed accuracy trade off.

In McLaren's experiment he found that the mean percentage correct (excluding the last 6) for the categorisation phase was 63%. In this experiment the mean percentage correct was 57% (excluding the last 10 responses, since these were always going to be correct) and was in the range 30% to 70%. All participants who fell below the 50% level, which could have been achieved by chance, were eliminated from the analysis. This resulted in 22 data sets remaining, and a mean percentage correct of 60%. 2 x 2 way ANOVAs were carried out on both the response times and the number correct and no significant effects were found.

In order to reach the discrimination phase 10 correct responses in a row were required. The possibility of achieving this by chance was 1 in 512 and thus on average it would take 2060 $((10 \times 512) / 2)$ trials to obtain this. Since the categorisation phase required participants to obtain 10 correct responses in a row before they reached the 500th trial it is
extremely unlikely that this was achieved by chance. Discussions with participants found that those who did manage to reach the criteria clearly felt like they had learnt to distinguish between the two groups. Whereas, those who did not reach criteria indicated that they could not see anything in the stimuli that enabled them to tell the two groups apart. As these participants did not go on to discrimination testing it was likely that those who did, had successfully learnt in the categorisation phase of the experiment.

2.3.3.3.2 Discrimination phase

The discrimination phase was conducted in 4 blocks. If people had to learn to perform the task during this phase then it might be possible that they would take longer and get more errors in the first half i.e. in blocks 1 and 2 than they would in blocks 3 and 4. To this end the data were divided into two parts. The overall mean percentage correct for the discrimination phase was 54.6%. For the first half the mean was found to be 51% whereas for the second half the mean was 58%. Thus, participants were performing at chance for the first half and above chance for the second half.

A 2 tailed t-test for the numbers correct in the first and second half was also significant (t (1,25) = -2.892, p = 0.008) indicating that there were significantly more errors made in the first half than the second. Therefore, participants, on average, obtained a greater number correct in the second half (58%) than the first (51%), and performance in the
second half was also quicker. This indicates that there is a period in which the task needs to be learnt, before performance is achieved both quickly and accurately.

The mean response times for accuracy in the first and second halves were examined using a 2 tailed paired t-test. The results of which showed a significant difference between the mean response times for the first and second halves ($t_{(1,25)} = 7.046$, $p = 0.007$). The mean response time for the first half was 1611 msec and for the second half was 1201 msec. The second half being conducted significantly quicker than the first half. It would appear that as participants became familiar with the task they were able to respond more quickly than they were at the onset of the task.

The data in the first and second half of the discrimination phase were then examined more closely. A 2 x 2 way ANOVA on the response times for each of the four conditions was carried out for both the first half data and for the second half data, neither of these was significant. Also a 2 x 2 way ANOVA for accuracy in each of the conditions for both the first half and second half data showed no significant differences. Thus, although participants responded more quickly and accurately in the second half than the first, no effects of either orientation or familiarity were found in either the first or second half of the data. Analysis of the results concluded that whilst participants effectively learnt to categorise the stimuli, no effects of orientation or familiarity were found.
2.3.4 DISCUSSION

The results of the experiment showed that participants developed expertise with the stimuli for the categorisation phase and the inversion effect was not found. If learning to distinguish between the stimuli in the categorisation phase and thus development of expertise was successful then why was the inversion effect not found?

Accuracy was better in the second half of the discrimination phase than the first and the second half was carried out more quickly than the first. These results indicated that as the task became familiar it was carried out more quickly and also more efficiently. It is therefore possible that attention was directed towards the task and the nature of the task and not to the stimuli. In the discrimination phase of the experiment participants were told that one of the stimuli was always the correct one to choose. However, initially they did not know which of the stimuli was the correct one. This required participants to learn to identify the correct one and to track its position. If this learning were taking place in the first half of the discrimination task then it might be expected that participants would take longer and get fewer right than in the second half. This was found to be the case. It could be that, in learning to track the position of the stimuli, participants were becoming equally familiar with all of the stimuli and therefore the orientation and prior exposure became irrelevant and thus the inversion effect was not found.
Alternatively, it may be that the inversion effect was not found with these stimuli because the stimuli themselves, unlike faces, do not have a definite orientation. McLaren thought that it was the lack of control of expertise that led faces to be considered special together with a failure of appropriate comparison of objects. The chequerboards were designed to overcome this limitation. However, the failure to replicate his experiment leads to question whether the experimental design and/or the stimuli actually overcome these two factors.

One way to test the ability of this design to show inversion effects is to use it with face stimuli, for which inversion effects are easily found (e.g. Yin, 1969). If the same experiment is conducted using faces and the face inversion effect not found this would indicate that there is a weakness in the design of this experiment.

Consequently, the experiment, as it stands, shall be replicated using face stimuli. If the inversion effect is found then it is likely that it is the chequerboard stimuli that are a problem. However, if no inversion effect is found with faces then it is more likely that there are problems with the method.
2.4 Experiment 3

2.4.1 INTRODUCTION

The previous two experiments did not show any effects of inversion of the chequerboard stimuli. This led to questions over both the method and the chequerboard stimuli. The current experiment addresses these issues.

If the inversion effect can be found with face stimuli and the same design that has been used in the previous experiment then the technique, possibly with further modifications, could potentially be a useful one. However, if the inversion effect is not found with face stimuli then it is more likely that the technique is not robust.

Thus, the current experiment used exactly the same design as experiment two but with face stimuli not chequerboards.
2.4.2 METHOD

2.4.2.1 Overall design

The experiment was conducted on the same PC that was used for the other two experiments. Participants were required to learn category membership of two groups of stimuli and then subsequently tested on them. Here the stimuli were faces. As in experiment 2, to facilitate learning, participants began with a pre-exposure phase in which the stimuli were viewed on the screen simultaneously for 3 minutes. Next a category learning phase was completed and finally a discrimination phase.

2.4.2.2 Participants

Thirty-one people between the ages of 18 and 35 were paid for their participation in this experiment. None had any previous experience with either the stimuli or the method.

2.4.2.3 Stimuli design and construction

As in the previous experiments the stimuli were presented in the centre of a computer screen. The stimuli were face images, which filled a 2cm square area and contained 64 X 64 pixels.
2.4.2.3.1 Stimuli construction

Photographs were taken of four bald headed Caucasian men using a Pentax MZ50 SLR camera. The pictures were all taken under similar lighting conditions, with neutral expressions. Faces with facial hair do not morph well (Busey, 2000) and were therefore not chosen. Each of the photographs was developed in colour and then scanned into an Apple Macintosh computer where they were grey-scaled, the backgrounds obliterated and made black in colour. Any identifying features such as earrings were removed from the images and the images were cropped so that they only contained the head and neck.

Using the software package *Morph* (Gryphon Software) on an Apple Macintosh computer the images were sequentially transformed from one to another. The morphing process is a two-step process in which control points are selected and placed on important landmarks on each of the faces for example, left eye, tip of the nose etc. The locations of these landmarks are averaged to create a set of average control points. The photographs of the two faces are then digitally warped so that the features of both faces align with the locations of the average control points. With the features in alignment, the two faces are now averaged together on a pixel-by-pixel basis to produce the average face.

Beale and Keil (1995) describe the morphing process as an algorithm with two primary components:- warp and fade. They say that ‘warping’ between the two images is accomplished by Delaunay Tessellation, a
type of finite element analysis, which uses linear triangulation. When the algorithm is applied, neighbouring control points are connected into optimal triangular regions with non-crossing line segments, resulting in a planar graph. This partitions the image such that all pixels within a particular triangular region are closer to the control points at the triangle’s vertices than to any other control points. Warping from one image to another shifts the control points from their initial positions (in one image) to their final positions (in the other) along linear trajectories. All control points are shifted by an equal percentage of the total distance between their initial and final positions: for example, a 40% morph warps all control points 40% of the distance along the linear path between their initial and final positions. The locations of intervening pixels in the images are linearly interpolated across the planar surface based on the positions of their nearest control points, which define the local triangular region.

The second component of the morph algorithm is a gradual ‘fade’ between the values of corresponding pixels in the two end images. Thus for the 40% morph image, the values in the final image contributing 40% while those of the initial image contribute 60%.
Control points were chosen in the following manner. Initially, a single point was placed in the centre of each pupil in the two end images. Next, points were placed along the outermost edges of the faces; approximately 150 points were selected in total. The 50% morph image was then consulted to determine the additional points to be added. Any discontinuities or blurring in the morph image were corrected by placing additional points in the two end images. The process of point placement was repeated until all oddities, blurrings, or discontinuities in the 50% morph were eliminated.

Each of the four faces was morphed with every other face. A 50% difference can be considered to be the mid-point between the two faces. A 25% transformation is therefore considered a 25% configural transformation of the first face towards the second face, i.e. 75% of one face with 25% of the other face. Six morphed images were produced. These were for faces A and B, 30%A - 70%B, 70%A – 30%B; 35%A - 65%B, 65%A – 35%B; 40%A - 60%B and 60%A – 40%B. The same was true for the other image pairs (A-C, A-D, B-C, B-D, C-D). At this stage, it was unclear as to how similar the morphed images would be deemed. Inspection suggested that the 10/90 and 20/80 were too dissimilar and
therefore would be too readily categorised. Likewise images that were 45/55 were too similar and therefore would be too difficult to categorise. Each of these six morphed images represents a category prototype. Exemplars were generated in the same manner as described for experiments 1 and 2.

From each prototype two sets of exemplars were created. This was done by randomly replacing entire horizontal rows with a black row. A row was a 4 x 64 pixel strip and as in the previous experiments replacement of rows was carried out eight times, every time all of the 16 rows were eligible for replacement. This created images that in essence, randomly blocked out different facial features. See figure 8 for examples of the stimuli.

![Figure 8 - This shows four exemplars from the 'A' category and four from the 'B' category for the categorisation phase.](image)
A pilot of the categorisation stage of the experiment was then run using exemplars based on the three different face proportions (70/30, 65/35 and 60/40) to determine which of the percentage images to use. These results found that the 40/60 – 60/40 images produced a mean percentage correct for the categorisation phase of 57%. Participants managed to complete the task with an average of 150 trials. Whereas the 70/30 images and 65/35 images were categorised on average in 100 and 120 trials with mean percentage correct of 57% and 58%. Therefore the 60/40 images were used for the rest of the experiment, since these gave results that were consistent with experiment 2.

2.4.2.3.1.1 Categorisation phase

Two of the 60/40 images or prototypes were selected to define two categories. Allocation of the images to the participants was designed so that each participant was allocated a different combination. The following table (table 1) shows the allocation of the combinations. Creation of exemplars was as described in the previous section for the pilot testing.
Table 1 - This shows the allocation of the prototype images to each of the participants, for the categorisation and discrimination phases of the experiment.

<table>
<thead>
<tr>
<th>Combination</th>
<th>Categorisation stage</th>
<th>Discrimination stage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category A</td>
<td>Category B</td>
</tr>
<tr>
<td>1</td>
<td>40a 60b</td>
<td>60a 40b</td>
</tr>
<tr>
<td>2</td>
<td>40a 60b</td>
<td>60a 40b</td>
</tr>
<tr>
<td>3</td>
<td>40a 60b</td>
<td>60a 40b</td>
</tr>
<tr>
<td>4</td>
<td>40a 60b</td>
<td>60a 40b</td>
</tr>
<tr>
<td>5</td>
<td>40a 60c</td>
<td>60a 40c</td>
</tr>
<tr>
<td>6</td>
<td>40a 60c</td>
<td>60a 40c</td>
</tr>
<tr>
<td>7</td>
<td>40a 60c</td>
<td>60a 40c</td>
</tr>
<tr>
<td>8</td>
<td>40a 60c</td>
<td>60a 40c</td>
</tr>
<tr>
<td>9</td>
<td>40a 60d</td>
<td>60a 40d</td>
</tr>
<tr>
<td>10</td>
<td>40a 60d</td>
<td>60a 40d</td>
</tr>
<tr>
<td>11</td>
<td>40a 60d</td>
<td>60a 40d</td>
</tr>
<tr>
<td>12</td>
<td>40a 60d</td>
<td>60a 40d</td>
</tr>
<tr>
<td>13</td>
<td>40b 60c</td>
<td>60b 40c</td>
</tr>
<tr>
<td>14</td>
<td>40b 60c</td>
<td>60b 40c</td>
</tr>
<tr>
<td>15</td>
<td>40b 60c</td>
<td>60b 40c</td>
</tr>
<tr>
<td>16</td>
<td>40b 60c</td>
<td>60b 40c</td>
</tr>
<tr>
<td>17</td>
<td>40b 60d</td>
<td>60b 40d</td>
</tr>
<tr>
<td>18</td>
<td>40b 60d</td>
<td>60b 40d</td>
</tr>
<tr>
<td>19</td>
<td>40b 60d</td>
<td>60b 40d</td>
</tr>
<tr>
<td>20</td>
<td>40b60d</td>
<td>60b 40d</td>
</tr>
<tr>
<td>21</td>
<td>40c 60d</td>
<td>60c 40d</td>
</tr>
<tr>
<td>22</td>
<td>40c 60d</td>
<td>60c 40d</td>
</tr>
<tr>
<td>23</td>
<td>40c 60d</td>
<td>60c 40d</td>
</tr>
<tr>
<td>24</td>
<td>40c 60d</td>
<td>60c 40d</td>
</tr>
</tbody>
</table>
2.4.2.3.1.2 Discrimination phase

Four pairs of images were used in this phase of the experiment. These were based on the prototypes allocated as in Table 1 and resulted in both familiar and novel stimuli. Each of these pairs was presented in both the upright and inverted orientation. Thus, producing both familiar upright and familiar inverted categories together with novel upright and novel inverted categories for each participant. Therefore as in the previous experiments there were two factors with two levels:- Pre-exposure (familiar and novel) and Orientation (upright and inverted).

Again, as in each of the previous experiments, each pair of exemplars were presented 0.5cm apart in the centre of the screen. The exemplars were constructed in pairs by taking the category prototype, selecting two different rows at random, replacing them with blank rows to form one exemplar and then repeating this process for the second exemplar. Thus, each pair of exemplars differed in four rows. See figure 9 for examples of these stimuli.
2.4.2.4 Procedure

2.4.2.4.1 Pre-exposure, Categorisation and Discrimination phase

The procedure used in each phase was identical to those used in experiment 2 but the participants were presented with face stimuli and not chequerboards.
2.4.3 RESULTS

2.4.3.1 Categorisation phase

Twenty-four participants from the 31 successfully completed the categorisation phase. One participant was allocated to each of the 24 prototype combinations. When a participant failed to complete the categorisation phase within 500 trials, they were replaced in that combination by another participant. The mean number of trials taken to complete the categorisation phase was 190 trials. The mean response time, per trial, during the categorisation phase was 1210 msec. The mean percentage correct, excluding the last 10 trials, was 56%. The data for the 7 participants who failed to complete the categorisation phase were disregarded.

2.4.3.2 Discrimination phase

The response times for each stimulus pair were correlated with the numbers correct in that category. Each of these correlations was not significant. This indicated that there was no speed accuracy trade off taking place.
Figure 10 shows a graphical representation of accuracy for the upright and inverted exemplars of the familiar and novel stimuli for the discrimination part of the experiment. It can be seen that there is no interaction. The novel inverted stimulus has a slightly higher percentage correct than the familiar upright stimuli, although not significant. In figure 11 the mean response times for the upright and inverted stimuli in the discrimination phase are plotted. Again it can be seen that there is no interaction.

Figure 10 - Accuracy data for the discrimination phase of the experiment (error bars show +/- 1 standard deviation).
Two way ANOVAs (Pre-exposure (2) – familiar vs. novel; Orientation (2) – upright vs. inverted) were carried out for both accuracy and mean response times for each of the four categories. In each case these tested the main effects: Pre-exposure and Orientation and the interaction between them. The Pre-exposure x Orientation interaction was not significant, and no significant main effect of either pre-exposure or orientation was found. Thus, whether the stimuli were familiar or novel, upright or inverted, there was statistically no difference in the results found. Indicating that there was no effect of inversion on either the familiar or novel stimuli.
These results have not found the face inversion effect that has been extensively reported in the literature. The results are also in direct contrast to the results found by McLaren (1997). He reported a significant effect of orientation on the familiar stimuli and showed performance on familiar upright stimuli was significantly better than on familiar inverted stimuli and thus the inversion effect.

This experiment was conducted using McLaren’s (1997) method and face stimuli. Faces have been extensively reported to show significant deterioration in identification when they are inverted and McLaren reported that this deterioration was not unique to faces. The previous experiments (1 and 2) failed to show the inversion effect using the same stimuli that McLaren used. This led to question whether there was a problem with the method or the stimuli used. This experiment used the same method as McLaren and replaced the chequerboard stimuli with face images. Faces are known to produce the inversion effect therefore, further investigation of these data was conducted.
2.4.3.3 Further analysis

2.4.3.3.1 Categorisation phase

The mean response times and the mean percentage correct for all 24 participants, in the categorisation phase, were correlated and were not significant. This indicates that there was no speed accuracy trade off in the categorisation phase.

In McLaren's experiment he found that the mean percentage correct (excluding the last 6) for the categorisation phase was 63%. In this experiment the mean percentage correct was found to be 56% (excluding the last 10 responses, since these were always going to be correct) and was between 45% to 66%. All participants who fell below the 50% level, which could have been achieved by chance, were eliminated from the analysis. This resulted in 20 data sets remaining, and a mean percentage correct of 64%. Two 2 x 2 way ANOVAs were carried out on both the response times and the number correct and no significant effects were found.
2.4.3.3.2 Discrimination phase

The discrimination phase was conducted in 4 blocks. If people had to learn the task during this phase then it might be possible that they would take longer and get more errors in the first half i.e. in blocks 1 and 2 than they would in blocks 3 and 4. To this end the data were divided into 2 parts. The total mean percentage correct for the discrimination phase was 58.5%. For the first half the mean was 57% whereas for the second half the mean was 60%. Although participants were performing slightly better in the second half, they were performing above chance for all of the discrimination phase.

The mean correct responses for the first and second halves were examined using a paired two tailed t-test. The results of which found no significant difference between the mean correct responses for the first and second halves. Therefore, there was no significant difference for accuracy between the first and second halves of the discrimination phase.

A two tailed t-test for the mean response times for the correct responses in the first and second half was significant ($t(7,23)= 4.723 \ p = 0.004$). The second half of the discrimination phase was conducted more quickly (1207 msec) than the first half (1468 msec). Although, since there was no significant difference in accuracy it appears that participants simply became quicker at making their responses whilst their accuracy remained constant.
The data in the first and second half of the discrimination phase were then examined more closely. A 2 x 2 way ANOVA for the response times, for each of the four conditions, in each of the halves was carried out and was not significant. Also, two 2 x 2 way ANOVAs of accuracy, for each of the conditions in each of the halves, showed no significant differences. Thus, although participants responded more quickly in the second half, no effects of either orientation or familiarity were found.

Analysis of the results therefore concluded that whilst participants effectively learnt to categorise the stimuli, no effects of orientation or familiarity were found in this experiment.
2.4.4 DISCUSSION

The results found that participants developed expertise with the stimuli for the categorisation phase but no significant effect of either pre-exposure or orientation of the face stimuli was found and therefore no inversion effect.

It was shown that the second half of the discrimination phase was conducted more quickly than the first half, although there were no differences in accuracy. It appears that participants simply became quicker at the task and not more accurate. It could be that as a result of experience with both the task and the stimuli in the discrimination phase that participants were more familiar with what was required of them. Alternatively, participants may have been disillusioned with the task and simply realised that by responding faster they were able to finish more quickly. However, they didn’t become any less accurate.

Criticisms could be levied at the stimuli used in this experiment. Not the fact that the stimuli were faces, but that the faces had lines across which obliterated features randomly. The lines in the categorisation phase simply added to task difficulty, a fact that was commented on by the participants and shown by the fact that not all the participants were able complete this phase within the 500 trials. However, in the discrimination phase it could be that the lines actually made the task simpler, in that by observing and tracking the line position it would be possible to ignore the
faces themselves. However, without first identifying the face you did not know which line positions indicate the correct stimulus in a pair to choose. In agreement with this, participants reported that the faces were being used to first establish which pair they were seeing, and then the lines to identify which was the correct one. Consequently, it would be expected that impaired recognition of the inverted faces would have most effect on the response times. Why, then was the inversion effect not found?

It might be that there were insufficient links between the categorisation phase and the discrimination phase of the experiment. Here, participants reported that they saw the discrimination phase as a new and separate experiment, they were surprised by the 'upside down faces' and realised, again with surprise, that there were faces that they did not recognise. The latter factors we would expect to show the inversion effect. However, if they saw the task as novel and they were having to learn afresh which of the faces to choose then the effects of inversion and familiarity may have been masked by the difficulty in learning to choose and track the correct face. Once participants were familiar with the task they were then equally familiar with all the stimuli regardless of whether they were previously encountered in the categorisation phase.
This experiment failed to produce the inversion effect with face stimuli, an effect that has been extensively reported. The participants clearly learned to categorise the stimuli and did develop expertise. Therefore, it is likely that this method is insufficiently sensitive.
Findings from the experiments reported here have failed to demonstrate any effects of familiarity or orientation on discrimination performance. The general aim of these studies was to investigate the claim made by McLaren that inversion effects are contingent upon expertise with a category, where members share an underlying common statistical structure. However, using the same method as McLaren it has not been possible to support this claim.

*Experiment 1* was conducted to replicate the work of McLaren to show that inversion effects, reported for face perception, are more generally applicable to members of any category defined by a prototype, providing that expertise is developed with these stimuli. No significant effects of orientation or familiarity were found. Extensive analysis of the data found that participants failed to develop expertise with the categories. Several modifications were designed and implemented in experiment 2, in order to facilitate learning and thus development of expertise.

*Experiment 2* was the modified version of experiment one, designed with particular intention to facilitate learning of the categories and the development of expertise. The results of this experiment showed that whilst participants did develop expertise, no effects of familiarity or orientation were found and therefore no inversion effect. At this stage, it was questioned whether the design was sufficiently sensitive as to show
the inversion effect, or whether perhaps the inversion effect does not
typically occur for any category defined by a prototype, such as the
chequerboard stimuli used here. The answer therefore lay in using
stimuli that were known to produce inversion effects i.e. faces. If the
inversion effect could not be produced using faces then it is likely that it
was the method and not the stimuli that were the problem. If however,
the inversion effect was found with faces then it could be that the
chequerboard stimuli were the problem.

In experiment 3 face stimuli were used in place of the chequerboards.
Face images were placed into the same method as experiment two,
where participants had been shown to develop expertise with the stimuli.
Analysis of the data found that participants developed expertise but no
effects of familiarity or orientation were found. It was therefore concluded
that the method used by McLaren (1997) is not a suitable technique for
reliably revealing inversion effects.

It was postulated in the discussions of both experiments 2 and 3, where
expertise was developed, that the discrimination phase of the experiment
was treated as a novel task and that learning the task masked any
effects of inversion and prior exposure of the stimuli. In essence, it is
speculated that it was the discrimination phase, of the experiment, that
was the problem with this method.
Thus, the basic question remains to be answered: can inversion effects be found, following acquisition of category expertise, for any stimulus category defined by a prototype using a different experimental design? To test this, the chequerboard stimuli could be used in a more traditional design where face inversion effects have been consistently found, for example, an old / new recognition paradigm.
3.1 General Introduction

Original demonstrations of the face inversion effect have used recognition memory paradigms and many subsequent studies have used similar approaches. Yin (1969) tested recognition memory by a two-alternative forced-choice procedure. Using this method he found that recognition memory for faces was disproportionately impaired by inversion compared with other stimuli that were normally only seen in one orientation (houses). There have been a number of replications of this experiment over the years e.g. Carey and Diamond (1977) replicated Yin's results using houses as the comparison material.

These results, and indeed the method, have not been without criticism. It has been argued that the findings are a consequence of the procedure and the stimulus set. However, the disproportionate effect of inversion on faces has been found across a wide variety of experimental conditions. Indeed, procedures using blocked presentation (Valentine and Bruce 1986a) and mixed lists of stimulus materials (Carey and Diamond, 1977) have all produced equivalent results. However, there is some evidence
that a disproportionate effect of inversion is not found in a face-matching task (Valentine, 1986). Overall, disproportionate effects of inversion on face recognition are found across a variety of different recognition memory tasks. Consequently, a recognition memory task is used to explore inversion effects with chequerboard and face stimuli in the current experiments.
3.2 Experiment 4

3.2.1 INTRODUCTION

The method used here was designed to ensure that there would be a face inversion effect. In experiment 3, McLaren’s method was used with face stimuli and no effects of inverting these faces were found. The same type of face stimuli from experiment 3 are used in this new method, so if the inversion effect is found it can be concluded that these stimuli were not the cause of the lack of inversion effect previously reported, and that the cause lies directly with McLaren’s method. To this end, an old / new recognition paradigm was used to replace the discrimination phase of the previous experiment. As noted above, this has been well documented and has proven successful in producing the face inversion effect (e.g. Leder and Bruce, 2000). This old / new recognition paradigm, coupled with the technique that was developed in the earlier experiments to ensure successful development of expertise at categorisation of stimuli, were thus combined. It is hypothesised that when expertise is successfully developed, and participants are certain of the task they are expected to perform, then an inversion effect will be found.
3.2.2 METHOD

3.2.2.1 Participants

Nineteen undergraduates between the ages of 18 and 35 were given one course credit each for their participation in this experiment.

3.2.2.2 Stimuli

The stimuli were the same four cropped and grey-scaled face images that were used in experiment 3 with the addition of a fifth photograph of another bald headed Caucasian man which was scanned into a computer, cropped and grey-scaled. Using the software package Morph Version 2.5 (Gryphon Software), and an Apple Macintosh computer, these images were then 'Morphed' to create the stimuli along continua. A detailed description of the morphing process can be found in experiment 3, and the same process was used here to create the face continua.
Faces 1 to 4 (the original faces from experiment 3) were individually morphed with face 5 to create four face continua. Six of the resultant images were selected from each. These each contained between 70 and 95 percent of face 5 in 5 percent incremental steps (see figure 12 for example of continua). Each set of 6 images comprised one face category, which, over four categories results in a total of 24 different face images. Note that each face image had face 5 in common. This technique is like adding 'noise' to all the faces, where face 5 represents the noise, thus making for a more difficult category learning task than if the noise were not present. The only way to tell the face categories apart is by attending to those characteristics of the face that are not features of the noise face.

![Figure 12 - This diagram shows face stimuli from two categories with variations in the percentage of the noise face.](image_url)
3.2.2.3 Overall design

The experiment was conducted on the same PC that was used for the earlier set of experiments. Participants were required to successfully learn the category membership of two groups of stimuli and were then subsequently tested on them. To facilitate learning, in a pre-exposure phase all the stimuli in each category were presented on the screen simultaneously for 3 minutes. Next participants completed category learning during which they were required to indicate the category membership of individually presented stimuli. Finally, in an old / new recognition memory task (the test phase) stimuli were individually selected from the two previously learned categories and from two new categories. These were presented in both their upright and inverted orientations.

Allocation of the images to the participants was designed so that every possible combination of images was used. This resulted in a total of 6 different combinations, which were randomly assigned to the participants. For example, if the participant saw face categories 3 and 4 in the pre-exposure and categorisation phase then face categories 1 and 2 would be their 'new' faces in the test phase. Likewise if they saw face categories 1 and 3 then categories 2 and 4 would be their 'new' faces in the test phase.
3.2.2.4 Procedure

3.2.2.4.1 Pre-exposure phase

Following an instruction screen, 12 images were presented on the screen simultaneously for 3 minutes. These images were 6 faces from one of the categories and 6 from another and labelled either A or B. Participants were instructed that they were not required to make any response in this phase of the experiment but they were required to examine the faces very carefully because they would need to tell them apart and to make other decisions in later parts of the experiment.

3.2.2.4.2 Category learning phase

Instructions were again presented on the screen prior to the start of this phase of the experiment. Participants were told that they would be presented with images one at a time and were asked to determine whether the face belonged to the ‘A’ group or the ‘B’ group. The ‘X’ key had a label stuck on it with an ‘A’ on, and a ‘B’ label was stuck on the full stop key. Therefore by pressing the key labelled ‘A’ they indicated that the face belonged to category ‘A’ and by pressing the key labelled ‘B’ they indicated that they thought that the face belonged to the ‘B’ category. They were told that they needed to examine each of the images carefully before making their choice and that if they failed to give a response in around 4 seconds then they would be ‘timed out’, and that
this would count as an incorrect response. Like the previous experiment, participants were required to obtain 10 correct responses in a row for this phase of the experiment to terminate, participants were informed of this. However, they were not informed that the 10 correct responses would only be counted after completion of the 44th trial. To encourage participants to treat the experiment seriously they were not told the minimum number of trials, only that 'after a certain minimum number of trials were completed and they achieved 10 correct responses in a row would this phase terminate. The earliest that this phase would terminate was at trial 54 and only if the last 10 responses were correct.

A fixation cross was presented for 1 second prior to each image. The same 12 face images that were viewed in the pre-exposure phase were then sequentially presented in random order. The 12 images formed a block of trials. Every face was presented for a maximum of 4.25 seconds. Feedback was given after each response was made: 'correct', 'incorrect' or 'timed out', and these messages were displayed for a total of one second. Once 10 correct responses in a row were obtained this phase terminated. However, if by trial 500 ten correct responses were not achieved then, although this phase still terminated participants were thanked, and did not proceed to the next phase.
In this phase 12 images were presented in both upright and inverted orientation. Three images were selected from each of the two categories that the participants had previously categorised ('old' stimuli) and three images were selected from each of the two other categories that had not been previously encountered ('new' stimuli). These were selected on the basis that they were alternate points of the morphed continua. Therefore, the 70, 80 and 90 percent face 5 images, from each of the categories were used. All the images were presented twice in each orientation. Thus, there was a total of 48 trials. Participants were asked to classify each image as either 'old' in that they had seen the image before, or as 'new', in that they had never seen the image before. They were asked to push either the W key for new (labelled N) or the O key for old (for continuity this also had a label stuck on). Again a fixation cross was presented for 1 second, and then the image was presented for a maximum of 4.25 seconds. If a response was made during this time the next trial appeared. If no response was made then they were timed out and the trial counted as an incorrect response. No feedback was given for this phase of the experiment. On completion of this phase participants were thanked and debriefed.
3.2.3 RESULTS

3.2.3.1 Category learning phase

The mean number of trials taken to complete this phase was 80.7, the mean percentage correct (accuracy), excluding the last ten trials was 68 percent and the mean response time, per trial, during the category learning phase was 1100 msec. This was better than the performance achieved in the category learning phases of the chapter 2 experiments.

3.2.3.2 Test phase

Response times for upright and inverted stimuli were correlated with the numbers correct, and correlations were non-significant. This indicated that there was no speed accuracy trade off taking place for these category conditions.

Figure 13 shows accuracy for the test phase of the experiment. It can be clearly seen that scores on the upright stimuli are greater than for the inverted stimuli. In figure 14, the mean response times are shown. There appears to be no difference in the response times for the upright and inverted stimuli and the error bars indicate that there was variation in the response times.
Figure 13 - Accuracy for upright and inverted stimuli during the test phase. Error bars show +/- 1 standard deviation.

Figure 14 - Mean response times in milliseconds for upright and inverted stimuli during the test phase. Error bars show +/- 1 standard deviation.
Two t-tests – upright vs. inverted, were carried out, one for accuracy and one for the mean response times. For the accuracy figures, there was a significant effect ($t (1,18) = 6.026, p = <0.0005 \text{ (one-tailed)}$) indicating that performance on the upright exemplars was significantly better than for the inverted stimuli. No significant effect was found for the response times.

These results show that accuracy for upright stimuli was significantly better than for inverted stimuli. In other words, there was an inversion effect. There is no significant effect of orientation on response times.
3.2.4 DISCUSSION

The results of this experiment showed that there was a significant effect of orientation on the stimuli. There was no significant effect on response times. Taken together these show there was an inversion effect for newly learned face categories.

It can be said that category learning improves discrimination between exemplars of that category, and that this advantage is lost on inversion. It was expected that, like McLaren's (1997) experiment, an inversion effect might also be found for the response times, this was not the case. However, since the face inversion effect is, by definition, that inverted faces are more difficult to recognise than upright faces, it may be that the lack of difference in the response times is of little consequence. Indeed the face literature does not concentrate on the effects of response times to any great extent, although this has been criticised. Gauthier, Behrmann and Tarr (1999) argued that the literature on prosopagnosia fails to demonstrate unequivocal evidence for a disproportionate impairment of faces compared to non-face objects. They tested two
prosopagnosic subjects for the discrimination of objects from several categories, several dependent measures were taken, including response times. They found that the response times might show impairments with non-face objects in subjects whose error rates only indicate a face deficit. Given the results reported here, the criticisms that were levied at the discrimination phase of the McLaren experiment seem valid. It would appear that the original method was not robust and that the discrimination phase may well have been the problem. Speculation that this phase was treated as a novel and separate task may be correct. Perhaps participants made considerable efforts to gain familiarity with the task and in doing so developed familiarity with all the stimuli including the novel stimuli. Here, when participants are clear as to what was expected of them they were able to perform the task without ambiguity and a face inversion effect was found.

In experiment 3, which used McLaren's method but with face stimuli, it was clear that the method was not effective, since no effect of inversion was found. So far, no effects of familiarity or orientation have been found for McLaren's (1997) chequerboard stimuli. This could be because the inversion effect is purely a face phenomena, or that McLaren's methods were fragile. McLaren argues that the inversion effect has two requirements. First, that the stimuli are very familiar (expertise). Secondly, that the stimuli are from a set defined by a prototype.
If McLaren were correct about expertise and prototypical structure then it would be expected that chequerboard stimuli could show effects similar to those found with faces. If the chequerboards were placed into the present method and effects congruent with those reported here were found, then it may be concluded that category learning and possibly underlying prototypical structure contribute, at least in part, to the face inversion effect.
3.3 Experiment 5

3.3.1 INTRODUCTION

Experiment 4 has shown that recognition memory is sensitive to orientation effects for faces. The current experiment investigates whether the same method produces inversion effects for prototypically defined chequerboard stimuli.

Following pilot experiments that used chequerboards in the old / new recognition paradigm it became clear that the lack of global orientation cues in chequerboard stimuli could cause the equivalent of a response bias. When a face is inverted the observer can detect this simply from the overall face shape, although evidence indicates that of itself face shape is not responsible for inversion effects. When a chequerboard is inverted there is no overall shape cue. Consequently, participants may simply respond to all inverted chequerboard stimuli by calling them 'new'. This of course would lead to a large number of errors on the 'old' stimuli leading to an inversion effect that may have little in common with that observed for face stimuli. Thus, in the subsequent experiments the chequerboard stimuli were all shaped to provide a global orientation cue. This should ensure that the possible sources of inversion effects studied here are equivalent between faces and chequerboards.
3.3.2 METHOD

3.3.2.1 Participants

Nineteen undergraduates who had not taken part in any of the previous experiments participated. Each was between the ages of 18 and 35 and was given one course credit for their participation in this experiment.

3.3.2.2 Stimuli

The PC was the same one as used for the earlier experiments. The stimuli were developed from 4 prototype chequerboards. Each chequerboard was 2cm square and contained 16 x 16 squares; each square consisting of 4 x 4 pixels (the same as in experiments 1 and 2). From each of these 4 prototype chequerboards, 6 exemplars were created. This was done by changing a number of complete rows. Every time a row was changed it was done from the prototype so each exemplar differed from the prototype only by the number of rows that were changed on that occasion. For example; the first exemplar was created by changing 2 rows; the second exemplar was created by changing 3 rows; and so on until the sixth exemplar was created by changing 7 rows. Thus, 6 exemplars were created from each of the four
prototypes and therefore 4 different categories. Each of the chequerboards was then shaped to give global orientation cues. This was done by removing the bottom two corners.

Figure 15 below shows two of the globally orientated chequerboard categories and the exemplars of that category. From this figure it is possible to see the common features that each category shares.

Figure 15 – Globally orientated chequerboards. The numbers indicating the number of rows changed from the prototype in order to create each exemplar.
3.3.2.3 Overall Design

As in experiment 4, participants were required to learn the category membership of two groups of stimuli and were then subsequently tested on them. To facilitate learning, in a pre-exposure phase all the stimuli in each category were presented on the screen simultaneously for 3 minutes. Next, participants completed category learning during which they were required to indicate the category membership of individually presented stimuli. Finally, in an old / new recognition memory task (the test phase) stimuli were individually selected from the two previously learned 'old' categories and from two 'new' categories. These were presented at both their upright and inverted orientations.

The images were allocated so that every possible combination of images was used. This resulted in a total of 6 different conditions, which were randomly assigned to the participants. For example, if the participant saw chequerboard categories 3 and 4 in the pre-exposure and categorisation phase then chequerboard categories 1 and 2 would be their 'new' chequerboards in the test phase. Likewise, if they saw chequerboard categories 1 and 3 then categories 2 and 4 would be their 'new' chequerboards in the test phase. However, regardless of which category of exemplars they received they were labelled A and B for the purposes of the participants in the experiment.
3.3.2.4 Procedure

3.3.2.4.1 Pre-exposure, category learning phase and test phase

Each of these was identical in every way to experiment 4 except that the stimuli were chequerboards instead of faces and in the old / new recognition (test) phase these chequerboards were the ones with 3, 5 and 7 lines changed.
3.3.3 RESULTS

3.3.3.1 Category learning phase

The mean number of trials taken to complete this phase was 74.4, the mean percentage correct (accuracy), excluding the last ten trials, was 72 percent and the mean response time, per trial, during the category learning phase was 1268.00 msec.

3.3.3.2 Test phase

Response times for each stimulus category were correlated with accuracy for that category. Correlations were not significant. Therefore no speed accuracy trade off was taking place.

Figure 16 shows the mean accuracy figures for the upright and inverted stimuli. Performance on the upright stimuli can be seen to be better than performance on the inverted stimuli. Figure 17 shows the mean response times. There appears to be no difference in the response times for the upright and inverted stimuli.
Figure 16 - Accuracy for the upright and inverted stimuli in the test phase. Error bars show +/- 1 standard deviation.

Figure 17 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase. Error bars show +/- 1 standard deviation.
Two t-tests were carried out for accuracy and for the mean response times. In each case these tested the effect of orientation on the stimuli. For accuracy the t-test found that there was a significant effect of orientation \((t(1,18) = 4.89, p = <0.0005 \text{ (one tailed)})\) indicating that performance on upright exemplars was significantly better than on the inverted. For the response times there was no significant effect of orientation.
3.3.4 DISCUSSION

The results showed that accuracy was significantly affected by the orientation of the stimuli indicating an inversion effect. Response times showed no significant effect.

McLaren’s theory regarding expertise with a category has been upheld and ability to discriminate between exemplars of abstract categories is reduced upon inversion. The only difference between experiment 4 and 5 is the stimuli that were used. For the category learning phases the mean number of trials to completion was 80.7 and 74.4 respectively and the mean percentages correct were 68% and 72%. In McLaren’s experiment, the number of trials to completion 80.9 and mean percent correct 59.4%. The difference in the mean percentage correct could be explained by the fact that in the present experiments 10 correct responses in a row were needed to terminate category learning whilst in McLaren’s experiment only 6 correct responses were required. Therefore, by comparing the performance in the categorisation phases, it can be said that there was, for all intents and purposes, the same level of difficulty of stimulus identification in each of the experiments.
A direct statistical comparison of the magnitude of the inversion effects for faces in experiment 4 and the chequerboards in experiment 5 was carried out to assess the relative size of these effects. Figure 18 shows that the chequerboards are identified more accurately than the faces in both their upright and inverted orientations and that the decrement in performance for upright versus inverted stimuli is approximately equal for the two classes of stimuli. This is in direct contrast to previous findings that faces are disproportionately affected by inversion when compared with other stimulus classes (Yin, 1969).

Figure 18 - shows a comparison of the size of the inversion effect for faces (experiment 4) and chequerboards (experiment 5). Error bars show +/- 1 standard deviation.
A 2 x 2 way ANOVA (Experiment (2) – Experiment 4 faces vs. Experiment 5 chequerboards; Orientation (2) – upright vs. inverted) of these data only showed a significant main effect of inversion (F (1,36) = 14.94, p = 0.001) and a significant main effect of experiment (F (1,36) = 20.13, p = 0.002). There was no significant interaction. This shows that the inversion effect for faces and chequerboards is indeed equal across experiments 4 and 5.
3.4 Chapter 3 – General Discussion

The two experiments of this chapter, using essentially the same method, have found equivalent inversion effects for faces and chequerboards. The procedure involved testing recognition memory after development of expertise via category learning. The consistency of these results supports that the lack of an inversion effect in earlier experiments was due to the insensitivity of McLaren's discrimination phase.

The results so far are consistent with McLaren expertise – prototype theory, however they have only tested it to a limited extent. No direct comparison of prototypical and non-prototypical categories has been made. The next chapter does so.
CHAPTER 4

4.1 General Introduction

This chapter investigates whether categories defined by a prototype are necessary for the inversion effect. So far all the stimuli used have been defined by a prototype. First, this chapter investigates non-prototypically defined chequerboards followed by multiple exemplars of both prototypical and non-prototypically derived chequerboards. Thus, investigations will address what types of stimuli are vulnerable to inversion.

The chequerboards used in the previous experiments were defined by prototypes and were from a small (limited) stimulus set. Further, the previous chapter found a comparable inversion effect for chequerboards and faces following development of expertise via category learning. However, it is not known whether similar inversion effects would result with stimulus categories that are not defined by a prototype and also whether multiple category exemplars can produce the same effects as stimuli from a limited stimulus set.
In McLaren's experiments there was no effect of inversion found for non-prototypically defined chequerboards. However, the method used by McLaren is questionable. Diamond and Carey (1986) studied inversion effects with landscapes and faces. Faces are defined by a prototype whereas they claimed that landscapes aren't. They found the inversion effect for faces to be superior to the effect found with landscapes. However, they also argue that experts represent items in memory in terms of distinguishing features of a different kind than do novices. Therefore it is possible that the inversion effect could be found with non-prototypically defined chequerboards, providing that a sufficient level of expertise was developed. However, this inversion effect might not be as great as for chequerboards defined by a prototype.

Further, the notion that the prototype can be abstracted from the category exemplars needs to be addressed (Bruce, Doyle, Dench and Burton, 1991). Therefore, in the present chapter, multiple exemplars are used, as in chapter 2, together with the existing method (developed in chapter 3). Thus, the question as to whether it is both prototype extraction and the development of expertise that leads to the inversion effect can be explored.
4.2 Experiment 6

4.2.1 INTRODUCTION

This experiment tested the prototype conjecture. It repeated experiment 5, but with non-prototypically defined chequerboard categories. If the conjecture is true, then no inversion effect should be found. On the other hand, if expertise is sufficient to produce inversion effects, then the results should be similar to experiment 5. Hence, keeping all else constant, only stimulus categories that are not defined by a prototype were investigated.

Non-prototypical chequerboard stimuli were generated for this experiment by shuffling rows of the base patterns, rather than substituting them. The intention was to create stimuli that shared the same overall level of white or black squares but that if averaged would not yield the base stimulus (or prototype) from which they were derived.
4.2.2 METHOD

4.2.2.1 Participants

Nineteen different undergraduates who had not taken part in any of the previous experiments participated. Each was between the ages of 18 and 35 and was given one course credit for their participation in this experiment.

4.2.2.2 Stimuli

The stimuli were created by generating four random base patterns (as in experiment 5), which defined each of the four categories. These base patterns were created in exactly the same way as they were in experiment 5. However, in this experiment exemplars were generated by shuffling the rows of each base pattern. All sixteen horizontal lines of a base pattern were shuffled to create the category exemplars. Shuffling rows means that, whilst each row remained the same, each of the rows were randomly moved about in the chequerboard, so that they ended up in a different place from that in which they started. Thus, a single base pattern was taken, and the sixteen rows were shuffled once to create the first exemplar, then the rows in the base pattern were shuffled again to create the second exemplar and so on until the base pattern had been shuffled 6 times and therefore 6 exemplars were created. This process
was carried out on each of the four base patterns and therefore 24 exemplars were created (6 for each of the 4 categories) were created. These chequerboards were then shaped by removing the bottom two corners, thus giving them global orientation cues. This is exactly the same as the shaping of the chequerboards in experiment five.

Figure 19 shows the chequerboards used in this experiment. The chequerboards in category A all contain the same 16 rows but each of the chequerboards differs in the fact that the rows are randomly shuffled and therefore in different places in each of the chequerboards. Likewise, the category B chequerboards all have a different set of 16 rows in common, but differently ordered across exemplars. It can be seen from this figure that for each category there are no common defining features, however the overall level of white or black squares is roughly shared by each category.

![Figure 19 - Non-prototypically defined, globally orientated chequerboards.](image)
4.2.2.3 Design

The design of the experiment was identical to experiments 4 and 5.

4.2.2.4 Procedure

4.2.2.4.1 Pre-exposure, category learning and test phase

Each phase was identical to experiments 4 and 5. For the test phase the exemplars were 12 randomly selected from the exemplars used in the category learning phase. Three of the exemplars were from each of the two categories in the learning phase (old) and three from each of the two other categories not previously seen (new).
4.2.3 RESULTS

4.2.3.1 Category learning phase

The mean number of trials taken to complete this phase was 176, the mean percentage correct, excluding the last ten trials was 71 percent and the mean response time, per trial, during the category learning phase was 1135 msec.

4.2.3.2 Test phase

Response times for each stimulus category were correlated with accuracy in that category. There were no significant correlations. This indicated that there was no speed accuracy trade off taking place.

Figure 20 shows the mean accuracy figures in the test phase. It can be seen that performance is worse for the inverted stimuli than stimuli in the upright orientation. Figure 21 shows the mean response times. Performance is about the same for both the upright and inverted stimuli.
Figure 20 - Accuracy for the upright and inverted stimuli of the test phase. Error bars show +/- 1 standard deviation.

Figure 21 - Mean response times in milliseconds for the upright and inverted stimuli of the test phase (error bars show +/- 1 standard deviation).
Two t-tests were performed on the upright and inverted stimuli for both accuracy and response times. These tested the effect of orientation on the stimuli.

For the accuracy data the t-test was significant ($t(1,18) = 2.876$, $p = 0.005$ (one tailed)) indicating that performance on upright exemplars was significantly better than on the inverted exemplars.

For the response times the t-test was not significant. This indicated that for the upright and inverted stimuli there was no difference in the speed of the response and therefore no significant effect of orientation on the response times.
4.2.4 DISCUSSION

The results showed that accuracy was significantly affected by orientation, in that performance on the upright stimuli was significantly better than on the inverted stimuli. Therefore, the inversion effect has been found. The response times did not show any significant effects.

When the results of the previous experiments are compared with the results of this experiment the most prominent difference is in the category learning phases. The mean number of trials taken to complete the category learning phase in this experiment was more than twice the mean number of trials taken in the previous experiments (176 compared with around 80). This was not unexpected, since with non-prototypically defined chequerboards there is no single feature or configuration present in every chequerboard that can be used to tell each one apart. Therefore, in order to develop expertise with these stimuli a greater number of trials were required in category learning. Presumably, the participants here were learning individual exemplars or row specific features. The other possibility is that they were able to distinguish the exemplars based on the overall level of black and white squares.
In the experiments so far the number of trials taken to complete category learning has until now compared with the results of McLaren. It was argued earlier that learning non-prototypical stimuli would be harder than prototypical categories. If this is the case, then McLaren's results present something of a puzzle since he reported the same number of trials (for completion of category learning) with both prototype and non-prototype versions. It may be that McLaren's subjects did not really learn the categories. Rather, they achieved criterion by chance. This is possible for two reasons. Firstly, there was no pre-exposure phase; and secondly the criterion was six correct in a row, rather than the 10 used here. If this suggestion were true, it would of course account for the lack of inversion effect.

The size of the inversion effect found here with the non-prototypical exemplars is comparable with the effects found in experiment 5 (prototypical exemplars). Figure 22 shows the inversion effects found both here and in experiment 5. It can be seen that the upright stimuli for the prototypical exemplars of experiment 5 are more accurately identified than the upright exemplars of this experiment.
A 2 x 2 way ANOVA (Experiment (2) - 6 vs. 5; Orientation (2) - upright vs. inverted) showed a significant effect of inversion ($F(1,36) = 21.91$, $p = 0.002$) but no significant effect of experiment, or interaction between these factors. Thus indicating that the size of the inversion effect was equal across the non-prototypical and prototypical chequerboard experiments.

McLaren argued that the inversion effect was based on both expertise with a category and the category being defined by a prototype. It has been shown here that firstly, expertise was developed with non-prototypical stimuli, and then that the inversion effect was still found. Therefore, these results indicate that expertise is the crucial requirement for the inversion effect and not category type. However, this issue needs to be addressed further.
4.3 Experiment 7

4.3.1 INTRODUCTION

it has so far been demonstrated that inversion effects that are analogous to those found with faces can be found with chequerboards when they are used in a category learning task followed by an old/ new recognition task. Familiarity with the stimuli has been proven to be a factor that contributes, at least in part, to the inversion effect. However, the chequerboards for categorisation so far, whilst either being defined by a prototype or not, were limited in number. To be specific, in experiments 5 and 6 participants learned to categorise 12 chequerboards from each of two categories. It could be argued that familiarity was obtained with the individual category exemplars and not the category defining features as a whole. One argument against this is the observation that in the case of the previous experiment (6), where categories were not defined by a prototype, category learning took more than twice as many trials. This implies that where exemplars were defined by a prototype, participants could use common features across category members to assist learning, indicating that at least partial prototype extraction occurred.
In the present experiment, prototypically defined chequerboards are generated so that the same chequerboard is never seen twice. This more directly ensures that category learning and development of expertise can only be achieved by observing the prototypical structure of the chequerboard category and not by learning individual chequerboard exemplars.
4.3.2 METHOD

4.3.2.1 Participants

Nineteen different undergraduates who had not taken part in any of the previous experiments participated. Each was between the ages of 18 and 35 and was paid for their participation.

4.3.2.2 Overall Design

The overall design was the same as for the previous experiment. The only difference in this experiment was the number of stimuli. Each of the stimuli could only be viewed once. Since the category learning phase terminated when 500 trials had been presented and each category here had 500 exemplars then it was impossible for a stimulus to be viewed more than once.

4.3.2.3 Stimuli

Four prototype chequerboard stimuli were generated at random. Each of these four prototypes defined a category. Entire horizontal lines were replaced at random with a randomly generated line. The process was repeated eight times and on each occasion all of the 16 rows were eligible for replacement. Thus, each exemplar shared roughly 80 % of its
squares with the category prototype. This process was carried out for each of the four prototypes and repeated so that there were 500 exemplars created from each of the four prototypes resulting in 500 exemplars for each category and a total of 2000 individual chequerboards. Each of the chequerboards was then shaped in exactly the same manner as in experiment 5, so that it had a definite global orientation. See figure 23.

Figure 23 - Example of stimuli from two chequerboard categories. Categories A and B are both defined by a prototype and are a sample of the multiple exemplars.

4.3.2.4 Procedure

4.3.2.4.1 Pre-exposure, Category learning phase and Test Phase

Each of these phases was identical in every aspect to the previous experiment.
4.3.3 RESULTS

4.3.3.1 Category learning phase

The mean number of trials taken to complete this phase was 172, the mean percentage correct (accuracy), excluding the last ten trials was 67 percent and the mean response time, per trial, during the category learning phase was 2290 msec.

4.3.3.2 Testing phase

Response times for each stimulus category were correlated with accuracy in that category. No significant correlations were found. This indicated that there was no speed accuracy trade off taking place for these category conditions.

Figure 24 shows the accuracy for the test phase of the experiment. Performance on the inverted stimuli is lower than it is for the upright stimuli. In figure 25, the mean response times for the test phase show performance on the upright stimuli is faster than performance on the inverted stimuli.
Figure 24 - Accuracy for the upright and inverted stimuli in the test phase, error bars show +/- 1 standard deviation.

Figure 25 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase, error bars show +/- 1 standard deviation.
Two t-tests were carried out for accuracy and for the mean response times. These tested the effects of orientation on the stimuli.

For the accuracy, there was a significant effect of orientation ($t(1,18) = 1.766$, $p = 0.047$ (one tailed)) indicating that the upright stimuli were identified significantly more accurately than the inverted stimuli in the test phase.

For the response times there was a significant effect of orientation ($t(1,18) = 2.897$, $p=0.005$ (one tailed)) whereby, responses were made more quickly to upright stimuli than to inverted stimuli.
4.3.4 DISCUSSION

The results of this experiment showed that performance on inverted stimuli was significantly different from performance on upright stimuli for both accuracy and response times. Hence the inversion effect was found for the multiple exemplars of the prototypical stimuli.

This experiment was conducted to see if participants were learning individual exemplars of the stimuli or were developing familiarity with the prototype. Since the inversion effect was found it would appear that it is the underlying prototype that is being extracted from the exemplars.

The inversion effect was found in experiments 5 & 6 with the chequerboard stimuli. However, with only 12 chequerboards from each category being presented it was possible that it was the individual exemplars that were being learnt. Here, creating multiple exemplars of each prototype has shown that the learning of the prototype appears to have been achieved.

The results of the category learning phase show that the mean number of trials to completion (excluding the last ten) was 172 here compared with 74.4 for experiment 5. The mean percentage correct for this experiment was 67% compared with 72% for experiment 5. These results
show that, it is more difficult to achieve learning of multiple exemplars of prototypical stimuli than it is to learn prototypical stimuli of a limited stimulus set. However, once learning is achieved the inversion effect is still found for these prototypical stimuli.

The accuracy figures in the old / new recognition tasks, of this experiment, are lower than for experiment 5 as can be seen in figure 26. This was probably due to the fact that when multiple prototypical exemplars are presented, the task of learning these exemplars is much harder than when only a limited stimulus set is presented. It would also indicate that it is more difficult to extract the prototype from a set of multiple exemplars than it is to extract it from a limited stimulus set.

Figure 26 - Comparison of accuracy for experiment 5 and experiment 7. Error bars show +/ -1 standard deviation.
A 2 x 2 way ANOVA (Experiment (2) – 7 vs. 5; Orientation (2) – upright vs. inverted) showed a significant effect of experiment \( (F(1,36) = 124.166, p = < 0.001) \), a significant effect of inversion \( (F(1,36) = 14.897, p = 0.001) \), but no significant interaction between these factors. Thus indicating that the size of the inversion effect was not significantly different across two prototypical chequerboard experiments.

This is the only experiment so far that has shown significant differences between the response times for the upright and inverted stimuli. Indeed, the response times here also show the effect of inversion on these stimuli. This again could be due to the fact that this experiment was harder than the previous experiments, in that, because of the level of difficulty, more time was needed to respond to the inverted stimuli than the upright stimuli.

The results found here indicate that prototype extraction may have been achieved. This raises questions over the inversion effect found for the non-prototypical limited stimuli in the previous experiment. It is therefore important to further address the issue of prototypical versus non-prototypical stimuli.
4.4 Experiment 8

4.4.1 INTRODUCTION

The results in experiment 6 showed the inversion effect with non-prototypically defined stimuli from a limited stimulus set. In experiment 7 the inversion effect was found with multiple exemplars of each prototype presented during category learning. Here, a further investigation as to whether it is possible to demonstrate the inversion effect with multiple exemplars is conducted.

Using the same method from experiment 7 and deriving multiple exemplars of the non-prototypical stimuli, further investigations regarding the need for categories to be defined by a prototype is investigated.
4.4.2 METHOD

4.4.2.1 Participants

Nineteen different undergraduates who had not taken part in any of the previous experiments participated. Each was between the ages of 18 and 35 and was given one course credit for their participation in this experiment.

4.4.2.2 Design

The design of the experiment was identical to experiment 7.

4.4.2.3 Stimuli

The stimuli were generated by randomly creating four base patterns. Each of these base patterns defined a category. The exemplars were created by shuffling the rows of these base patterns. All sixteen horizontal lines of a base pattern were shuffled to create the category exemplars (see stimuli rationale in experiment 6). As in experiment 7, 500 exemplars of each base pattern were created. These stimuli were then shaped in exactly the same manner as the chequerboards in the previous experiment to create global orientation cues. Figure 27 shows some of the stimuli used in this experiment.
Figure 27 - Example stimuli from 2 categories of non-prototypically defined chequerboards.

4.4.2.4 Procedure

4.4.2.4.1 Pre-exposure, category learning and test phase

Each was identical to experiment 7 in every aspect.
4.4.3 RESULTS

4.4.3.1 Category learning phase

The mean number of trials taken to complete this phase was 179, the mean percentage correct (accuracy), excluding the last ten trials was 56 percent and the mean response time, per trial, during the category learning phase was 1308 msec.

4.4.3.2 Test phase

Response times for each stimulus category were correlated with the numbers correct in that category, all correlations were not significant.

Figure 28 shows the mean accuracy figures for the upright and inverted stimuli. Performance on the upright stimuli is slightly better than on the inverted stimuli. Overall, performance on both upright and inverted stimuli is around chance. In figure 29 the mean response times are shown. There appears to be no difference between the results of the stimuli in either orientation.
Figure 28 - Accuracy figures for the upright and inverted stimuli in the test phase. Error bars show +/- 1 standard deviation.

Figure 29 - Mean response times in milliseconds for the upright and inverted stimuli in the test phase. Error bars show +/- 1 standard deviation.
Two t-tests were carried out which tested the effect of orientation on the stimuli for both accuracy and response times.

For accuracy the t-test was not significant ($t(1,18) = 0.704$, $p = 0.245$ (one tailed)) indicating that performance on the upright and inverted stimuli was not significantly different. The accuracy was investigated to see if performance was different from chance. For the upright stimuli the results were non-significant ($t(1,18) = 1.499$, $p = 0.151$) and for the inverted stimuli the results were also non-significant ($t(1,18) = 0.559$, $p = 0.583$). These results indicated that accuracy for both the upright and inverted stimuli was not significantly different from chance.

Systematic investigations of these accuracy data were conducted by firstly removing all participant data where performance was less than chance (50%). Secondly, all data where performance was at chance was removed, and finally the data from participants whose performance was between chance and 55% was eliminated from the analysis. This removed 4 sets of data, then an additional 3, then another 4. Each time the data were analysed using t-tests and the results of each were non-significant. This confirmed that there were no significant effects of inversion to be found for this accuracy data.

For the response times the t-test was not significant ($t(1,18) = 1.239$, $p = 0.115$ (one tailed)) indicating that there was no significant effect of orientation found for the response times.
4.4.4 DISCUSSION

These results showed no difference in the accuracy and speed of response between the upright and inverted stimuli. Therefore, there was no inversion effect with these multiple exemplars of non-prototypically defined chequerboards.

The categorisation data here are similar to the categorisation data for experiments 6 and 7 in that the mean number of trials taken to complete category learning here was 176 and 172 and 179 in experiments 6 and 7 respectively. Overall, the mean number of trials in these experiments is greater than the mean number of trials in the previous set of experiments reported in chapter 3. This was to be expected in that stimuli are more difficult to categorise when they are not defined by a prototype and are harder to categorise when there are multiple exemplars.

The inversion effect has not been found with these multiple exemplars of the non-prototypical stimuli. In this experiment it was not possible to learn individual exemplars of the category since there were too many stimuli in each of the sets and each of these stimuli were only viewed on one occasion. In experiment 6 the exemplars were a limited set of non-prototypical chequerboards and the inversion effect was demonstrated. It would therefore appear that in experiment 6 it may have been the individual category members which were being learnt.
4.5 Chapter 4 – General Discussion

In this chapter expertise was developed with the stimuli in each of the experiments via category learning. The inversion effect was found with both limited training sets and multiple exemplar training sets for prototypically defined chequerboards (experiments 5 & 7). It was also found with non-prototypically defined chequerboards when a limited category training set was used (experiment 6), but not when a large number of exemplars were viewed during category training (experiment 8).

Expertise was developed with the non-prototypical exemplars in both experiments 6 and 8. For expertise to be developed with these non-prototypical stimuli, where there was no single defining feature that dictated category membership, it is likely that participants used a different strategy to distinguish between category exemplars from that used for the prototypically defined categories. As described previously, ‘shuffling’ the base pattern created non-prototypically defined category exemplars. It is possible that participants could have learned the pattern of white and black squares in one (or more) individual row(s) and then used this to identify category membership. However, inspection of the stimuli suggests it would be extremely difficult to identify individual rows in this way and participants did not report using this strategy.
Further, the finding of an inversion effect in experiment 6 but not in experiment 8 is suggestive that different strategies might have been adopted across these two experiments, rather than one common strategy. In experiment 6, where only a few stimuli had to be identified, it may be that participants opted to learn the category membership of each individual stimulus. Recognition of these individuals was then presumably impaired by stimulus inversion. In experiment 8, it was not possible to learn all 500 individual category exemplars. Thus, participants would have needed a more general strategy such as discriminating exemplars on the basis of the overall level of light and dark squares that were present in that category. This type of general strategy would not be affected by inversion and may account for the lack of an inversion effect in experiment 8 even though participants had learned to categorise the stimuli.

Alternatively, it may be that the 'shuffled' exemplars, whilst not being generated as prototypes, were internally represented by the participants in terms of general characteristics. In that, by learning something general about each category, they created their own kind of idiosyncratic 'prototypical representation' of the category members. It could be that this led participants to be able to extract their 'prototype representation' from the limited set of shuffled exemplars and hence the inversion effect was found. However, when there were multiple exemplars it was much harder and therefore the inversion effect was not found.
Like experiment 6, experiment 5 also used a small category training set. However, category learning required less than half as many trials in experiment 5 where the exemplars were all defined by the category prototype. This implies that participants were able to use the features in common across exemplars to aid category learning. It supports the suggestion that the inversion effect found in experiment 5 follows at least partial prototype extraction whilst in experiment 6 it looks likely to have resulted from a different process such as the learning of individual exemplars as discussed previously.

Experiment 7 required subjects to learn categories with a much larger number of exemplars. Subjects never saw the same exemplar twice. Thus, category learning here is consistent with the suggestion that participants learned something about the underlying category prototype in order to categorise the stimuli. More than twice as many trials were required to do this with the large training set used in experiment 7 compared with the limited set used in experiment 5. This suggests that learning about the category prototype is more difficult when a larger and therefore noisier training set is used. However, in both cases it seems likely that prototype extraction was involved in the inversion effect observed in both these experiments.
Thus, together the results of this chapter are consistent with the possibility that inversion effects are contingent upon members of a category being defined by a prototype. In addition, it may be that learning individual stimuli can also lead to inversion effects, or that participants create their own 'prototypical representation', as indicated by the findings of experiment 6, but this may be something of a special case.

Thus far, at surface level, the inversion effects for chequerboards and faces appear to be similar. However, it is possible that they are produced by different underlying processes. The following chapter will investigate the processing of chequerboard stimuli.
CHAPTER 5

5.1 General Introduction

This chapter investigates whether similar mechanisms are responsible for the inversion effect found with both faces and chequerboards. How is it possible that stimuli so different in kind are able to produce comparable inversion effects? So far it has been concluded that the effects found with chequerboards are analogous to those found with faces and that these effects are dependent on expertise developed through category learning. The analogous results that have been obtained for stimuli that are so different in kind leads to the question of whether the nature of the processing of these stimuli is equivalent. The aim of the experiments here is to elucidate the nature of the underlying process. This was done by first using the alignment / mis-alignment method (Young et al., 1987) and secondly using a 'moving window' technique, to explore which components of the images are attended to.

Previous work has suggested that upright faces are processed as a configuration of features. One such source of evidence has come from the study of composite faces (Young et al., 1987). Composites are created from the top half of one person's face and the bottom half of another. Subjects make decisions about the identity of one half of the face. Typically, responses take longer if the two halves are in alignment than if the two halves are misaligned. It has been argued that when the
faces are aligned they form a configural whole and that this is processed as a single face, not as the top of one face and the bottom of another. Thus, the observer effectively has to overcome this configural processing in order to attend to and recognise just one half of the face when they are presented aligned. In experiment 10, the same technique will be applied to the chequerboards in an attempt to ascertain whether the chequerboards are processed in a similar way to faces.

Evidence that stimuli other than faces can be processed as configurations comes from Gauthier, et. al. (1998) who trained participants to be ‘Greeble’ experts. Greebles, like faces, share a common spatial configuration. Their studies found that greebles were processed configurally, following acquisition of expertise. It may be that chequerboards are also configurally processed following expertise acquired in category learning. An experimental design using a ‘moving window’ technique, and the old / new recognition task is used to investigate this possibility. This technique allows only a portion of the stimuli to be viewed on any occasion. Tracking the position of the window as it is moved by the observer, enables ‘intensity maps’ to be created. These maps, together with the responses made, allows for direct comparisons to be drawn between the faces and chequerboards.
5.2 Experiment 9

5.2.1 INTRODUCTION

Young et al. (1987) used composite faces to investigate the importance of configural information in face perception, and showed that configurations are only properly perceived in upright faces. They found that the perception of a complete face, in top and bottom half composites interferes with identification of the constituent halves. Reaction times for identifying the top half of composite faces (where the top and bottom half of faces were aligned) were compared with the response times for identifying non-composites (top and bottom halves misaligned). They found reaction times to be substantially slower for composites than non-composites which, they believed, indicated that the perception of a novel facial configuration in the composites interfered with the identification of the constituent parts. Thus, they demonstrated the importance of configurational information in face perception. However, there was no difference between the perception of the composites and non-composites when they were inverted, in agreement with the suggestion that the configurations are only properly perceived in upright faces.

The current experiment investigates the way in which chequerboards are processed via the configural alignment method. If the effect is found with chequerboards then this would imply that in this respect, at least, faces and chequerboards are processed in the same way.
5.2.2 METHOD

5.2.2.1 Participants

Thirty-eight undergraduates who had not taken part in any of the previous experiments participated. Each was between the ages of 18 and 35 and was paid for their participation.

5.2.2.2 Stimuli

The chequerboard stimuli were the same chequerboards that were used in experiment 5, where they produced an inversion effect. They were prototypically defined and had a definite global orientation. As in experiment 5 these chequerboards were presented unaltered for the pre-exposure and category learning phases of the experiment.

For the test phase each of the chequerboards was divided, horizontally across the middle. Thus creating a top and bottom half. The tops of the chequerboards were joined with different bottoms to create the stimuli. This resulted in four different categories; old top with new bottom; new top with old bottom; old top with a different old bottom; new top with a different new bottom. The stimuli tops and bottoms were joined either aligned to create a composite or mis-aligned (to both the right and
to the left) to give non-composites. All the stimuli from each of the
categories were presented both as composites and non-composites to
both the left and the right. Figure 30 shows examples of the composite
and non-composite chequerboards used in this experiment.

Figure 30 - Chequerboard composites and non-composites (left and right).
5.2.2.3 Overall Design

The overall design for the pre-exposure and category learning phase were the same as for experiment 5. However, in the old / new recognition memory task (the test phase), the composite and non-composite stimuli were all presented upright and participants asked to state whether they had seen the top half of each stimulus before or not.

5.2.2.4 Procedure

5.2.2.4.1 Pre-exposure and category learning phase

These were exactly as detailed for experiment 5.

5.2.2.4.2 Test Phase / old – new recognition

In this phase the composites and non-composites were presented individually for a maximum of 4.25 seconds. Participants were asked to respond 'old' or 'new' to indicate whether they had seen the top half of a stimulus before or not. Responses was made as in experiment 5 by pushing the 'o' key (for old) or the 'w' key – labelled 'n' (for new). No feedback was given.
5.2.3 RESULTS

5.2.3.1 Category learning phase

The mean number of trials taken to complete this phase was 77, the mean percentage correct, excluding the last ten trials was 60 percent and the mean response time, per trial, during the category learning phase was 1479msec.

5.2.3.2 Test phase

Response times for each stimulus category were correlated with the numbers correct in that category. No significant correlations were found. This indicated that there was no speed accuracy trade off taking place for these category conditions.

Figure 31 shows the average accuracy figures for the test phase of the experiment. There is no difference between performance for the composites and non-composites. In figure 32, the mean response times are shown. Again, there is no difference between reactions times to the composites and the non-composites of the old and new stimuli.
Figure 31 - Average accuracy figures for the composite and non-composite chequerboards. Error bars show +/- 1 standard deviation.

Figure 32 - shows the mean response times in milliseconds for the composites and non-composites. Error bars show +/- 1 standard deviation.
Two t-tests were carried out on the accuracy figures and on the mean response times. In each case these tested the effects of stimulus structure. No significant effects were found for either accuracy or response times.

These results show that whether the chequerboard was presented as a composite or a non-composite there was no difference in either accuracy or the response times.
5.2.4 DISCUSSION

The results show that there was no significant difference between performance on the composite and non-composite chequerboards for either accuracy or response times.

These results are in contrast to the results found, with face stimuli by Young et. al. (1987). They found that composite faces were less accurately identified than non-composite faces and took significantly longer. This they concluded demonstrated the importance of the configurational information in face perception. The results found here are very different from those found with faces. This might indicate that configurational information is not as important with chequerboards as it is with faces. However, the composite stimuli used here perturb the configural information in the centre of the image not around the edges. If participants were not using the centre of the images to identify them then this could explain these results. The next experiments explore the underlying process in more detail by estimating which components of the images are attended to.
If the earlier conjecture is true, that chequerboards and faces are analogous (since equal size inversion effects were found, with both, following equivalent category learning) then here, it is clear that there is a difference in the processing of face and chequerboard stimuli. However, it is unclear from the results of this experiment exactly what the nature of this difference is.
5.3 Experiment 10

5.3.1 INTRODUCTION

The aim of this present experiment was to measure the parts of the chequerboard and face images that were attended to. This was accomplished using a 'moving window' technique.

As in the previous experiments, expertise will be developed with the stimuli via category learning. Then in the old / new recognition task, search of the image will be done through the 'moving window' and decisions made about whether the image is old or new. This 'moving window' technique allows only a small area of the chequerboard or face to be viewed through the window at any one time. Participants move the window around, as they choose, to view the areas of the stimulus. Thus, it is expected that the participants' search of the image will be driven 'top-down' by their internal representations of the stimulus categories. The restriction of their view to only one part of the image at a time prevents image features attracting attention 'bottom-up'.

1 Note that this is quite distinct from the moving window technique of Van Diepen, Wampers, & d'Ydewalle (1998) where a full spatial frequency (SF) bandwidth window is moved around over a SF filtered image in synchrony with an observer's eye movements. In their technique because the whole image is visible, bottom-up factors can attract attention and thus determine eye movements and window position. Thus, their technique does not reveal the observer's internal representation of the diagnostic image regions.
allows the derivation of a ‘diagnostic image’ which will be systematically examined. This will enable the patterns of observers' movements to be identified and thus, their internal representations of a particular stimulus category.

It is speculated that face processing will be more affected by the window because it prevents overall viewing of the configuration of image features. Consequently, it would be expected that the advantage for processing upright faces over inverted faces might be lost. It is also predicted that there will be greater consistency across participants in the area of the face searched than for chequerboards. In the former case we would expect, based on past research, that participants will focus on the region of the internal features (e.g. eyes, nose and mouth) of the face. In the latter case it is speculated that they will pick on idiosyncratic features in various image regions to identify the stimuli. Further, we might expect, given the findings of the previous experiment, that these features are less likely to be in the centre of the images since if observers were using central features then this would presumably have led to a difference in recognition of aligned vs. non-aligned composite stimuli.
5.3.2 METHOD

5.3.2.1 Participants

Thirty-eight undergraduates between the ages of 18 and 35 were paid for their participation in this experiment. Nineteen were allocated at random to the face condition and the other nineteen to the chequerboards condition.

5.3.2.2 Stimuli

The base stimuli were the same four cropped and grey-scaled face images that were used in experiment 4 with the same exemplars, and the same four shaped chequerboards that were used in experiment 5 together with the same exemplars from that experiment.

5.3.2.3 Overall design

There were three parts to the experiment. Participants were required to successfully learn the category membership of two groups of stimuli and then subsequently tested on them. The learning was facilitated by a pre-exposure phase, followed by a category learning phase. Responses were made and feedback given until the learning criterion was met. Then in an old / new recognition memory task (the test phase) stimuli were presented from the two previously learned (old) categories together with
stimuli from two new categories. These were all presented randomly in both their upright and inverted orientations. Here, the majority of a stimulus was covered and the only area that the subjects were able to view was through a window. The window was 16 x 16 pixels in size. Participants were able to move the window in increments of 4 pixels and as many times as they liked until they were able to make a response as to whether the stimulus was old or new. The time taken for their responses was recorded along with both the number of window moves made and the areas of the image that the window was moved over. Responses were made and no feedback was given. The experiment terminated after all the images had been viewed twice.

There were 4 conditions in total, two chequerboard conditions: condition 1 in which categories A and B were old, C and D new: condition 2 in which categories C and D were old, A and B new. And two face conditions: condition 3 in which A and B were old and C and D new: condition 4 in which C and D were old with A and B new. Allocation of participants to the conditions was random.
5.3.2.4 Procedure

5.3.2.4.1 Pre-exposure phase

Following an instruction screen 12 images were presented on the screen simultaneously for 3 minutes. Depending on condition these images were 6 faces from one of the categories and 6 from another and labelled either A or B, or they were 6 chequerboards from one of the categories and 6 from another and labelled A and B. Participants were instructed that they were not required to make any response in this phase of the experiment but they were required to examine either the chequerboards or the faces very carefully because they would need to tell them apart and to make other decisions in later parts of the experiment.

5.3.2.4.2 Category learning phase

This was identical to the previous experiments.

5.3.2.4.3 Test phase

In this phase 12 images were presented in both upright and inverted orientation. Three images were selected from each of the two categories that the participants had previously categorised (old stimuli) and three images were selected from each of the two other categories that had not been previously encountered (new stimuli). For the faces these were selected on the basis that they were alternate points of the morphed
continua (as in experiment 4) that were created. Therefore, the 70, 80 and 90 percent images from each of the categories were used. For the chequerboards they were again the alternative points where 3, 5 and 7 rows were changed (as in experiment 5). All the images were presented twice in each orientation. Thus there was a total of 48 trials. Participants were asked to classify each image as either ‘old’ in that they had seen the image before or as ‘new’ in that they had never seen the image before. They were asked to push either the W key for new (labelled N) or the O key for old (for continuity this also had a label stuck on). They were told that they could only view a small segment of each image at any one time and that they were able to view the image by pressing the arrow keys on the keyboard. They would first need to move the window and then they should be able to make a decision as to whether the image was old or new. The window started at a randomly selected position on each trial.

Again a fixation cross was presented for 1 second and then the image was presented. There was no time out for the image; it stayed on the screen until a response was made. Once a response was made the next trial appeared. No feedback was given for this phase of the experiment. On completion of this phase participants were thanked and debriefed.
5.3.3 RESULTS

5.3.3.1 Category learning phase

Faces: The mean number of trials taken to complete this phase was 78.68, the mean percentage correct, excluding the last ten trials was 58.8 percent and the mean response time, per trial, during the category learning phase was 1179 msec.

Chequerboards: The mean number of trials taken to complete this phase was 82.94, the mean percentage correct, excluding the last ten trials was 58.88 percent and the mean response time, per trial, during the category learning phase was 960 msec.

The category learning results were analysed using t-tests. There was no significant difference in the mean number of trials, mean percentage correct and the mean response times between the faces and the chequerboards.
5.3.3.2 Testing phase

5.3.3.2.1 Accuracy and response time data

Response times for each stimulus category were correlated with the numbers correct in that category. All correlations were non-significant. This indicated that there was no speed accuracy trade off taking place for these category conditions.

5.3.3.2.1.1 Faces

Figure 33 shows the accuracy for the testing phase of the experiment. Overall the upright stimuli are identified more accurately than the inverted stimuli. Figure 34 shows the mean response times for the test phase. There appears to be no difference in the response times for the upright and inverted faces.
Figure 33 - Accuracy figures for upright and inverted face stimuli for test phase. Error bars show +/- 1 standard deviation.

Figure 34 - shows the mean response times for the upright and inverted face stimuli in the testing phase with error bars showing +/- 1 standard deviation.
Two t tests were performed for accuracy and response times and tested the effects of orientation on the face stimuli. For accuracy, there was a significant effect of orientation (t(1, 18) = 2.04, p = 0.04). Performance was significantly better on the upright faces than the inverted and hence an inversion effect with the face stimuli. There was no significant effect of orientation on the response times.

5.3.3.2.1.2 Chequerboards

Figure 35 shows the accuracy for the test phase of the experiment with the chequerboard stimuli. There appears to be no difference between the accuracy for the upright and inverted stimuli. Figure 36 shows the mean response times for the chequerboards in the testing phase of the experiment. It would appear that the inverted stimuli took longer to identify than the upright stimuli.
Figure 35 - Accuracy for the test phase with the chequerboard stimuli. Error bars show +/- 1 standard deviation.

Figure 36 - shows the mean response times for the upright and inverted chequerboard stimuli in the testing phase. Error bars show +/- 1 standard deviation.
Two t-tests were carried out to assess the effect of orientation on the accuracy and response times of the chequerboard stimuli. For both the accuracy and response time data there were no significant effect of orientation. Therefore indicating that the inversion effect was not found with these chequerboard stimuli.

5.3.3.2.2 Accuracy and response time data – summary.

These results show that for the face stimuli accuracy performance on upright stimuli was significantly better than for inverted stimuli. Hence, there was an inversion effect for faces. No inversion effect was found for the chequerboards.

The effects found here for chequerboards and faces are different both from each other and from the previous experiments. It would appear that in this moving window experiment that, the window prevents the effect of inversion, seen in previous experiments for the chequerboards, hence, performance is at chance. Whereas for faces, there is an effect of inversion. This provides some evidence that there may be a difference in the way in which these two stimuli are processed. In fact the size of the inversion effect seen in the present experiment is virtually unaffected by the presence of the moving window as seen through comparison with the data from Experiment 4 in Figure 37. However, overall accuracy is reduced when stimuli are viewed through a moving window.
To compare the size of the face inversion effect between moving window and full image viewing conditions (e.g. experiment 4) a two way ANOVA (Experiment (2) - experiment 4, experiment 10; Orientation (2) - upright, inverted) was conducted. The results of this showed a significant main effect of orientation ($F(1,36) = 3.67, p = 0.006$) and a significant effect of experiment ($F(1,36) = 4.82, p = 0.005$). There was no significant interaction. This result indicates that the size of the inversion effect does not differ across the two experiments and therefore the moving window although reducing accuracy has not had an effect on the size of the inversion effect.
5.3.3.3 Sequence data

Examination of the pattern of movements made as observers moved the window around to view the images provides information about those regions of observers' internal representations of the categories that were diagnostic for identifying the face and chequerboard stimuli respectively. Here, the upright and inverted stimuli conditions have been further divided into 'old' (familiar stimuli) and the 'new' (novel) stimuli to give a total of four conditions (familiar upright, familiar inverted, novel upright and novel inverted). This allows detailed examination across the four conditions.

5.3.3.3.1 Number of iterations

A first analysis is simply to explore whether the amount of searching of face vs. chequerboard stimuli differed. To explore this, the number of times that the window was moved was recorded and compared. For the faces the average number of moves per image was 27.31 and for the chequerboards 28.28. A t-test was of these data was not significant (p = >0.05), indicating that the window was moved a similar number of times, and a similar amount of searching, was done for chequerboards and faces.
The overall number of window moves was averaged across the face and chequerboard conditions and shown in table 2 below.

Table 2 - Averaged overall means for faces and chequerboards

<table>
<thead>
<tr>
<th></th>
<th>Upright</th>
<th>Inverted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>27.89</td>
<td>28.92</td>
</tr>
<tr>
<td>Novel</td>
<td>26.56</td>
<td>27.97</td>
</tr>
</tbody>
</table>

A 2 x 2 way ANOVA of these data (Pre-exposure (2) – familiar, novel vs. Orientation (2) – upright, inverted) did not find any significant differences (p = >0.05). This indicates that whether the images were; upright or inverted, familiar or novel, a similar number of moves was taken to reach a decision as to whether the image was old or new.

5.3.3.3.2 Average position of window moves

A second analysis was conducted in order to identify those regions of an image that were searched for faces and for chequerboards. To do this a visual representation of the pattern of movements was derived as follows:
First, for each subject the position of each location to which the window was moved was recorded on a trial by trial basis. Second, the total number of times the window was moved to each location in the image over a series of trials was calculated. Third, this was converted to a grayscale representation where locations that are visited more frequently are shown as lighter (an ‘intensity map’). Separate intensity maps were derived for each subject for Familiar Upright, Familiar Inverted, Novel Upright and Novel Inverted stimuli. These intensity maps were then used to derive a mask through which to view the images. Locations that exceed some threshold criterion in the intensity map are unmasked. Thus, only those areas that were most important for identifying a stimulus will be visible. Here, masks are derived that show only those regions of the image that were visited half as often or more as the most visited image location.

Intensity maps and masked images derived from those maps can be seen, averaged across subjects, in Figures 38 and 39, for faces and chequerboards respectively. As can be seen for the face images on average the areas most visited were the areas of the eyes, nose and mouth. However, for the chequerboards on average the areas most visited were the edges and the corners.
Figure 38 - Upright and inverted, familiar and novel face moves. Shown as both intensity maps (left) and as 'masked' images (right).
Figure 39 - Upright and inverted, familiar and novel chequerboard moves. Shown as both intensity maps and as 'masked' images.
However, averaged intensity maps only tell part of the story. To take an example it is possible that, whilst on average participants searched the left and right hand edges of the chequerboard stimuli in order to identify them, an individual observer may focus on just the left edge where another focuses on just the right. In fact, following the findings of experiment 9, it was predicted that for chequerboard stimuli, individual observers would pick on idiosyncratic image regions (e.g. just the left-hand edge) to learn how to identify the stimuli. Whilst for faces, it was predicted there would be a more general tendency to focus on the centre of the image common to all observers. Thus, to formally compare the degree of similarity between individual participants' search patterns for face and chequerboard stimuli, further statistical analyses were conducted.

5.3.3.3.3 Statistical examination

As described above for each subject and image type (familiar upright, familiar inverted, novel upright and novel inverted) the proportion of times that each image location was visited was calculated and used to derive intensity maps. In numerical terms for each image type, these data consist of 64 x 64 (4096) values where each value represents how frequently a single pixel in the image was visited relative to the most visited pixel. For each image condition and for faces and chequerboards separately, a 19 x 4096 matrix was derived by putting together every participant's data. This gave eight different matrixes (4 for the face...
conditions and 4 for chequerboard conditions). Each matrix contained nineteen participants' data and 4096 visited areas. Correlations were carried out for each matrix. For both the face and chequerboard conditions the majority of these correlations were significant (p<0.05 and r's between > 0.3 and <0.7). This justifies the subsequent Principal Components Analyses (see below).

*Face data.* Principle component analysis was carried out for each of the face conditions. The results showed that for each face condition, one factor emerged. The Eigen values and the percentage of variance that these accounted for are shown in table 3 for each of the face conditions.

**Table 3 - Face PCA results**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Eigen value</th>
<th>Percentage of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>15.38</td>
<td>81%</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>14.52</td>
<td>76%</td>
</tr>
<tr>
<td>Novel upright</td>
<td>15.0</td>
<td>79%</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>14.71</td>
<td>77%</td>
</tr>
</tbody>
</table>

For each of the face conditions one factor emerged which accounted for a large proportion of the variance. This indicates that for each of the face conditions, the majority of the participants searched in the same area of the face. By examining the individual subject's intensity maps it is possible to see that the area searched by most of the participants was the central area of the face. That is, the eyes, nose and mouth. Typical individual maps and masked face images can be seen in Figure 40.
Figure 40 - Intensity maps and ‘masked’ face images from 2 different participants.
Chequerboard data. Principle component analysis was carried out on each of the chequerboard conditions. For each condition the PCA showed that four factors emerged. These can be seen in table 4.

Table 4 - Chequerboard PCA results.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Number of factors</th>
<th>Eigen values</th>
<th>Percentage of variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>4</td>
<td>6.64, 3.63, 3.10, 1.79</td>
<td>35%, 19%, 16%, 10%</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>4</td>
<td>7.05, 3.32, 2.67, 1.89</td>
<td>35%, 19%, 16%, 10%</td>
</tr>
<tr>
<td>Novel upright</td>
<td>4</td>
<td>6.91, 3.32, 3.25, 1.93</td>
<td>33%, 24%, 15%, 11%</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>4</td>
<td>6.91, 3.32, 3.25, 1.93</td>
<td>37%, 18%, 18%, 10%</td>
</tr>
</tbody>
</table>

Thus, for each of the chequerboard conditions, across subjects, there were four different image-viewing patterns. From the visual examination of their intensity maps individual subjects seemed to focus on just one image region in order to identify stimuli and these regions often corresponded to one of the edges or one of the corners. This can be seen in the typical individual maps and masked chequerboard images of Figure 41.
Figure 41 - Intensity maps and 'masked' images from 2 different participants.
5.3.3.4 Summary of findings for sequence data

Both the individual and averaged window moves show that the areas of the stimuli visited were different for faces and chequerboards. Four areas of the chequerboard were visited, searches were focused on the four corners. For the faces, one central portion was visited in the region of the eye, nose and mouth. These areas, whilst being very different between the two different stimulus types show viewing patterns that are similar for the familiar, novel, upright and inverted stimuli, within the two different stimuli types.
5.3.4 DISCUSSION

5.3.4.3 Faces

These results show that performance on upright stimuli was significantly better than on inverted stimuli and hence, show the inversion effect. Patterns for the moving window found that the areas of the eyes, nose and mouth were viewed most often and were most influential in the decision making.

5.3.4.4 Chequerboards

These results did not find the inversion effect. Patterns for the moving window showed that the edges of the chequerboards were viewed most often and were the most influential in the decision making.

5.3.4.5 Comparison of the faces and chequerboards

The inversion effect was found with the face stimuli. It was not expected that this effect would be found at all since faces have been said to be processed configurally and it was thought that when only a small section of the face was being viewed then this would disrupt the processing. Here, the inversion effect may have been found because, although, the whole of the face could not be viewed at the same time, the area that
appears to be of greatest importance in the recognition of these face stimuli, was the central portion (eyes, nose and mouth). A substantial portion of these features could be simultaneously viewed within one window width. Thus, we might expect a reduction in window width would lead to a reduction or even complete elimination of the inversion effect. In comparison, for the chequerboards to be identified the edges were predominantly viewed. There may have been greater disruption to the chequerboards because the window had to be moved further to see the crucial areas. Alternatively, it may be that the presence of an internal feature in the chequerboards was used for recognition. Participants might have used the edge or corner to identify the location of this internal feature and the presence of the window prevented participants from being able to judge the location of this feature with any degree of accuracy. Hence, performance was around chance.

Thus, from the evidence here it is possible that chequerboards and faces are both processed as configurations. For chequerboards, the moving window is at a size that disrupts the relevant edge or corner based configurations, or the distances between edge and internal information. Whilst, for faces, the size of the window is sufficient not to disrupt configural processing of the internal features of the face.
Further investigation needs to be conducted by firstly reducing the size of the window. A smaller window may be more disruptive to the facial configurations. However, increasing the window size may actually benefit the chequerboard configurations and thus show the inversion effect.
5.4 Chapter 5 – General Discussion

This chapter investigated the mechanisms responsible for inversion effects for chequerboards and faces.

Using composite stimuli, experiment 9 found that the nature of processing occurring with chequerboards appeared to be different from that of face processing. However, the source of the difference was unclear.

Experiment 10 found that a 'moving window' abolished the inversion effect for chequerboards, but not for the face stimuli. Further, the patterns of viewing the chequerboards and faces, through the moving window, were very different. Faces were examined in the central portion (eyes, nose and mouth) whereas chequerboards were viewed around the edge or the corner. It could be simply that the corners of the chequerboards are used for identification since these provide an area that is easily located and thus an easy reference point.

The findings of experiment 9 with composite chequerboards might be explained by the edge / corner based strategy, used to identify the chequerboard stimuli, compared with the central feature used to identify faces. In the latter case, viewing a composite disrupts the central facial
features needed for recognition. However, since the area for chequerboard recognition appears to be in the edge or corner, there is little difference to the recognition of a chequerboard since there is no disruption to the crucial corner regions.

It is concluded that both chequerboards and faces might be processed as configurations (see general discussion in chapter 6), although the configurations necessary for the recognition of chequerboards and faces are located in different areas.
CHAPTER 6

6 General Discussion

These series of experiments have investigated the nature of the inversion effect by looking at:

I. The effect of category expertise acquired through learning (chapters 2 and 3).

II. The importance of prototypically defined categories for the inversion effect (chapter 4).

III. The types of stimulus processing underlying inversion effects (chapter 5).

6.1 Summary of chapters

6.1.1 Chapter 2

Experiments 1, 2 and 3 sought to replicate the basic inversion effect reported by McLaren (1997) for chequerboard stimuli.

Experiment 1 replicated McLaren's experiment. However, there was no inversion effect. It was concluded that insufficient category expertise was acquired for an inversion effect to occur.
Experiment 2. This made modifications to the design of experiment one. The method was modified to facilitate effective learning, and thus development of expertise with the stimuli. However, whilst expertise was acquired, there were no effects of inverting the stimuli.

Experiment 3. The same method was used as for experiment two except that face stimuli were used. Still no inversion effect occurred.

Conclusions: Given the face inversion effect is a well-documented phenomenon it appears that the methods used here were either inappropriate to induce it, or too insensitive to detect it.

6.1.2 Chapter 3

Experiments 4 and 5 sought to explore whether inversion effects occurred after acquisition of category expertise with chequerboard stimuli using a standard old / new recognition task. Further, it sought to compare the relative size of the inversion effects for face stimuli to those for chequerboard stimuli under equivalent conditions.

Experiment 4. The old / new recognition paradigm has been shown to be sensitive to the face inversion effect (Yin, 1969). The categorisation phase of experiments 2 and 3 had already been shown to facilitate the
development of expertise. Therefore, the method for experiment 4 used experiment 2's category learning phase coupled with the old / new recognition task and the face stimuli from experiment 3. This time the face inversion effect was found.

Experiment 5. The chequerboard stimuli were used in the method developed in experiment 4. The chequerboards were shaped to give them global orientation cues to better match the global orientation cues in facial images. The results showed the inversion effect.

Conclusions: The inversion effect can be produced with abstract stimuli following acquisition of category expertise but it is task dependent. Using McLaren’s method an inversion effect was not observed with chequerboard stimuli but using an old-new method it was. Further, comparable effects of inversion can be obtained for chequerboards and faces.

6.1.3 Chapter 4

Experiments 6, 7 and 8 sought to determine whether prototypically defined categories are necessary for the inversion effect.

Experiment 6. This investigated McLaren’s argument about prototypicality being necessary for the inversion effect. Using non-prototypical stimuli, and the same method as in experiment 5 the
inversion effect was found. This indicated that whilst the inversion effect was contingent upon category expertise being developed, the stimuli may not need to be derived from a prototype.

Experiment 7. In experiment 5, as there were only six exemplars of each prototype, individual category exemplars may have been learned rather than the prototype that they were derived from. Here, the number of exemplars presented was increased considerably, and they were never repeated. This made learning of individual exemplars difficult and forced learning of the prototypes. The inversion effect still occurred.

Experiment 8. This investigated whether the inversion effects found in experiment six with non-prototypical categories might merely have been due to learning of particular exemplars. As in experiment 7, the number of exemplars was increased, and they were never repeated during learning. There was no inversion effect. This suggested that the inversion effect found in experiment 6 was probably due to individual exemplar learning.

Conclusions: The inversion effect can be found with stimuli that are prototypically and non-prototypically derived. However, in the latter case this is only true when the stimulus set is of a limited size.
Experiments 9 and 10 explored whether the inversion effects found for face and chequerboard stimuli resulted from the same underlying mechanism.

Experiment 9. Composite faces (two faces combined) take longer to identify than non-composites (Young et. al., 1987). This effect is assumed to be due to the disruption of configural processing. Composite and non-composite chequerboards were compared, using the same old-new test as previous experiments. There was no difference between composites and non-composites. This implies that the processing of chequerboards and faces may be different.

Experiment 10. This explored whether the same regions of face and chequerboard stimuli were important for recognition. The same category learning and old-new recognition method, as earlier, was used, except that during the test phase it was only possible to view a small segment of the stimulus at any one time. Moving a 'window' enabled segment by segment viewing of the entire stimulus. The inversion effect was found for faces but not for the chequerboards. Moreover, patterns of viewing differed for the two types of stimuli: faces were examined in the central portion whereas chequerboards were viewed around the corners and edges.
Conclusions: Categorisation of chequerboard stimuli tends to be based on search for corner and edge based image features. This is quite unlike the internal features used for face recognition and may explain why composite chequerboards are no harder to recognise than non-composites: the method used here to generate composites does not perturb corner and edge based features, but does perturb the crucial internal features used for face recognition.

6.2 Overall Conclusions

- Expertise is necessary for the inversion effect.

- Prototypical category exemplars are vulnerable to the inversion effect, following category learning. However, the inversion effect can occur with non-prototypical stimuli if only a small number of exemplars have to be learned.

- Faces and chequerboards can show equal size inversion effects. Although, they appear to result from the processing of features in different image regions. Further discussion of the possible processing mechanisms follows in subsequent sections.
6.3 Are faces special?

So far as the inversion effect is concerned faces are not special. The inversion effect has, for a long time, been used as evidence that faces are special (e.g. Valentine, 1988). The effect of inverting faces has been shown to give a decrement in performance which is disproportionate compared with other non-face objects (e.g. Yin, 1969). However, evidence presented here has shown that inversion effects are task and expertise dependent and that it is possible to gain inversion effects, equivalent to those found with faces, with stimuli very different in kind (chequerboards).

6.4 Categorisation

Most objects are recognised first and most efficiently at what has been called a 'basic' level of abstraction (Rosch, 1978). However, objects can be recognised at several different levels including more subordinate levels. To discriminate objects at a more subordinate level including faces, information about colour, texture, surface details and metric variations of the basic configuration of features need to be relied upon (e.g. Bruce and Humphries, 1994 and Tanaka and Taylor, 1991).
In order to discriminate the chequerboards in these experiments the basic level was not sufficient. This basic level of categorisation would only yield the fact that the stimulus was a chequerboard. To achieve category learning of the chequerboards, they needed to be identified at the sub-ordinate level of recognition as identifying which chequerboard was being viewed had to take place. It is possible that this move from basic to sub-ordinate level accompanied the development of category expertise.

6.4.1 Expertise

Gauthier, Skudlaski, Gore and Anderson (2000) and Diamond and Carey (1986) suggest that the reason why inversion effects are associated with expertise is that they result from a change in the basic level of categorisation, which accompanies acquisition of expertise. In the current case, face stimuli were identified as belonging to a subclass of faces; the basic level is the face, the subordinate level being a face from a particular category. Similarly, subjects learned to identify chequerboards as belonging to a particular category of chequerboards, the subordinate level again. Further, following this category learning an inversion effect was observed consistent with the argument of Gauthier, et. al., (2000) and Diamond and Carey (1986).
A recent functional magnetic resonance imaging (fMRI) study by Gauthier, Tarr, Anderson, Skudlarski and Gore (1999) showed a strong relationship between expertise and the neural substrate of face recognition. They used 'Greeble' stimuli and found that the 'face area' was more activated in expert greeble perceivers than in novices. This shows that those neurones thought to be specialised for face processing can be activated by stimuli other than faces. It may be that these stimuli share the same or some of the same processing requirements even though the visual features are very different – i.e. that these objects are processed at sub-ordinate level (Gauthier, 2000). On the basis of these and related findings Gauthier (2002) argues that it is likely that this one system is specialised for expert, subordinate level, stimulus classification rather than for face processing per se. In the present experiments it is possible that, like the Greeble stimuli, expertise was developed with chequerboards such that they were identified at the sub-ordinate level. Consequently, it may also be possible that chequerboard stimuli would also start to activate the same neural population that had previously been regarded as specialised for face processing. This has obviously not been investigated here, but it may be that future research to identify the neural area activated by the chequerboards for experts compared to novices might be of interest.
6.5 Comparison with McLaren's work

McLaren argued that two conditions needed to be met to produce the inversion effect. First, the expertise requirement; the effect of expertise acquisition has been discussed previously. Second, the prototype requirement: the stimuli need to be variations on a category prototype (this is discussed in a subsequent section). Although the experiments reported here had difficulty replicating McLaren's results when using the same methods, the importance of his two conditions was supported by later experiments using the 'learning-old-new recognition method'. It remains unclear why the early experiments did not replicate his results. This may have been due to insufficient learning, but it also appears that the discrimination test he used is not very robust or reliable.

6.6 Chequerboards

The chequerboard stimuli used in these experiments are abstract stimuli and very useful to work with. They can easily be produced by computer generation, giving them advantages over more naturally occurring stimuli. A chequerboard prototype can give many category exemplars by adding 'noise' in the form of changing randomly selected squares from black to white and vice versa. It is also possible to produce
chequerboards that are not derived from a prototype. The benefit of using chequerboards here is that participants had no previous experience with them. This is extremely useful since there is no previously developed expertise and therefore all participants started from the same level of experience.

At a surface level, faces and chequerboards are very different. However, at a fundamental level they are more similar. In particular, both can be defined within category by a common statistical image structure. For instance, if described in terms of pixel intensities, images from the same category would be more strongly inter-correlated than images from different categories. Also, as discussed earlier, like faces, it is possible to require participants to learn to categorise chequerboards at the subordinate level of categorisation. These similarities may account for the inversion effect occurring with both kinds of stimuli.

In contrast with the chequerboards, the investigations by Gauthier, et al., (1997) with 'Greeble' stimuli have been criticised because the Greeble shape is somewhat similar to the face shape (Farah, 2000). It has been argued that it is this overall face similarity that leads to effects that are similar to those found with faces. Here, the chequerboard stimuli are overall very different in appearance from faces and therefore, it is unlikely that the similar effects found with chequerboards and faces are as a result of any similarity in appearance between chequerboards and faces.
6.7 Prototypes

Faces are naturally occurring prototypical stimuli (Bruce, Doyle, Dench and Burton, 1991). It has been suggested that the ability to extract a prototype from the category exemplars could be used as a criterion to define expertise in discrimination within an object stimulus class (Valentine and Bruce, 1986c). From the results of the experiments here, it would appear that the prototype might have been extracted from the chequerboard stimuli.

Here, when the chequerboards were all defined by a category prototype it was possible to use the features in common across exemplars to aid category learning. The subsequent inversion effect found was comparable with faces and also supports the suggestion that at least partial prototype extraction may have occurred. This also supports the notion that for inversion effects to be found categories need to be defined by a prototype (McLaren, 1997).

Conversely, for non-prototypical chequerboards, no single defining feature dictates category membership and the inversion effect was found when a limited set of category members was presented. It may be that there was learning of individual category members. Or, it is possible that by learning something general about each category, a kind of idiosyncratic ‘prototypical representation’ of the category members was created and this was then subsequently extracted from these non-prototypical chequerboards.
However, when unlimited sets of non-prototypical category members are presented, the learning of these members is much harder, as is the ability to extract any idiosyncratic prototype representation and this may be why any subsequent effects of inversion are not found. Although, this also supports the notion that for inversion effects to be found categories need to be defined in term of a prototype.

Many experiments have used limited stimulus sets to develop expertise with stimuli and to show the effects of this expertise e.g. Diamond and Carey (1987) and Gauthier, et. al., (1998, 2000 & 2001). It appears that it is only in the experiments here, and those of McLaren (1997), that unlimited stimulus sets have been used to investigate the inversion effect and only here that comparable effects of inversion have been found for faces and chequerboards.

When limited stimulus sets are presented, it could be that expertise developed with these stimuli leads to prototype extraction. However, for unlimited sets of category members, it may be that prototype extraction, and hence the inversion effect, is contingent upon both expertise and members of the category being defined by a prototype. Thus, consistent with the notion that prototypes may have been extracted from the chequerboard stimuli, it is possible that, as Valentine and Bruce (1986c) suggest, prototype extraction may be used as a criterion by which to define expertise.
6.8 Configural processing

The specific relations between object parts are thought to be of particular importance in the heightened discriminability of objects for experts (Diamond and Carey, 1986 and Gauthier and Tarr, 1997) and the mechanisms most often suggested to mediate the acquisition of expertise is the use of configural processing.

Configural information may be very important for sub-ordinate level discriminations (Diamond and Carey, 1986). Rhodes, Brake and Taylor (1989) compared the inversion effect on recognition of own race faces (high expertise) and other race faces (low expertise). They found a larger effect of inversion for own race faces than for other race faces, indicating that expertise is associated with greater use of configural information in faces. In contrast, inversion does not affect processing of featural information because the features are thought to be processed similarly regardless of orientation (e.g. Tanka and Sengco, 1997).

Configurational information has been classed at three different levels (Maurer, LeGrand and Mondloch, 2002). That of first order (local feature) information, holistic processing (global features) and second order (spatial distances among internal features) relational processing. Inversion has been said to affect each type of processing, although it has
typically been attributed to second order relations. In the experiments here the effects of inversion found are comparable for chequerboards and faces, and it is argued that both can be attributed to configural processing occurring (see the discussion below of composites and moving windows).

6.8.1 Composites

An elegant demonstration of the configural perception of faces, has been provided by Young, Hellawell and Hay (1987), in their use of composites. They combined the top half of one face with the bottom of another. When correctly aligned, it was hard to recognise the individual identities of the two halves. If mis-aligned, identification was much easier. When these results are compared with the chequerboard stimuli it became clear that the effect of composites on chequerboards was very different. The chequerboards gave the same level of performance whether they were aligned or mis-aligned. This was the first indication that there may be differences in the way that chequerboards and faces are processed.
6.8.2 Moving window

The moving window experiment further investigated the processing that was occurring in the face and chequerboard stimuli. Faces have already been said to depend on configural processing. In the moving window experiment a comparison of the chequerboard and face stimuli found that different areas of the stimuli were used in the identification of faces and chequerboards. However, it was still possible that, although different areas of each stimulus were viewed, both the chequerboards and faces might be being processed as configurations.

The moving window experiment indicated that subjects focused on the central area of the faces to identify them. This is in agreement with previous research, which has suggested that internal facial features are used for face identification (Tanka and Sengco, 1997). Further, work has suggested detecting the distance between facial features (second order configural information) may be important for face identification, but that this is impaired by inversion (Maurer, et. al., 2002). Thus, one explanation of the inversion effect observed here is that the size of window used in the present experiment allowed subjects to recover the second order information in the upright images, but that inversion of these images prevented them from obtaining this second order information.
In the case of the chequerboard stimuli performance was at chance for both upright and inverted images. This may also be consistent with the importance of second order configural information in the processing of these stimuli. For instance, it is possible that the size of the window was too small to allow subjects to recover information on the distance between various diagnostic chequerboard features even when they were presented upright. Without this information it may be that subjects were unable to distinguish the categories.

Further, in the case of the chequerboards subjects may have used the edges and corners of the images as a reference point for finding features and judging the distance between them. The moving windows technique may have prevented them from doing this. Subjects may have been unaware of the location of the window in the image relative to these reference points further hampering the recovery of second order relational information. In the case of faces because of the distinct appearance of different facial regions there are many distinct possible reference points and so the same problem would not be expected.

These results coupled with the results of the composites provide further evidence for configural processing of the chequerboards. It may be that the chequerboard composites and non-composites gave comparable results since this edge / corner region was unaffected by alignment or misalignment.
Thus, chequerboards and faces are viewed in different areas but can give equal sized inversion effects. The second-order relational information may be necessary for both faces and chequerboards and recovery of this relational information may have been disproportionately affected by the presence of the moving window for chequerboard stimuli.

6.9 Importance of face recognition

Both developmental studies and prosopagnosia provide evidence of the importance of face recognition (e.g. Johnson et al., 1991 and Whitley and Warrington, 1977) and they also show the early age in which faces are encountered. It may be that early exposure to faces leads children to acquire expertise, a process that is on-going throughout life. Therefore it might be that, faces are not special, but the early age at which we first encounter faces leads to the recruitment, or development, of a neural module that is specialised for sub-ordinate classification. Faces are the most commonly encountered case where sub-ordinate classification is required and perhaps the area becomes more strongly activated by exposure to faces. However, this would imply that faces are special in terms of experience and not innate factors. It could be this experience has led to the subsequent development of expertise, and it is this expertise together with the lack of a suitable object comparison, that leads faces to be considered special.
6.10 Conclusions

The inversion effect has been used as evidence that face processing is special. However, other stimuli can give inversion effects.

Here it is shown that an equal size inversion effect will occur even with very abstract stimuli when those stimuli are from categories defined by a prototype and when someone has learned those categories. This suggests that the inversion effect does not necessarily disproportionately affect face processing. Instead, it is argued that the level of expertise is what is important, and that objects used for comparison with faces, need to be defined by a prototype for similar effects of inversion to be found.

Further, it is argued that although the diagnostic image regions used for recognising faces and chequerboards, at the sub-ordinate level, differs, both may require extraction of second order relational information for the purposes of recognition.

The findings have implications for the extent to which the inversion effect can be used as a source of evidence for the 'specialness' of face processing. Further, in the light of findings from Gauthier and colleagues it may be that other lines of evidence (e.g. the proposal that there is an innate dedicated neural module for face processing) should be re-evaluated using highly abstract stimuli of the type used here.
Therefore, to answer the question - *Are faces special?* With respect to the inversion effect, faces are not special per se. The life-long encounters we have with faces make them unique with regard to the expertise that is developed with faces, and it is this 'uniqueness' that has led to faces being considered 'special'.

6.11 Further Analysis

As previously discussed the 'moving window' technique has permitted the identification of the area of the image that was viewed. For the face stimuli the area viewed contained the eyes nose and mouth. However, for the chequerboard stimuli the edges were viewed. In the edge region of a chequerboard it is much more difficult to understand the features of the chequerboard that were used for identification. As with faces it may be that certain critical features are more pertinent than other features within the individual chequerboard stimulus. Thus, by manipulating the features present in a chequerboard it may be possible to identify which defining features are used for chequerboard identification.
The moving window technique could be used (as before) to identify the critical regions of the chequerboards on a participant by participant basis. For each participant the squares in these crucial regions could then be manipulated by randomly rearranging or removing them. By comparing accuracy performance before and after the manipulation of these critical features it would be possible to measure how recognition performance was affected by these manipulations. This may provide information as to the types of features that are present within a chequerboard that enable their identification.

However, as discussed earlier, it may be that these critical features are relative to the edge or corner of the chequerboards and may therefore be affected by the size of the window. It was thought that the size of the window used in these experiments was large enough to allow chequerboard identification, but small enough to destroy the processing of second order configural properties, and hence the inversion effect was not found. The size of the window could therefore be optimised to allow sufficient information to be available at any one time so that the critical features might be more easily identified, as well as possibly enabling the inversion effect to be found.
A modification of the moving window technique may also give indications of the critical features used in identification of the chequerboards. By modifying the technique so that an outline of the chequerboards is viewed, the participant could move the cursor to the area they wish to view and then click to reveal that desired area. Thus only this area of interest would be exposed. This could be used in conjunction with critical features technique (previously discussed). For instance, if the participant were only permitted to view a limited number of areas (i.e. two or three) then hopefully prior knowledge would direct viewing to the area containing the critical feature that enabled identification of the chequerboard. Performance accuracy could be assessed together with inspection of the features in the critical area. This may then lead to the identification of which features and the types of features, within a chequerboard that are needed for accurate identification.

The moving window is an extremely useful technique that can be used, as it has been developed in this thesis, with a variety of different stimuli. Also modifications could be made to this technique that might enable additional information to be elicited.
References


*Pediatrics.* 56, 544-549.

*Perception,* 13, 505-512.


## APPENDIX

Results of analyses, means and standard deviations.

### Experiment 1

Correlations between accuracy and response times for all categories.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>FAMUP</th>
<th>FURT</th>
<th>FAMINVER</th>
<th>FIRT</th>
<th>NOVUP</th>
<th>NURT</th>
<th>NOVINVER</th>
<th>NIRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FAMUP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>.049</td>
<td>.041</td>
<td>.036</td>
<td>.047</td>
<td>.019</td>
<td>.046</td>
<td>.020</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.010</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>FURT</strong></td>
<td>-039</td>
<td>1.000</td>
<td>-0.096</td>
<td>-0.091</td>
<td>-0.090</td>
<td>-0.089</td>
<td>-0.088</td>
<td>-0.087</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>FAMINVER</strong></td>
<td>-0.096</td>
<td>-0.120</td>
<td>1.000</td>
<td>-0.095</td>
<td>-0.094</td>
<td>-0.093</td>
<td>-0.092</td>
<td>-0.091</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>FIRT</strong></td>
<td>-0.096</td>
<td>-0.120</td>
<td>1.000</td>
<td>-0.095</td>
<td>-0.094</td>
<td>-0.093</td>
<td>-0.092</td>
<td>-0.091</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
<td>.012</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>NOVUP</strong></td>
<td>-0.096</td>
<td>-0.120</td>
<td>1.000</td>
<td>-0.095</td>
<td>-0.094</td>
<td>-0.093</td>
<td>-0.092</td>
<td>-0.091</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>NURT</strong></td>
<td>-0.096</td>
<td>-0.120</td>
<td>1.000</td>
<td>-0.095</td>
<td>-0.094</td>
<td>-0.093</td>
<td>-0.092</td>
<td>-0.091</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>NOVINVER</strong></td>
<td>-0.096</td>
<td>-0.120</td>
<td>1.000</td>
<td>-0.095</td>
<td>-0.094</td>
<td>-0.093</td>
<td>-0.092</td>
<td>-0.091</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
<td>.049</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

** Note: Correlation is significant at the 0.01 level (2-tailed).

### Figure 3  McLaren results

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>74</td>
</tr>
<tr>
<td>Novel upright</td>
<td>64</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>45</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>69</td>
</tr>
</tbody>
</table>
**Figure 4**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>57</td>
<td>8.55</td>
</tr>
<tr>
<td>Novel upright</td>
<td>58</td>
<td>8.7</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>56</td>
<td>7.84</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>57</td>
<td>7.98</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

- Pre-exposure: \( F(1,29) = 0.012, p = 0.912 \)
- Orientation: \( F(1,29) = 0.074, p = 0.787 \)
- Pre-exposure x Orientation: \( F(1,29) = 0.000, p = 1.000 \)

**Figure 5**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>2643</td>
<td>528.6</td>
</tr>
<tr>
<td>Novel upright</td>
<td>2471</td>
<td>494.2</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>2473</td>
<td>494.6</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>2403</td>
<td>480.6</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

- Pre-exposure: \( F(1,29) = 0.893, p = 0.352 \)
- Orientation: \( F(1,29) = 0.738, p = 0.397 \)
- Pre-exposure x Orientation: \( F(1,29) = 0.255, p = 0.617 \)
**Expertise and chance values: - 2.2.3.3.2**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>55</td>
<td>14</td>
</tr>
<tr>
<td>Novel upright</td>
<td>61</td>
<td>20</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>56</td>
<td>24</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>50</td>
<td>16</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure      (F (1,14) = 1.304, p = 0.268)

Orientation       (F (1,14) = 0.000, p = 1.000)

Pre-exposure x Orientation       (F (1,14) = 0.2066, p = 0.168)

**Time out: - 2.2.3.3.2**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>57</td>
<td>13</td>
</tr>
<tr>
<td>Novel upright</td>
<td>55</td>
<td>13</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>57</td>
<td>15</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>57</td>
<td>17</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure      (F (1,23) = 0.085, p = 0.773)

Orientation       (F (1,23) = 0.094, p = 0.762)

Pre-exposure x Orientation       (F (1,23) = 0.073, p = 0.790)
30 participants

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>59</td>
<td>17</td>
</tr>
<tr>
<td>Novel upright</td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>58</td>
<td>18</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>56</td>
<td>18</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure       (F (1,29) = 0.018, p = 0.895)

Orientation      (F (1,29) = 0.368, p = 0.552)

Pre-exposure x Orientation  (F (1,29) = 0.005, p = 0.944)
Experiment 2

Correlations between accuracy and response times for all categories.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>FAMUP</th>
<th>FURT</th>
<th>FAMINVER</th>
<th>FIRT</th>
<th>NOVUP</th>
<th>NOVUPRT</th>
<th>NOVINVER</th>
<th>NOVINRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAMUP Pearson Correlation</td>
<td>1.000</td>
<td>.025</td>
<td>-.029</td>
<td>.247</td>
<td>-.060</td>
<td>.402*</td>
<td>-.632</td>
<td>.094</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.904</td>
<td>.890</td>
<td>.323</td>
<td>.697</td>
<td>.042</td>
<td>.878</td>
<td>.548</td>
<td>.848</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>FURT Pearson Correlation</td>
<td>.025</td>
<td>1.000</td>
<td>.178</td>
<td>.713**</td>
<td>.262</td>
<td>.504**</td>
<td>.693</td>
<td>.765*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.323</td>
<td>.890</td>
<td>.383</td>
<td>.000</td>
<td>.166</td>
<td>.009</td>
<td>.550</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>FAMINVER Pearson Correlation</td>
<td>-.029</td>
<td>.179</td>
<td>1.000</td>
<td>-.102</td>
<td>.163</td>
<td>.006</td>
<td>-.146</td>
<td>.202</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.890</td>
<td>.383</td>
<td>.616</td>
<td>.344</td>
<td>.976</td>
<td>.472</td>
<td>.322</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>FIRT Pearson Correlation</td>
<td>.247</td>
<td>.713**</td>
<td>-.102</td>
<td>1.000</td>
<td>-.051</td>
<td>.763**</td>
<td>.293</td>
<td>.716*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.890</td>
<td>.383</td>
<td>.616</td>
<td>.344</td>
<td>.976</td>
<td>.472</td>
<td>.322</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>NOVUP Pearson Correlation</td>
<td>-.032</td>
<td>.262</td>
<td>.163</td>
<td>-.051</td>
<td>1.000</td>
<td>-.294</td>
<td>-.661</td>
<td>.521</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.890</td>
<td>.383</td>
<td>.616</td>
<td>.344</td>
<td>.976</td>
<td>.472</td>
<td>.322</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>NOVUPRT Pearson Correlation</td>
<td>.402*</td>
<td>.504**</td>
<td>.006</td>
<td>.763**</td>
<td>-.294</td>
<td>1.000</td>
<td>.354</td>
<td>.685*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.042</td>
<td>.009</td>
<td>.076</td>
<td>.000</td>
<td>.146</td>
<td>.076</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>NOVINVER Pearson Correlation</td>
<td>-.032</td>
<td>.262</td>
<td>.163</td>
<td>-.051</td>
<td>1.000</td>
<td>-.294</td>
<td>-.661</td>
<td>.521</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.890</td>
<td>.383</td>
<td>.616</td>
<td>.344</td>
<td>.976</td>
<td>.472</td>
<td>.322</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>NOVINRT Pearson Correlation</td>
<td>.644</td>
<td>.769**</td>
<td>.202</td>
<td>.716**</td>
<td>.021</td>
<td>.685*</td>
<td>.046</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.042</td>
<td>.009</td>
<td>.076</td>
<td>.000</td>
<td>.146</td>
<td>.076</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

*• Correlation is significant at the 0.05 level (2-tailed).
**• Correlation Is significant at the 0.01 level (2-tailed).

Figure 6

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>55</td>
<td>8.8</td>
</tr>
<tr>
<td>Novel upright</td>
<td>50</td>
<td>7.6</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>57</td>
<td>8.9</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>50</td>
<td>7.8</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure \( (F(1,25) = 2.172, p = 0.153) \)

Orientation \( (F(1,25) = 0.075, p = 0.787) \)

Pre-exposure x Orientation \( (F(1,25) = 0.078, p = 0.782) \)
Figure 7

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1395</td>
<td>175</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1367</td>
<td>165</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1382</td>
<td>172</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1394</td>
<td>170</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure  \( (F(1,25) = 0.019, \ p = 0.892) \)

Orientation \( (F(1,25) = 0.030, \ p = 0.863) \)

Pre-exposure x Orientation \( (F(1,25) = 0.085, \ p = 0.773) \)

2.3.3.3.1

ANOVA for accuracy

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>57</td>
<td>19</td>
</tr>
<tr>
<td>Novel upright</td>
<td>54</td>
<td>20</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>51</td>
<td>19</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>53</td>
<td>18</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure \( (F(1,21) = 0.803, \ p = 0.380) \)

Orientation \( (F(1,21) = 0.018, \ p = 0.894) \)

Pre-exposure x Orientation \( (F(1,21) = 0.219, \ p = 0.645) \)
Response times

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1330</td>
<td>505</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1338</td>
<td>553</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1338</td>
<td>520</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1336</td>
<td>495</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure \( (F (1,21) = 0.004, p = 0.948) \)

Orientation \( (F (1,21) = 0.005, p = 0.946) \)

Pre-exposure x Orientation \( (F (1,21) = 0.004, p = 0.951) \)

Discrimination phase: - 2.3.3.3.2

ANOVA first half accuracy

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>51</td>
<td>22</td>
</tr>
<tr>
<td>Novel upright</td>
<td>61</td>
<td>26</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>57</td>
<td>26</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>56</td>
<td>22</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure \( (F (1,25) = 0.241, p = 0.627) \)

Orientation \( (F (1,25) = 0.094, p = 0.762) \)

Pre-exposure x Orientation \( (F (1,25) = 0.219, p = 0.644) \)
Second half accuracy

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>60</td>
<td>23</td>
</tr>
<tr>
<td>Novel upright</td>
<td>58</td>
<td>24</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>51</td>
<td>28</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>63</td>
<td>22</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure        (F (1,25) = 0.081, p = 0.782)
Orientation         (F (1,25) = 0.888, p = 0.366)
Pre-exposure x Orientation (F (1,25) = 0.585, p = 0.461)

First half response times

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1276</td>
<td>514</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1206</td>
<td>522</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1188</td>
<td>533</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1279</td>
<td>487</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure        (F (1,25) = 0.017, p = 0.897)
Orientation         (F (1,25) = 0.039, p = 0.845)
Pre-exposure x Orientation (F (1,25) = 1.256, p = 0.273)
Second half response times

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1452</td>
<td>399</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1308</td>
<td>587</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1365</td>
<td>578</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1359</td>
<td>400</td>
</tr>
</tbody>
</table>

Pre-exposure \( (F(1,25) = 0.039, p = 0.846) \)

Orientation \( (F(1,25) = 0.775, p = 0.397) \)

Pre-exposure x Orientation \( (F(1,25) = 292, p = 0.600) \)
Experiment 3

Correlations between accuracy and response times for all categories.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>FAMUP</th>
<th>NURT</th>
<th>FAMINVER</th>
<th>NIRT</th>
<th>NOVUP</th>
<th>FURT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>-.629**</td>
<td>.236</td>
<td>.507*</td>
<td>.340</td>
<td>-.222</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.001</td>
<td>.011</td>
<td>.011</td>
<td>.011</td>
<td>.011</td>
<td>.011</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-.629**</td>
<td>1.000</td>
<td>-.166</td>
<td>.856**</td>
<td>-.515**</td>
<td>.660**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
<td>.001</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.236</td>
<td>-.166</td>
<td>1.000</td>
<td>-.273</td>
<td>.077</td>
<td>-.021</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.266</td>
<td>.439</td>
<td>.196</td>
<td>.721</td>
<td>.721</td>
<td>.721</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-.507*</td>
<td>.856**</td>
<td>-.273</td>
<td>1.000</td>
<td>-.432*</td>
<td>.588**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.011</td>
<td>.000</td>
<td>.196</td>
<td>.325</td>
<td>.035</td>
<td>.003</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.340</td>
<td>-.015**</td>
<td>-.077</td>
<td>-.432*</td>
<td>.000</td>
<td>-.405*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>104</td>
<td>.010</td>
<td>.721</td>
<td>.935</td>
<td>.935</td>
<td>.935</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-.222</td>
<td>.060**</td>
<td>-.021</td>
<td>.588**</td>
<td>-.405*</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.239</td>
<td>.000</td>
<td>.921</td>
<td>.003</td>
<td>.050</td>
<td>.050</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Figure 10

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>56</td>
<td>5.6</td>
</tr>
<tr>
<td>Novel upright</td>
<td>55</td>
<td>5.5</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>56</td>
<td>5.6</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>62</td>
<td>6.2</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure \( (F(1,23) = 0.375, p = 0.546) \)

Orientation \( (F(1,23) = 0.525, p = 0.476) \)

Pre-exposure x Orientation \( (F(1,23) = 0.675, p = 0.420) \)
Figure 11

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1404</td>
<td>400</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1350</td>
<td>392</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1380</td>
<td>407</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1399</td>
<td>397</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure \((F(1,23) = 0.071, p = 0.792)\)

Orientation \((F(1,23) = 0.051, p = 0.823)\)

Pre-exposure x Orientation \((F(1,23) = 0.556, p = 0.463)\)

2.4.3.3.1

Accuracy

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>56</td>
<td>23</td>
</tr>
<tr>
<td>Novel upright</td>
<td>55</td>
<td>23</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>56</td>
<td>25</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>61</td>
<td>21</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure \((F(1,19) = 0.586, p = 0.453)\)

Orientation \((F(1,19) = 0.078, p = 0.782)\)

Pre-exposure x Orientation \((F(1,19) = 652, p = 0.429)\)
Response times

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1372</td>
<td>486</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1380</td>
<td>533</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1358</td>
<td>433</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1334</td>
<td>463</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure       (F (1, 19) = 0.203, p = 0.657)
Orientation        (F (1, 19) = 0.640, p = 0.600)
Pre-exposure x Orientation  (F (1, 19) = 0.941, p = 0.690)

2.4.3.3.2

Accuracy first half

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>56</td>
<td>33</td>
</tr>
<tr>
<td>Novel upright</td>
<td>60</td>
<td>21</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>44</td>
<td>20</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>56</td>
<td>27</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure       (F (1, 23) = 0.831, p = 0.382)
Orientation        (F (1, 23) = 1.837, p = 0.202)
Pre-exposure x Orientation  (F (1, 23) = 0.221, p = 0.647)
Accuracy second half

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>59</td>
<td>21</td>
</tr>
<tr>
<td>Novel upright</td>
<td>55</td>
<td>18</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>63</td>
<td>23</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>61</td>
<td>25</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for accuracy:

Pre-exposure  \( (F(1,23) = 2.529, p = 0.140) \)

Orientation  \( (F(1,23) = 1.687, p = 0.221) \)

Pre-exposure x Orientation  \( (F(1,23) = 0.529, p = 0.462) \)

Response times first half

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1531</td>
<td>365</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1394</td>
<td>260</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1421</td>
<td>619</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1383</td>
<td>267</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

Pre-exposure  \( (F(1,23) = 0.268, p = 0.615) \)

Orientation  \( (F(1,23) = 0.717, p = 0.415) \)

Pre-exposure x Orientation  \( (F(1,23) = 0.292, p = 0.600) \)
### Response times second half

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar upright</td>
<td>1376</td>
<td>550</td>
</tr>
<tr>
<td>Novel upright</td>
<td>1367</td>
<td>514</td>
</tr>
<tr>
<td>Familiar inverted</td>
<td>1380</td>
<td>603</td>
</tr>
<tr>
<td>Novel inverted</td>
<td>1415</td>
<td>570</td>
</tr>
</tbody>
</table>

2 x 2 way ANOVA for response times:

- Pre-exposure: \( (F(1,23) = 0.231, p = 0.640) \)
- Orientation: \( (F(1,23) = 0.132, p = 0.400) \)
- Pre-exposure x Orientation: \( (F(1,23) = 0.429, p = 0.526) \)
Experiment 4

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>UPRIGHT</th>
<th>INVERTED</th>
<th>UPRT</th>
<th>INVRT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UPRIGHT</strong></td>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>-.241</td>
<td>-.286</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.320</td>
<td>.236</td>
<td>.123</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td><strong>INVERTED</strong></td>
<td>Pearson Correlation</td>
<td>-.241</td>
<td>1.000</td>
<td>.458*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.320</td>
<td>.</td>
<td>.049</td>
<td>.588</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td><strong>UPRT</strong></td>
<td>Pearson Correlation</td>
<td>-.286</td>
<td>.458*</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.236</td>
<td>.049</td>
<td>.</td>
<td>.003</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td><strong>INVRT</strong></td>
<td>Pearson Correlation</td>
<td>-.366</td>
<td>.133</td>
<td>.649**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.123</td>
<td>.588</td>
<td>.003</td>
<td>.</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Figure 13

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>62.5</td>
<td>8.9</td>
</tr>
<tr>
<td>Inverted</td>
<td>47.5</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Figure 14

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1559</td>
<td>300</td>
</tr>
<tr>
<td>Inverted</td>
<td>1540</td>
<td>350</td>
</tr>
</tbody>
</table>
**Experiment 5**

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th></th>
<th>Correlations</th>
<th>UPRIGHT</th>
<th>INVERTED</th>
<th>UPRT</th>
<th>INVRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPRIGHT</td>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>.366</td>
<td>-.181</td>
<td>.021</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.123</td>
<td>.458</td>
<td>.932</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVERTED</td>
<td>Pearson Correlation</td>
<td>.366</td>
<td>1.000</td>
<td>-.328</td>
<td>.202</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.123</td>
<td>.170</td>
<td>.408</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>UPRT</td>
<td>Pearson Correlation</td>
<td>-.181</td>
<td>-.328</td>
<td>1.000</td>
<td>.614**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.458</td>
<td>.170</td>
<td>.005</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVRT</td>
<td>Pearson Correlation</td>
<td>.021</td>
<td>.202</td>
<td>.614**</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.932</td>
<td>.408</td>
<td>.005</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

**Figure 16**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>74.5</td>
<td>13</td>
</tr>
<tr>
<td>Inverted</td>
<td>57</td>
<td>9.5</td>
</tr>
</tbody>
</table>

**Figure 17**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1497</td>
<td>325</td>
</tr>
<tr>
<td>Inverted</td>
<td>1315</td>
<td>380</td>
</tr>
</tbody>
</table>
Experiment 6

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>67</td>
<td>13</td>
</tr>
<tr>
<td>Inverted</td>
<td>55</td>
<td>13</td>
</tr>
</tbody>
</table>

Figure 20

Stimulus type: Upright, Inverted
Mean: 67, 55
Standard deviation: 13, 13

Figure 21

Stimulus type: Upright, Inverted
Mean: 1595, 1662
Standard deviation: 276, 279
**Experiment 7**

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>UPRIGHT</th>
<th>INVERTED</th>
<th>UPRT</th>
<th>INVRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPRIGHT Pearson Correlation</td>
<td>1.000</td>
<td>.288</td>
<td>-.263</td>
<td>-.002</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.232</td>
<td>.277</td>
<td>.995</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>INVERTED Pearson Correlation</td>
<td>.288</td>
<td>1.000</td>
<td>-.060</td>
<td>.251</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.232</td>
<td>.806</td>
<td>.299</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>UPRT Pearson Correlation</td>
<td>-.263</td>
<td>-.060</td>
<td>1.000</td>
<td>.526*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.277</td>
<td>.806</td>
<td>.021</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>INVRT Pearson Correlation</td>
<td>-.002</td>
<td>.251</td>
<td>.526*</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.995</td>
<td>.299</td>
<td>.021</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).

**Figure 24**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>57</td>
<td>5.7</td>
</tr>
<tr>
<td>Inverted</td>
<td>51</td>
<td>5.1</td>
</tr>
</tbody>
</table>

**Figure 25**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1060</td>
<td>276</td>
</tr>
<tr>
<td>Inverted</td>
<td>1274</td>
<td>265</td>
</tr>
</tbody>
</table>
Experiment 8

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>UPRIGHT</th>
<th>INVERTED</th>
<th>UPRT</th>
<th>INVRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPRIGHT</td>
<td>1.000</td>
<td>.209</td>
<td>.117</td>
<td>-.072</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.390</td>
<td>.633</td>
<td>.768</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVERTED</td>
<td>.209</td>
<td>1.000</td>
<td>.035</td>
<td>.060</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.390</td>
<td>.885</td>
<td>.807</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>UPRT</td>
<td>.117</td>
<td>.035</td>
<td>1.000</td>
<td>.870**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.633</td>
<td>.870</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVRT</td>
<td>-.072</td>
<td>.060</td>
<td>.870</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.768</td>
<td>.000</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed).

Figure 28

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>53</td>
<td>8.9</td>
</tr>
<tr>
<td>Inverted</td>
<td>51</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Figure 29

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1451</td>
<td>497</td>
</tr>
<tr>
<td>Inverted</td>
<td>1371</td>
<td>502</td>
</tr>
</tbody>
</table>
**Experiment 9**

Correlations between accuracy and response times.

<table>
<thead>
<tr>
<th></th>
<th>COMP</th>
<th>NONCOMP</th>
<th>COMPRT</th>
<th>NOCOMP RT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>1.000</td>
<td>.778**</td>
<td>.185</td>
<td>.158</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.000</td>
<td>.265</td>
<td>.344</td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td><strong>NONCOMP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.778**</td>
<td>1.000</td>
<td>.154</td>
<td>.153</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.</td>
<td>.356</td>
<td>.359</td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td><strong>COMPRT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.185</td>
<td>.154</td>
<td>1.000</td>
<td>.904**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.265</td>
<td>.356</td>
<td>.</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td><strong>NOCOMPRT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.158</td>
<td>.153</td>
<td>.904**</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.344</td>
<td>.359</td>
<td>.000</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

**Figure 31**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composites</td>
<td>83.27</td>
<td>4.2</td>
</tr>
<tr>
<td>Non-composites</td>
<td>83.08</td>
<td>4.3</td>
</tr>
</tbody>
</table>

**Figure 32**

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composites</td>
<td>941.32</td>
<td>145</td>
</tr>
<tr>
<td>Non-composites</td>
<td>946.04</td>
<td>158</td>
</tr>
</tbody>
</table>
## Experiment 10

Correlations between accuracy and response times. - Chequerboards.

<table>
<thead>
<tr>
<th></th>
<th>UPRIGHT Pearson Correlation</th>
<th>INVERTED Pearson Correlation</th>
<th>UPRT Pearson Correlation</th>
<th>INVRT Pearson Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPRIGHT</td>
<td>1.000</td>
<td>0.306</td>
<td>0.150</td>
<td>-0.315</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.203</td>
<td>.539</td>
<td>.189</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVERTED</td>
<td>0.306</td>
<td>1.000</td>
<td>-0.171</td>
<td>-0.315</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.</td>
<td>.484</td>
<td>.188</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>UPRT</td>
<td>0.150</td>
<td>-0.171</td>
<td>1.000</td>
<td>.718**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.</td>
<td>.754</td>
<td>.492</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVRT</td>
<td>-0.315</td>
<td>-0.315</td>
<td>1.000</td>
<td>.718**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.189</td>
<td>.188</td>
<td>.001</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

Correlations between accuracy and response times. - Faces

<table>
<thead>
<tr>
<th></th>
<th>UPRIGHT Pearson Correlation</th>
<th>INVERTED Pearson Correlation</th>
<th>UPRT Pearson Correlation</th>
<th>INVRT Pearson Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPRIGHT</td>
<td>1.000</td>
<td>.213</td>
<td>-0.077</td>
<td>-0.168</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.382</td>
<td>.754</td>
<td>.492</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVERTED</td>
<td>.213</td>
<td>1.000</td>
<td>-0.275</td>
<td>-0.322</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>.382</td>
<td>.255</td>
<td>.178</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>UPRT</td>
<td>-0.077</td>
<td>-0.275</td>
<td>1.000</td>
<td>.939**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.754</td>
<td>.255</td>
<td>.</td>
<td>.000</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>INVRT</td>
<td>-.168</td>
<td>-0.322</td>
<td>.939**</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.492</td>
<td>.178</td>
<td>.000</td>
<td>.</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
### Figure 33

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>57</td>
<td>10.4</td>
</tr>
<tr>
<td>Inverted</td>
<td>40</td>
<td>8.0</td>
</tr>
</tbody>
</table>

### Figure 34

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1747</td>
<td>262</td>
</tr>
<tr>
<td>Inverted</td>
<td>1839</td>
<td>277</td>
</tr>
</tbody>
</table>

### Figure 35

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>42</td>
<td>8.4</td>
</tr>
<tr>
<td>Inverted</td>
<td>42</td>
<td>8.6</td>
</tr>
</tbody>
</table>

### Figure 36

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright</td>
<td>1818</td>
<td>272</td>
</tr>
<tr>
<td>Inverted</td>
<td>2064</td>
<td>309</td>
</tr>
</tbody>
</table>