The representation of colour in episodic object memory: Evidence from a recognition-induced forgetting paradigm.

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The Representation of Colour in Episodic Object Memory: Evidence from a Recognition-Induced Forgetting Paradigm

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Summary

Empirical evidence suggesting colour influences object recognition is mixed; leading to conclusions that colour may not always be represented in object memory. Positive evidence for the representation of colour in episodic object memory is often complicated by the possibility that encoding specificity may be responsible for such observations. The current thesis examined whether colour is represented and makes an independent contribution of shape in episodic memory for familiar and novel objects, using a modified paradigm based on the typical retrieval-practice task (e.g., Anderson, Bjork, & Bjork, 1994).

Participants studied pictures of objects, presented one at a time. In a subsequent practice phase, participants either performed Old/New recognition with a subset of the studied objects and their distractors (Experiments 1-7), or they rated a subset of the studied objects for attractiveness, complexity, and usefulness (Experiments 8 and 9). The critical manipulation concerned the nature of unpracticed objects. Unpracticed objects shared either shape only (Rp-Shape), colour only (Rp-Colour), both shape and colour (Rp-Both), or neither shape nor colour (Rp-Neither), with the practiced objects. Interference effects in memory between practiced and unpracticed items are revealed in the forgetting of related unpracticed items – *retrieval-induced forgetting* (RIF). If both shape and colour information is explicit in the object representations in episodic memory, then there would be significant RIF for unpracticed objects sharing shape only and colour only with the practiced objects.

RIF was significant for Rp-Shape and Rp-Colour objects, suggesting that shape and colour are represented and independently drive competition effects in episodic object memory. The use of RIF to probe those representations improves on previous evidence, because it bypasses alternative encoding specificity explanations. The current work provides proof of concept for a modified retrieval-practice paradigm and establishes it as a tool to probe feature-based representations that do not easily lend themselves to retrieval practice.

Declaration and Statements

Declaration
This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed.. .... (Candidate)

Date 22/5/14

Statement 1
This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references and a bibliography is appended.

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I give consent for this thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

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List of Abbreviations

ANOVA	Analysis of Variance
IT	Inferior temporal
LGN	Lateral geniculate nucleus
M	Magnocellular
Nrp	No retrieval practice
P	Parvocellular
RIF	Retrieval-induced forgetting
Rp	Retrieval practice
Rp+	Practiced objects from a practiced category
Rp-B	Rp-Both
Rp-C	Rp-Colour
Rp-S	Rp-Shape
SD	Standard Deviation

Conference Presentations and Awards.

Conference Presentations

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General Introduction

The ability to recognise objects is a fundamental aspect of cognition, serving one of the main purposes of the visual system: to represent objects in order to be identified and acted upon. Following the generation of a perceptual representation of an external visual object, recognition is achieved through the comparison of that perceptual representation with one stored in long-term memory. Object recognition is considered as an end state of the visual system allowing classification at different levels of specificity (e.g., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). For instance, we can identify an object as a chair (basic level recognition), as a desk chair (subordinate recognition), or as a piece of furniture (superordinate recognition).

Object recognition can succeed across a highly variable visual input, including transformations in size and mirror reversals (e.g., Biederman & Cooper, 1991a; 1992; Srinivas, 1996), depth orientation (e.g., Biederman & Gerhardstein, 1993), edge degradation (e.g., Biederman & Cooper, 1991b), and variations in texture and colour (e.g., Biederman & Ju, 1988). Such demonstrations of invariant object recognition performance are used as evidence that the feature over which invariance occurs is not necessary for object recognition. One such object feature is colour.

The perception and recognition of colour is one of the most unique experiences known to humans. Other visual features like shape can be appreciated by other sensory modalities, such as touch, whereas colour is a property exclusively available to visual perception. Apart from its aesthetic value in visual perception, colour can under some circumstances be useful to object recognition, particularly in situations where it is highly diagnostic of object identity (e.g., Tanaka & Presnell, 1999). For instance, with fruit often the only reliable visual difference between an orange and an apple (both round in shape) is in their colour (and texture). Understanding when colour information is represented and used in object recognition is empirically important because unlike shape whose necessity is indisputable, the necessity of representing and using colour in object recognition is less clear.

Recognition memory paradigms have often been used to examine whether colour is automatically represented in object representations in long-term memory or whether it is only represented when it is diagnostic of object identity or when shape information is insufficient (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003). In particular, Old/New recognition memory tasks have been used to examine whether colour is represented as part of the long-term memory representations of objects and not just as part of the perceptual/visual representation used in online processing tasks (e.g., naming or classification). Studies using Old/New recognition memory tasks, where participants study a set of stimuli and their memory of those stimuli is subsequently explicitly examined, have discovered that colour contributes to object memory representations. However, evidence from such studies is complicated by possible encoding specificity effects. According to the encoding specificity principle (e.g., Tulving & Thomson, 1973), recognition memory performance is superior when the recognition cues available for retrieval of an object (e.g., a specific colour) were also present during the encoding of the item. In other words, the greater the similarity in contexts between encoding and retrieval, the greater the success will be in retrieving the original item. Therefore, if the retrieval context contains a cue that was not part of the original encoding content (e.g., a new colour), or does not contain a cue that was available at the encoding context (e.g., is now black-and-white), recognition memory will be poorer than when the retrieval context includes all the original encoding cues (e.g., the original colour).

Studies examining the representation of colour in recognition memory have done so by comparing conditions where the colour of objects remains the same between study and test (same colour condition) against conditions where object colour has changed between study and test (colour change condition). Decrements in recognition memory performance in the colour change condition are taken to suggest that colour must have been part of the encoded representation of the object. However, changing the colour of an object between study and test may be detrimental to recognition performance, not because colour was encoded, but because there has been a change between the encoding context (where there was a specific colour present) and the retrieval context (where there is another colour present or colour is absent). Therefore, previous positive evidence for the representation of colour in recognition memory is often confounded with possible encoding specificity effects.

The current experiments examined whether colour information is explicit in the memory representation of objects, and whether it makes an independent contribution from shape information in object memory. To address these questions the current experiments modified the retrieval-practice paradigm (e.g., Anderson, Bjork, & Bjork, 1994; 2000). Participants studied objects (Familiar and Novel) that appeared in different shapes and colours. Then they were presented with a subset of the studied objects to either perform a Yes/No (Old/New) recognition task (Experiments 1-7) or to rate the re-presented subset of studied objects on various attributes, such as attractiveness, complexity, and usefulness (Experiments 8 & 9). Finally in a test phase participants performed a Yes/No recognition task to examine their memory for all the studied objects. Interference effects in memory between the practiced and unpracticed objects are typically revealed in the forgetting of related unpracticed items – known as *retrieval-induced forgetting (RIF* – Anderson et al., 1994*)*.

The rationale of the current thesis was that interference effects, expressed as significant RIF, would inform us about the representation of the two types of information (object shape and colour) on the visual episodic memory representations of objects. As shape is an undisputed feature that is represented in object memory, RIF was expected to be significant if unpracticed objects shared the same shape as the practiced objects. If colour is not represented in object memory then unpracticed objects sharing colour only with practiced objects would not be susceptible to RIF, as there would be no interference during practice. However, if colour information is represented in object memory, then unpracticed objects sharing colour alone with the practiced objects would be susceptible to RIF. The current research therefore focused on whether colour information is represented in episodic perceptual object memory and whether it is used to guide object recognition. This issue was examined separately for familiar (e.g., chairs, tables) and unfamiliar (e.g., novel or never before seen) objects.

The proposed work aimed to examine hypotheses stemming from theories in two areas of human cognition: object recognition and memory. On the one hand it is a novel approach to the study of representation and recognition of three-dimensional objects; a topic of current interest across a variety of disciplines in human vision. The procedure proposed for the study of this area is a new departure from traditional methods used to examine hypotheses about the way objects are represented in visual episodic long-term memory. Using a variation of the RIF paradigm allowed the current experiments to circumvent the issue of encoding specificity, as performance was based on objects that remained in their same colours and shapes between study and test. On the other hand, the proposed research aims to contribute to the understanding of the nature of representations that induce competition during practice and more specifically if object properties, such as shape and colour, are susceptible to forgetting. Furthermore, the current work aims to contribute and elaborate on an established paradigm that can potentially be used as a basis for future empirical work to examine perceptual properties of objects and their impact on object recognition memory.

Thesis Outline

In Chapter 1 evidence is reviewed and discussed regarding the impact of colour in object recognition memory. At the end of Chapter 1 outstanding issues to be empirically addressed by the current work are summarised.

In Chapter 2, the methodology of the *retrieval practice paradigm* and the associated *retrieval-induced forgetting effect* (RIF) is introduced and some associated classic findings are introduced. Importantly, Chapter 2 discusses how this paradigm was adapted in the current thesis to test the empirical predictions regarding the representation of colour in object recognition memory.

The thesis proceeds to present the experimental work in Chapters 3, 4, and 5. Here each experiment is presented separately, but in Experiment 1 there is a detailed delineation of the methods used to analyse the data and the reasoning behind them, which applies to all experiments.

In Chapter 6 the findings from the current research are discussed in terms of their implications for the object recognition memory literature and for RIF as a tool to elucidate the structure of object representations.

Chapter One

The Representation of Colour in Object Recognition Memory

1.1 The Impact of Colour in Object Recognition Memory

Recognition memory paradigms have been used in order to examine whether colour is automatically represented in object representations in long-term memory or whether it is only represented when it is diagnostic of object identity or when shape information is insufficient (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003). In particular, Old/New recognition memory tasks have been used to examine whether colour is represented as part of the long-term memory representations of objects and not just as part of the perceptual/visual representation used in online processing tasks (e.g., naming or classification). Old/New recognition memory tasks involve episodic memory, which refers to the record of our experiences (e.g., Tulving, 1972). The use of episodic memory tests allows greater experimental flexibility and control over the stimuli used, or amount of exposures prior to testing, where tasks such as naming are necessarily constrained in some of those aspects (e.g., naming tasks typically have to use familiar objects with learnt names, while Old/New recognition studies can use both familiar and novel or unreal objects to examine the same questions).

Old/new recognition tasks involve a study phase, where to-be-remembered stimuli are presented to participants, and a test phase, where participants are shown the old stimuli (targets) and new stimuli (distractors). Participants' memory can then probed either implicitly or explicitly. Implicit memory is memory for information that is incidentally or unintentionally learned and does not rely on the recognition or conscious recall of a specific learning episode (e.g., Cleermans, 1993; Schacter, 1987). In implicit tests of memory such as repetition priming, participants are given a task during the test phase, such as name or state their preference for studied and unstudied items, which does not require them to consciously consult their memory of the study phase events.

In contrast, explicit memory tests require participants to decide whether they have seen the stimuli before or not during the study phase (e.g., Schacter & Buckner, 1998). Typically, in explicit recognition memory tests participants respond 'Yes' to old items and 'No' to new items. When Old/New recognition studies have examined the role of object features, such as colour on memory, they have done so by comparing conditions where there is no change in colour between study and test against conditions where there is a change (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986). The rationale is that if the change in colour influences performance it means that it was encoded during study and the decrement in performance is due to the discrepancy between the memory (which contains colour) and the test image that does not.

1.1.1 The role of colour in explicit episodic memory

Recognition memory studies using explicit Old/New recognition tasks - henceforth referred to as Yes/No recognition tasks – are typically unified in their conclusions that colour is represented in memory for objects (e.g., Cave, Bost, & Cobb, 1996; Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986; Zimmer & Steiner, 2003; but see Ostergaard & Davidoff, 1985, Experiments 2 & 3). Yes/No recognition tasks typically involve a study phase, where to-be-remembered stimuli are presented to participants, and a test phase, where participants are shown the old and new stimuli, and their task is decide whether they saw the stimuli or not during the study session. Learning of items during the study phase can either be deliberate or incidental. In deliberate learning conditions participants are instructed to try to memorise the items. In incidental learning conditions, participants are given a task to do with each of the stimuli, such as rate them for complexity (e.g., Lawson, 2004), or perform a size-judgment task (e.g., Koutstaal & Cavendish, 2006), but are not informed of a later memory test. In the test phase, participants respond 'Yes' to indicate they saw the item during the earlier study phase, and 'No' to indicate that the item was not in the study phase.

As previously mentioned, many of the Yes/No recognition studies (e.g., Cave et al., 1996; Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986; Zimmer & Steiner, 2003) examine the role of object features, such as colour, on memory by comparing conditions where there is no change in colour between study and test against conditions where there is a change. The rationale is that if the change in colour influences performance it means that it was encoded during study and the decrement in performance is due to the discrepancy between the memory representation (which contains colour) and the perceptual representation test image that does not. If however, the change in colour (from colour to achromatic or vice versa) does not influence performance, it suggests that colour was not encoded as part of the object's representation during study. There are some differences between the studies examining the effects of colour, which include whether they use incidental learning (e.g., Cave et al., 1996; Vernon & Lloyd-Jones, 2003) or not (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986; Zimmer & Steiner, 2003), whether they base their conclusions on response times (e.g., Nicholson & Humphrey, 2003; Vernon & Lloyd-Jones, 2003) or accuracy (e.g., Hanna & Remington, 1996; Stefurak & Boynton, 1986), and whether they find that shape and colour are bound (e.g., Nicholson & Humphrey, 2003) or independent (e.g., Hanna & Remington, 1996) in memory representations.

The first study to examine episodic recognition memory for object colour and shape was by Stefurak and Boynton (1986). In a comprehensively designed study, they examined memory for shape and colour of animal silhouettes. The colours used were not diagnostic to the animals in the stimulus set – for instance participants saw a red camel or a blue penguin during study. In half of the conditions they examined memory for object shape when it appeared in colour at study and at test (e.g., red camel/red camel), when they appeared coloured at study but greyscale at test (e.g., red camel/grey camel), when they appeared greyscale at study and coloured at test (e.g., grey camel/red camel), and when they appeared greyscale at study and at test (e.g., grey camel/grey camel). They found that memory for object shape (e.g., the camel) was better than chance, but was not influenced by the presence or absence of colour at study or at test – it did not matter whether the colour in which the camel appeared in during the test phase was the same or different from the one it was studied in.

In the remaining conditions they examined memory for object colour when it appeared on the same shape both at study and at test (e.g., red camel/red camel), and when it appeared on different shapes between study and test (e.g., red camel/red starfish). They found that recognition memory for object colour was significantly better than chance and that it was not influenced by changes in shape between study and test – it did not matter whether the colour appeared on the same shape or on a different shape between study and test. Their findings suggested that colour is represented in memory and that shape and colour information were independently stored in memory.

In a study examining the effect of colour on object recognition memory for geometric shapes, Hanna and Remington (1996, Experiment 1) compared performance in conditions where the stimuli were identically coloured at study and test [colour/colour (col/col) or black-white/black-white (bw/bw)], against conditions where stimuli appeared in different colours between study and test (col/bw or bw/col). There were four phases, for each of the four conditions, each consisting of a study and test phase. In each study phase 12 stimuli appeared sequentially, each stimulus consisting of six parts (horizontal rectangles, vertical rectangles, and circles). The stimuli would be either black-and-white with black outlines and white filling, or coloured with each part coloured differently (blue, yellow, red, brown, green, and purple). In the test phase participants had to discriminate between targets and distractors in a Yes/No recognition task. Apart from a significant congruency effect, with better accuracy overall when stimuli appeared in the same state both at study and at test (compared to the incongruent condition), two findings suggested that colour is important for recognition memory. First, they found that the col/col condition led to better recognition accuracy than the bw/bw condition, suggesting that the presence of colour at both study and test benefited recognition memory. Second, the presence of colour on the object during study (encoding) enhanced the encoding of the object in memory for both congruent (col/col) and incongruent (col/bw) conditions. This suggests that object colour information is represented in object memory.

In both of the aforementioned studies by Stefurak and Boynton (1986) and Hanna and Remington (1996), participants had been instructed to attend to the colour dimension during study, which might have explained the results showing that colour was encoded. Therefore, colour may only be encoded when it becomes a relevant dimension (by task instruction) but not be an automatically represented feature in object memory. To examine this possibility, Cave et al. (1996) used the Yes/No recognition memory task to examine whether colour between study and test would influence recognition memory performance even when participants were not instructed in any way to pay attention to colour or to shape. During the study phase participants named line drawings of objects such as tools, furniture, animals etc. In the test phase participants had to discriminate between objects that remained either in the same colour or changed in colour from the study phase (Experiment 1B –colour was a task-relevant attribute in the test phase) or they were required to disregard colour and simply decide whether the object had appeared in the study phase (Experiment 1C –colour was not a task-relevant attribute in the test phase).

Participants were able to discriminate between objects that changed colour between study and test and those that remained in the same colour. Furthermore, when stimuli from the study phase remained in the same colour at test they were recognised more frequently than old items that were presented in a different colour between study and test, and recognition hits were faster for congruent colour stimuli between study and test. Therefore, colour as an object attribute influenced recognition performance, even when it was not task relevant either in the study or in the test phase. Given that an effect of colour emerged even when participants were not instructed to attend to colour (as opposed to the studies of Hanna &Remington, 1996 and Stefurak & Boynton, 1986, where participants were instructed to attend to colour during the study phase), suggests that colour is automatically represented in explicit object memory.

The findings from Stefurak and Boynton (1986), Hanna and Remington (1996), and Cave et al. (1996) were the first to show that in recognition memory colour information is part of the object representation, for both artificially coloured objects (Stefurak & Boynton, 1986), coloured geometric shapes (Hanna & Remington, 1996) and naturally coloured familiar objects (Cave et al., 1996), regardless of whether encoding of colour information is encouraged or not. The findings were also the first to show that colour information offers an advantage not only for objects with learned colours, as shown with studies using naming and classification (e.g., Davidoff & Ostergaard, 1988; Ostergaard & Davidoff, 1985; Price & Humphreys, 1989) but also for objects without any learned colours (e.g., furniture or tools) and for geometric shapes.

The three aforementioned studies (Stefurak & Boynton, 1986; Hanna & Remington, 1996; Cave et al., 1996) were not designed to discount any possible effects of verbal coding on pictorial object recognition, and potentially on any effects of colour. For instance, according to Paivio's Dual Code Theory (e.g., Paivio, 1971, 1986, 1991; Paivio & Csapo, 1973; Paivio, Rogers, & Smythe, 1968) visual stimuli can be coded in terms of a visual and a verbal code. Therefore, it has been suggested that verbal labels may preserve binding so that features such as shape and colour are bound to the correct object during retention (e.g., Wheeler & Treisman, 2002).

To examine the possible role of verbal labels in observing effects of colour in object recognition memory, Nicholson and Humphrey (2003) used novel 3-D objects to examine the representation of colour in object recognition memory when a verbal coding strategy could not be used to help recognise objects. Using novel objects also meant that none of the objects were associated with any particular colours (a prevalent issue within online recognition memory tasks involving high colour diagnostic objects, e.g., Tanaka & Presnell, 1999). The congruency of object colour was manipulated across the study and test phase. In the study phase participants learned the shape of 24 novel objects depicted in one of four colours, then in the test phase they were asked to discriminate between the 24 old objects and 24 new objects, where 12 of the old objects were depicted in their original colour (or part colour conjunctions) and 12 were depicted in a new colour (or part colour conjunctions).

Participants were faster at correctly identifying old objects when they were presented in their original colour compared to a new colour, suggesting that colour is automatically encoded and stored in memory. Participants were also faster at correctly identifying old objects when they were presented in their original part-colour conjunctions compared to reversed part colour conjunctions, suggesting that shape and colour were both represented and were bound in the representation mediating object recognition memory. Furthermore, the finding that a new (incongruent) colour at test was only detrimental if it was on the object, rather than when it was on the background, suggests that colour was encoded as part of the object's representation and not simply as part of an episodic representation.

In conclusion, findings from explicit recognition memory studies show that colour information is represented in episodic memory for objects, even when novel objects (Nicholson & Humphrey, 2003), geometric shapes (Hanna & Remington, 1996), and familiar objects (Cave et al., 1996; Stefurak & Boynton, 1986) are used. Furthermore, effects of colour have been observed when colour information was irrelevant for the task and when incidental learning of the objects took place with no reference to attend to any particular features of the objects (e.g., Cave et al., 1996). This supports previous evidence that has suggested that colour information is a feature that is encoded, even when no instructions to encode colour have been provided (e.g., Ellis & Rickard, 1989; Logan, Taylor, & Etherton, 1996).

1.1.2 Encoding Specificity

Changes in colour from study to test may be detrimental to recognition performance, not because of the change in colour, but because of the change between the encoding and retrieval context – a well-documented phenomenon known as *encoding specificity* (e.g., Tulving & Thompson, 1973). According to the encoding specificity principle, recognition memory performance would be superior when the recognition cues available for retrieval of an object (e.g., a specific shape, colour, or word) were also present during the encoding of the same item. In other words, the greater the similarity in contexts between encoding and retrieval, the greater will be the success of retrieving the original item. Therefore, if a retrieval context includes a cue that was not part of the original encoding content (e.g., a new colour or texture), will be overall weaker than a retrieval context that includes all the original cues.

When interpreting results from episodic recognition memory studies regarding the representation of colour in object memory, the issue of encoding specificity must be considered. There have been some efforts to exclude encoding specificity as a plausible explanation for the detrimental effects of colour change between study and test (e.g., Brady, Konkle, Alvarez, & Oliva 2012; Nicholson & Humphrey, 2003). For instance, Nicholson and Humphrey (2003) showed that changing the object colour from study to test was more detrimental to recognition memory than changing the background colour from study to test. Therefore, it must have been the specific change of object colour causing the detriment, as opposed to any type of contextual change. However, the response time data did not show such a difference (between the effect of object change and background change), which suggests that encoding specificity could not be completely excluded as contributing to memory performance.

1.1.3 Is colour information represented independently from shape information?

Some Yes/No recognition studies have systematically examined whether colour information contributes to object representations independently from shape information. The plausibility of independent representation of form and colour information is rooted in neurophysiology. Neurophysiological and behavioural studies have shown that colour is a distinct perceptual feature. For instance, evidence from neurophysiology has shown that colour and form (e.g., orientation) information is processed in different visual and different cortical areas of the brain (e.g., Desimone & Ungerleider, 1989; Livingstone & Hubel, 1988). Starting from the retina, one class of retinal ganglion cells has large cell bodies and brief response to visual stimulation (e.g., see Milner & Goodale, 1995 for review), and feed into the magnocellular layers of the lateral geniculate nucleus (LGN). Those cells carry information along the magnocellular (M) pathway to V1 about edges in the visual image but are insensitive to colour information.

Another class of retinal ganglion cells has smaller cell bodies and a sustained response to visual stimulation, allowing them to detect colour changes in the visual image. Those cells project onto the parvocellular layers of the LGN, and carry information about colour along the parvocellular (P) pathway to V1. Even within V1 there is separation between these streams of processing with parvocellular processing proceeding within the ventral stream and magnocellular processing proceeding forward to the dorsal stream.

Later, in the inferior temporal (IT) cortex, which is part of the ventral cortical stream, known to mediate object recognition (e.g., Milner & Goodale, 1995), neurophysiological studies have shown that some IT neurons respond for the first time to a combination of shape and colour information (e.g., for evidence from macaques: Edwards, Xiao, Keysers, Földiák, & Perrett, 2003; Gross, Rocha-Miranda, & Bender, 1972; Tanaka, Saito, Fukada, & Moriya 1991; evidence from humans: Zeki & Marini, 1998). Overall, evidence from neurophysiology suggests neurons in IT are sensitive to colour information (an area involved in object recognition).

Complementing neurophysiological evidence, behavioural studies using perception and attention paradigms in humans have shown that colour is a distinct feature in perception, alongside other features such as orientation, texture, and luminance (e.g., Nothdurft, 2000;

Treisman, 1986; 1988; 2006; Treisman & Gelade, 1980). For example, Cole, Kuhn, Heywood, and Kentridge (2009) used the change blindness task to examine whether participants could discover the location of an item (letter in Experiment 2, or square in Experiment 3) that changed in a display of simultaneously presented stimuli (other letters or other squares). One of the items in the display would be coloured differently than the remaining display items – it would thus be a colour singleton. They found that when the changed item was also the one that was differently coloured (i.e., the colour singleton), then participants detected the change faster, compared to when the changed item was not the colour singleton. Cole et al. suggested that attention elicited by colour changes may result in an enhanced representation of the stimuli making it more robust against change blindness.

Perceptual classification studies have also shown that colour can be perceived independently of shape (e.g., Arguin & Cavanagh, 1988; Bundesen, Kyllingsbæk, & Larsen, 2003). For example, Bundesen et al. (2003) found that when participants were exposed to pairs of coloured objects and asked to report both the colour and shape of the objects, shape was correctly reported independently of whether the colour was also correctly reported. A similar conclusion was reached by Cant, Large, McCall, and Goodale (2008). They used the Garner speeded classification task (Garner, 1974) to examine the independent processing of shape (width/length) and surface (colour/texture) information in object perception. Participants had to classify objects on the basis of width or length while ignoring surface properties (colour or texture) and vice versa. The objects used were bricks and pieces of wood. The results revealed that varying the length of an object interfered with width judgments and vice versa, which suggested that width and length are not dissociable shape properties. In contrast, varying either the width or the length of the objects did not interfere with colour or texture judgments; neither did varying surface properties interfere with the shape judgments. Those findings suggested that the object properties of shape and colour must be represented independently. This conclusion was also supported by an earlier neuro-imaging study by Cant and Goodale (2007) showing that the shape and surface properties of objects are processed in separate neural pathways in the occipito-temporal cortex.

1.1.3.1 Shape – colour independence in memory

The most direct evidence for the independence of shape and colour in memory comes from Stefurak and Boynton (1986), who showed that participants remembered a previously seen colour regardless of whether it appeared on the studied object, and a previously seen shape regardless of whether it appeared in the same colour as during the study phase. However, when they examined whether colour information was remembered independently of shape, Stefurak and Boynton had instructed their participants to attend to colour information (and the same happened with shape information), leaving open the question of whether the finding of independence was an artefact of attention to the task-relevant attribute (e.g., colour), as opposed to colour and shape being automatically encoded as independent objects features.

Later, Hanna and Remington (1996) also showed evidence for the independence of shape and colour in recognition memory for objects. Participants studied objects that were composed of rectangles of varying sizes, with each rectangle coloured differently. Recognition memory performance was compared in a *colour/colour* condition, where objects at test appeared with their component rectangles appearing in the same colours as in the study phase, against performance in a *re-assigned colour* condition, where the same object with the same rectangles and the same colours appeared in both study and test, but at test, the colours were re-assigned among the component rectangles. There was no difference between the colour/colour and colour/re-assigned colour conditions. This suggested that colour and shape could be accessed independently to facilitate recognition memory. However, as was the case in the study by Stefurak and Boynton (1986) participants were informed about the changes in colour (when they occurred), a fact which, as Hanna and Remington also suggested, may have biased participants to attend to and encode that feature.

Extending the evidence for a possible independent contribution of shape and colour information in memory for objects, Brady et al. (2012) examined whether object shape and colour are represented independently in memory for everyday realistically surface-rendered objects. In a study phase participants were asked to remember a set of objects, with the display consisting either of 3 objects (short-delay condition) or each object in the study being presented individually (long-delay condition). In a subsequent test phase two objects would appear on the left and right side of the screen. In the *colour* condition the target object (e.g., a pink sofa) would appear next to an identical object in a different colour (e.g., a green sofa). In the *state* condition a target object (e.g., an open yellow deck chair) would appear next to the same object but in a different state (e.g., a closed yellow deck chair). Participants had to indicate whether the studied object was on the left or on the right of a central fixation cross. The rationale of the study was that if object shape and colour were bound into an undifferentiated object representation, then both features would be forgotten at similar rates (e.g., accuracy in finding the correct object would be similar for the colour and the state condition at both delays), whereas if they are independent, then different object features may be forgotten at different rates (e.g., colour information may be forgotten more over time compared to state information).

The results of their study confirmed the independence hypothesis: participants' accuracy in finding the target object during the short delay were similar regardless of whether the decision had to be based on colour (choosing the pink sofa) or based on state (i.e., choosing the open deck chair). However, when there was a long delay between study and test (3 days), accuracy was much worse in the colour condition compared to the state condition: participants found it harder to remember the correct colour object (e.g. the pink sofa), compared to the correct object state (the open deck chair). The fact that object colour information was forgotten more quickly than object shape information suggested that the two different properties are stored independently in memory.

In contrast to the studies suggesting that shape and colour are represented independently in object memory (e.g., Brady et al., 2012; Hanna and Remington, 1996; Stefurak & Boynton, 1986), some findings in the study by Nicholson and Humphrey (2003) suggested that shape and colour information might be bound in the representation of objects – that is, the representation of one (e.g., colour) is only activated when the representation of the other (i.e. shape) is also activated. In their study, new objects were identical in colour but slightly different in shape from the old objects. For instance, say participants studied an object in a combination of red and blue – let us call it Old 1/red-blue. The associated new object (in the test phase) would be identical in colour but in a slightly different shape – New 1/red-blue. In the test phase, the Old 1 object would appear either in the same colour as during the study (Old 1/red-blue) and its associated new object would be New 1/red-blue; or it would appear in a different colour combination, such as Old 1/yellow-green, and its associated new object would be New 1/yellow-green. If colour information was encoded independently from shape information, then it would be expected that the New 1/red-blue object would be faster than the New 1/yellow-green object, because the former had the studied colour. Interestingly, there was no difference in response latencies for the new objects (New 1/red-blue = New 1/yellow-green), suggesting that colour was not encoded independently of shape.

In summary, to-date explicit episodic memory studies have discovered some evidence that colour information contributes to the representation of objects in memory and is often used to facilitate object recognition. Positive evidence for the contribution of colour to object memory is complicated in studies using the same-different colour paradigm, by the possible effects of encoding specificity (e.g., see Hanna & Remington, 1996; Nicholson & Humphrey, 2003). Meanwhile, studies specifically designed to examine whether shape and colour information are bound or independent in the memory representation of objects has yielded mixed results. On the one hand, when participants were explicitly instructed to attend to shape and colour information, and objects were arbitrary combinations of shapes and colours, then shape and colour information were found to make independent contributions to object memory (e.g., Hanna & Remington, 1996; Stefurak & Boynton, 1986). Even when conclusions for the independence of shape and colour information in memory have been based on designs where object colour and shape information have been automatically encoded (i.e., no explicit instruction to attend to either feature), and familiar coloured objects have been used (e.g., Brady et al., 2012), the results have not been based on colour and shape being manipulated as part of the same object.

On the other hand, when the stimuli have been colour diagnostic objects, shape and colour information appear to be represented in an integrated fashion in object memory, (e.g., Vernon & Lloyd-Jones, 2003; Zimmer & Steiner, 2003). The single exception has been the study by Nicholson & Humphrey (2003) who used novel coloured objects. However, apart from accepting a null finding as evidence, all objects in their study shared a total of six colours, so participants may have simply not *used* colour information to make recognition memory decisions.

1.2 Outstanding issues and scope of the current thesis

Empirical evidence has emerged suggesting that colour can influence object recognition. Such evidence, however, emerged more frequently under some conditions than others; leading to conclusions that colour may not always be an explicitly represented feature for all objects in memory, and if it is, then it is only accessed when an object's shape information is also accessed (e.g., Cave et al., 1996; Nicholson & Humphrey, 2003; Price & Humphreys, 1989). Such conclusions cast doubts about the exact role of colour in object representations and leave open the question of whether colour is *always* a represented object feature, regardless of whether the represented information is used or not.

Evidence for the representation of colour information in explicit recognition memory tasks:

1) has only rarely been examined or found using novel objects (e.g., Nicholson & Humphrey, 2003)
2) has been found primarily in response latencies (e.g., Cave et al., 1996; Lloyd-Jones & Nakabayashi, 2009; Nicholson & Humphrey, 2003; Vernon & Lloyd-Jones, 2003; Zimmer & Steiner, 2003), but only rarely in accuracy (e.g., Hanna & Remington, 1996; Stefurak & Boynton, 1986)
3) has not always been confidently distinguished from encoding specificity explanations (see Hanna & Remington, 1996; Nicholson & Humphrey, 2003)
4) has typically been found when participants have been directed to attend to the object features (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986).

The current thesis proposes that colour, far from being a secondary property in object representations, is explicit in the representations of *all* objects in memory independently of object shape and regardless of object familiarity and of how predictive of object identity colour might be. Application of the modified retrieval practice paradigm (described in Chapter 2) allowed the probing of object memory for novel and familiar objects to test whether colour information is present and utilised during recognition. Furthermore, the use of the modified retrieval practice paradigm will allow any conclusions drawn regarding the impact of colour to be clearly distinguished from assumptions of encoding specificity.

Chapter Two

Retrieval-Induced Forgetting (RIF)

Our memories allow us to function in a complex social world where we are continuously bombarded with constantly changing information. Our memories, therefore, need to be regularly updated, and in order to achieve this feat we may need to forget old or currently irrelevant information that may be competing for recollection with new up to date information that we wish to recall. For example, when trying to locate where we parked the car at the supermarket, it would be beneficial to forget any other details about the car, such as where we parked it last week and concentrate on trying to remember where we parked it on the current occasion. Therefore, a mechanism must be in place that allows us to forget irrelevant and unwanted information and allow us to focus on retrieving the desired information. Research has suggested that competition for retrieval may be resolved through the forgetting of unwanted but related information (Anderson et al., 1994; Anderson & Spellman, 1995).

2.1 The Retrieval-induced forgetting (RIF) paradigm

In order to study interference effects in long-term memory, Anderson et al. (1994) developed the retrieval-practice paradigm. The typical paradigm involves giving participants a list of category-exemplar word pairs to study (e.g., Fruit-Orange, Fruit-Banana, Body-Leg). Subsequently participants undergo a retrieval practice session whereby they are asked to retrieve half of the target exemplars from half of the categories (e.g., Fruit-Orange). Practiced categories are labeled 'Rp'; items from these categories that are individually practiced are labeled 'Rp+' (e.g., Fruit-Orange), non-practiced items from the same practiced categories are labeled 'Rp-' (e.g., Fruit-Banana), and items from non-practiced categories are labeled 'Nrp', which stands for 'no retrieval-practice' (e.g., Body-Leg). Once the practice phase is over, and following a short distractor task, participants are asked to recall all exemplars from all categories. The findings typically reveal that recall is best for the practiced (Rp+) items, but impaired for items that were not practiced (Nrp and Rp-). Critically, memory for the unpracticed exemplars from the practiced category (Rp- items, e.g., Fruit-Banana) is worse than memory for unpracticed items whose category did not appear during the retrieval practice phase (Nrp items, e.g., Body-Leg). Anderson et al. (1994) termed this pattern of impaired recall *'retrieval-induced forgetting'* (RIF).

There are thought to be up to 200 published studies focusing on the prevalence, dynamics, and boundary conditions of RIF (see Anderson, 2003 and Storm & Levy, 2012, for reviews). Empirical evidence has revealed that RIF emerges with semantic material (e.g., Anderson et al., 1994; Anderson, 2003), episodic material (e.g., Racsmány & Conway, 2006), factual information (e.g., Anderson & Bell, 2001), phonological information (e.g., Bajo, Gómez-Ariza, Fernandez, & Marful, 2006), text passages (e.g., Little, Storm & Bjork, 2011), visuo-spatial material (e.g., Ciranni & Shimamura, 1999; Koutstaal, Schacter, Johnson, & Galluccio, 1999), arithmetic facts (e.g., Phenix & Campbell, 2004), eyewitness memory (e.g., Saunders & MacLeod, 2002), mental imagery (e.g., Saunders, Fernandez, & Kosnes, 2009), creative problem solving (e.g., Storm, Angello, & Bjork, 2011), autobiographical memory (e.g., Storm & Jobe, 2012), social contexts (e.g., Storm, Bjork, & Bjork, 2005), and actions (e.g., Reppa, Worth, Greville, & Saunders, 2013). It is therefore likely that the paradigm will provide a useful tool for studying the nature of memory representations that guide episodic object recognition.

There are differing theoretical accounts to explain the RIF phenomenon. One prominent account of the RIF effect is the inhibitory account (e.g., Anderson et al., 1994; Anderson & Spellman, 1995; see Storm and Levy, 2012 for a recent review), according to which retrieval practice leads to reduced activation of Rp- items. The inhibitory account of RIF posits that during retrieval practice, Rp- items compete with the Rp+ items, and in order to allow efficient retrieval practice of the target Rp+ items the memory representation of the Rp- items is inhibited or suppressed (e.g., Anderson et al., 1994; Anderson & Spellman, 1995). This inhibition of Rp- items is expressed in their lower accuracy in the later test phase, compared with items whose category was never practiced (Nrp items).

In contrast, non-inhibitory accounts do not support the idea that RIF emerges from the inhibition of competing items during practice. Instead, some non-inhibitory accounts, for example, associative blocking (e.g., Butler, Williams, Zacks, & Maki, 2001; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003) and encoding specificity (e.g., Perfect, Stark, Tree, Moulin, Ahmed, & Hutter, 2004), suggest that RIF occurs because the memory of practiced items is strengthened by retrieval practice and blocks the retrieval of weaker non-practiced memories. Another non-inhibitory account of RIF is the context-based account (e.g., Jonker, Seli, & MacLeod, 2013), which posits that RIF is an entirely contextual effect. According to the context-based account, RIF occurs when the context between study and practice changes, and the context of the practice phase is activated during the test phase.

Although the current research was specifically concerned with the *presence and pattern* of RIF as opposed to the mechanisms mediating the phenomenon (inhibitory or non-inhibitory), these theories have been highly influential in guiding the design of many RIF experiments, and findings from the current research could potentially be used as evidence in support for the differing accounts.

2.2 Using RIF to Examine the Role of Colour in Object Recognition Memory

The current experiments examined the nature of object representations in explicit episodic memory, by examining which visual properties of objects guide their retrieval. Specifically, the experiments examined whether recognising an object can later impair memory for objects that share with it the same shape only, or the same colour only. Through examining the properties of objects which guide competition and interference in memory we can make inferences about the representations of shape and colour information in visual object memory.

Critically, using the RIF paradigm to examine object representations can circumvent the issue of encoding specificity – which can undermine conclusions regarding colour representations in object memory. In previous episodic object recognition studies, conclusions about the effects of colour were based on performance decrements when an object changed colour from study to test. This decrement in performance could have been due not to the representation of colour per se, but to the fact that there was a change in the context between study and test. Although some studies directly examined and rejected this possibility (e.g., Nicholson & Humphrey, 2003) the majority of the Old/New recognition studies examining the representation of colour cannot confidently discount the encoding specificity explanation. In the current experiments objects presented during the study phase remained in their exact same shapes and colours in the test phase, therefore, any decrement in performance could be attributed directly to the forgetting of specific objects and not due to any visual property changes.

Unlike previous studies on the role of colour information in episodic object memory (with the exception of Stefurak & Boynton, 1986; see relevant discussion in Chapter 1) the RIF paradigm can be used to examine memory for object colour alone and object shape alone, independently of each other, by measuring their relative ability to induce interference in memory, as measured by RIF.

Previous evidence has shown that colour and shape can be used as categories and induce RIF. For instance, to examine whether shape can be a grouping feature of items (and cause interference with other items with the same shape), Ciranni and Shimamura (1999) had participants learn the locations of 12 uniquely coloured stimuli grouped by shape (4 circles, 4 triangles, 4 crosses). Then in a retrieval-practice phase participants were required to recall the shape of a subset of the stimuli (e.g., 2 of the circles and 2 of the triangles). Finally, in a test phase participants were required to recall the shape of all the 12 stimuli. Their results showed that retrieving stimuli on the basis of their shape or colour can lead to the suppression of memory representations of other objects that share the same properties.

When they examined whether colour could be a grouping feature (and therefore interfere with items that shared the same colour), their participants studied a set of 12 uniquely shaped stimuli grouped by colour (e.g., 4 green shapes, 4 orange shapes, and 4 purple shapes), and subsequently practiced a subset of stimuli from two of the colour categories (e.g., 2 of the green shapes, and 2 of the orange shapes). In the test phase, unpracticed shapes that shared the same colour as the practiced items were susceptible to significant RIF. Overall, the results from the study by Ciranni and Shimamura showed that episodic retrieval on the basis of a certain visual object property can impair retrieval of the other objects that share the same property.

Although the study by Ciranni and Shimamura (1999) showed that both shape and colour could elicit RIF, in their experiments shape and colour were never varied simultaneously as properties of the same object, or as part of the same experimental episode. The current experiments, in contrast, were designed to assess the representation of shape and colour information through the independent competition of both those properties when they were varied as part of the same object and within the same experimental episode. Furthermore, the current experiments employed a more usable paradigm than that used by Ciranni and Shimamura (they used location to probe memory), which allows the examination of shape and colour properties directly without any confounding issues, such as the use of location in order to cue memory.

Participants in the current experiments studied sets of objects (Familiar and Novel) from different categories that appeared in different shapes and colours. Then they practiced a subset of the studied objects either through a Yes/No (Old/New) recognition task (Experiments 1-7) or by rating re-presented objects on various attributes, such as complexity (Experiments 8 and 9). For each practiced (Rp+) object there were different types of unpracticed Rp- objects: Rp- objects sharing either the same shape only (Rp-Shape), the same colour only (Rp-Colour), neither shape nor colour (Rp-Neither), or both shape and colour with the Rp+ objects (Rp-Both; Experiments 4-9 only). In a test phase participants performed a Yes/No recognition task on all the studied objects. Given that interference effects in memory between the practiced and unpracticed objects are typically revealed in the forgetting of related unpracticed items (i.e., RIF), the design allows the comparison of retrieval-induced forgetting induced by colour against retrieval-induced forgetting induced by shape (objects remained in the same shapes and colours between study and test, thereby circumventing any encoding specificity explanations, an effect known to be an issue in previous explicit episodic recognition memory tasks). Theoretically, discovering the relative magnitude of competition of the two properties during practice would inform us on the representations of objects in episodic memory.

2.2.1 RIF without cued-recall at practice

Typically RIF has been shown to be a recall specific effect that only arises when active retrieval of practiced items takes place. Previous evidence shows that presentation alone of the studied stimuli is not sufficient to induce competition in memory to subsequently produce significant RIF (e.g., Anderson, 2003; Anderson & Bell, 2001; Anderson & Spellman, 1995; Anderson et al., 2000; Bäuml, 2002; Bäuml & Aslan, 2004, Ciranni & Shimamura, 1999; Dobler & Bäuml, 2013; Hanslmayr, Staudigl, Alsan & Bäuml, 2010; Saunders et al., 2009). According to the retrieval specificity assumption of the inhibitory theory of RIF (e.g., Anderson, 2003; Anderson & Spellman, 1995; Storm & Levy, 2012), if a target item is re-presented during practice then no activation or competition of non-target items occurs, therefore non-practiced items will not receive any inhibition or be susceptible to RIF. Results from previous experiments suggest that RIF can only be caused by inhibitory control mechanisms operating during retrieval practice and not just from the increased competition arising from the strengthening of practiced items (Anderson & Spellman, 1995). For example, Anderson et al. (2000) examined the retrieval specificity assumption by asking participants to either recall target items from the category cue (competitive condition) or recall the category from the target item given as a cue (non-competitive condition) during the practice phase. The results revealed that only the competitive condition led to impairment of non-practiced items from a practiced category. This suggests that simply strengthening target items does not lead to a RIF effect.

Although the study of Anderson et al. (2000) compared competitive vs. non-competitive practice phases, other studies that have simply re-presented items in the practice phase (e.g., Anderson & Bell, 2001; Bäuml & Aslan, 2004; Ciranni & Shimamura, 1999; Hanslmayr et al. 2010; Johansson, Aslan, Bäuml, Gäbel, & Mecklinger, 2007) have also found no RIF effects for un-practiced items. However, Raaijmakers and Jakab (2012) point out that the majority of such studies (the exception being the Ciranni & Shimamura, 1999 study) failed to provide participants with any feedback during the practice phases. Therefore, if an item is successfully recalled during the first practice phase then it will be likely recalled on subsequent practice phases while an item that is not recalled during the first practice phase will not be recalled on subsequent practice phases. With each successful recall during practice, the association between category and target becomes stronger, while the strength of non-recalled items becomes weak. This means that interference between recalled target items and their competing items increases leading to subsequent RIF, while no interference is produced between non-recalled items and their potentially competing items leading to an absence of RIF.

Raaijmakers and Jakab (2012) used a modified version of the RIF paradigm where participants were presented with a target item during practice and required to recall the category to which the target belonged. Furthermore, low frequency items were used that were grouped by property (e.g., round) as opposed to semantic category. Feedback was also provided after each trial in order to optimise learning. The results revealed significant RIF for non-practiced items from a practiced category, which suggests that the strengthening of practiced items did lead to interference of non-practiced items. This is the only experiment that has successfully shown a RIF effect by simply re-presenting target items during practice. The authors concluded that the findings are consistent with strength-based models of RIF.

2.2.2 RIF using Old/New recognition tasks at the test phase

Recognition tasks have been successfully used on previous occasions during the test phase to examine retrieval-induced forgetting (e.g., Anderson, De Kok, & Child, 1997; Gómez-Ariza, Lechuga, Pelegrina, & Bajo, 2005; Hicks & Starns, 2004; Radvansky, 1999; Spitzer & Bäuml, 2007, 2009; Veling & van Knippenberg, 2004; Verde, 2004). The only exception was in the study of Koutstaal et al. (1999), who found a RIF effect with free recall but not for recognition of photographs.

Hicks and Starns (2004) examined whether or not RIF could be found in the context of a recognition test as opposed to the recall tests that have traditionally been used. The rationale was that if RIF is attributable to inhibition of the Rp- item representation (e.g., Anderson et al., 1994; Anderson & Spellman, 1995), then the effect should be obtained in recognition tasks because the availability of the item is directly affected. Participants studied a list of words, then performed retrieval practice on a subset of the words, and then either performed an Old/New decision task on each word (Experiment 1) or indicated whether the word was studied and practiced, whether the word was studied but not practiced, or whether it was a new word (Experiment 2). The results revealed that retrieval practice on items from semantic categories reduced the correct recognition of unpracticed (Rp-) items from the same categories. These results conceptually replicate those of previous retrieval-induced forgetting studies done with cued recall (e.g., Anderson et al., 1994).

The advantage of using a recognition task at test allows for the control of output order and helps to mitigate the effects of output interference. That is, if participants were allowed to recall the items themselves then they would be more likely to recall the practiced items first, thus producing an output interference effect on the remaining items regardless of the practice manipulation.

2.2.3 Can recognition at practice induce interference?

The current experiments used the Old/New recognition task in both the practice (Experiments 1-7) and the test phase (Experiments 1-9). Using a recognition task during the practice (as well as the test) phase is pragmatic in that it is difficult to conduct a recall task for objects (as opposed to the word stimuli that most previous RIF studies have used), as objects do not lend themselves easily to cued-recall.

The use of a recognition practice task, as opposed to recall practice tasks, is a novelty in the RIF literature. But on what grounds can one expect that the recognition task would induce sufficient competition between practiced and unpracticed objects, and thus RIF? Recall – the task typically used in studies examining RIF – is a process of competitive search in memory. Based on a cue participants search in memory for specific items (e.g., specified by task instruction) that are related to that cue, amongst other items (not task relevant at present) which are related to the same cue. Therefore, recall can lead to interference effects in memory between the target and distractor items that share the same cue (e.g., Wixted, Ghadisha, & Vera, 1997; Wixted & Rohrer, 1994).

It has been suggested that the retrieval process mediating the recollection component of recognition tasks is similar or identical to that found in recall tasks (e.g., Brown, 1976; Clark, 1999; Humphreys, 1978; Mandler, 1980). If this is true, manipulations that affect recall should have similar effects on recollection-based recognition. Therefore, if recognition memory includes a recollection component, then a task that would encourage the use of a recollection process would create sufficient conditions for interference to emerge and subsequent RIF. The conditions that would encourage recollection in the current studies involved the use of non-speeded recognition (see Verde & Perfect, 2011), the use of unstudied items/or distractors (new items) that were similar to the studied objects/or targets (old items), and the use of feedback during the practice phase - a manipulation that has been shown as necessary for interference to occur between practiced and unpracticed items (e.g., Raaijmakers & Jakab, 2012).

2.3 Current Experiments and Predictions

The current research examined whether object colour information is represented in episodic object memory. This issue was examined separately for familiar (e.g., chairs, tables) and unfamiliar (e.g., novel or never before seen) objects. Assuming that the task employed in the current studies was sufficient to induce competition and interference as gauged by the RIF effect, then the rationale of the experiments was that the pattern of RIF would reveal the representation of object shape and object colour in episodic memory. Significant RIF for unpracticed objects that share a property with the practiced objects, would suggest that the property (i.e., shape or colour) is represented in object memory and guides competition during recognition practice.

Figure 1a shows the critical manipulations of object Rp status for each of the experiments in the thesis. If colour information is not represented in episodic object memory, then significant RIF would not be expected for objects sharing colour only (Rp-Colour) with practiced objects, and there would only be RIF for objects that share the same shape (Rp-Shape) as the practiced objects. In contrast, if colour is part of the representation of objects in memory, then significant RIF would be expected both for objects that have the same shape as practiced objects (Rp-Shape) *and* for objects that share the same colour only as the practiced objects (Rp-Colour). Significant RIF for Rp-Shape *and* Rp-Colour objects would suggest that both object shape and object colour make independent contributions in object memory.

Furthermore, an object sharing neither shape nor colour (Rp-Neither) with practiced (Rp+) objects was included in order to examine whether category sharing alone could compete during practice, given that sharing category is the single most important condition for the majority of studies examining RIF (see Anderson, 2003). Therefore, Rp-Neither objects were expected to display RIF based on the sharing of category. However, the level of RIF for the Rp-Neither objects was expected to be less than that of the Rp-Shape and Rp-Colour objects, given that they shared category only but did not share any visual properties with practiced objects and were, therefore, likely to compete at a lesser degree during practice. Finally, in Experiments 4-9, objects sharing both shape and colour (Rp-Both) with practiced objects were included in order to examine whether the combination of both visual properties on one object would lead to greater competition with Rp+ objects during practice and thus lead to greater RIF than for objects sharing either property (shape or colour) alone. Rp-Both objects were designed by recombining the colour and shape of the practiced (Rp+) objects in a novel way to make a new object. Therefore, the level of RIF for Rp-Both objects was expected to be greater than the level of RIF for the Rp-Shape and Rp-Colour objects on their own based on the fact that they share both object properties and might compete to a greater degree during practice.

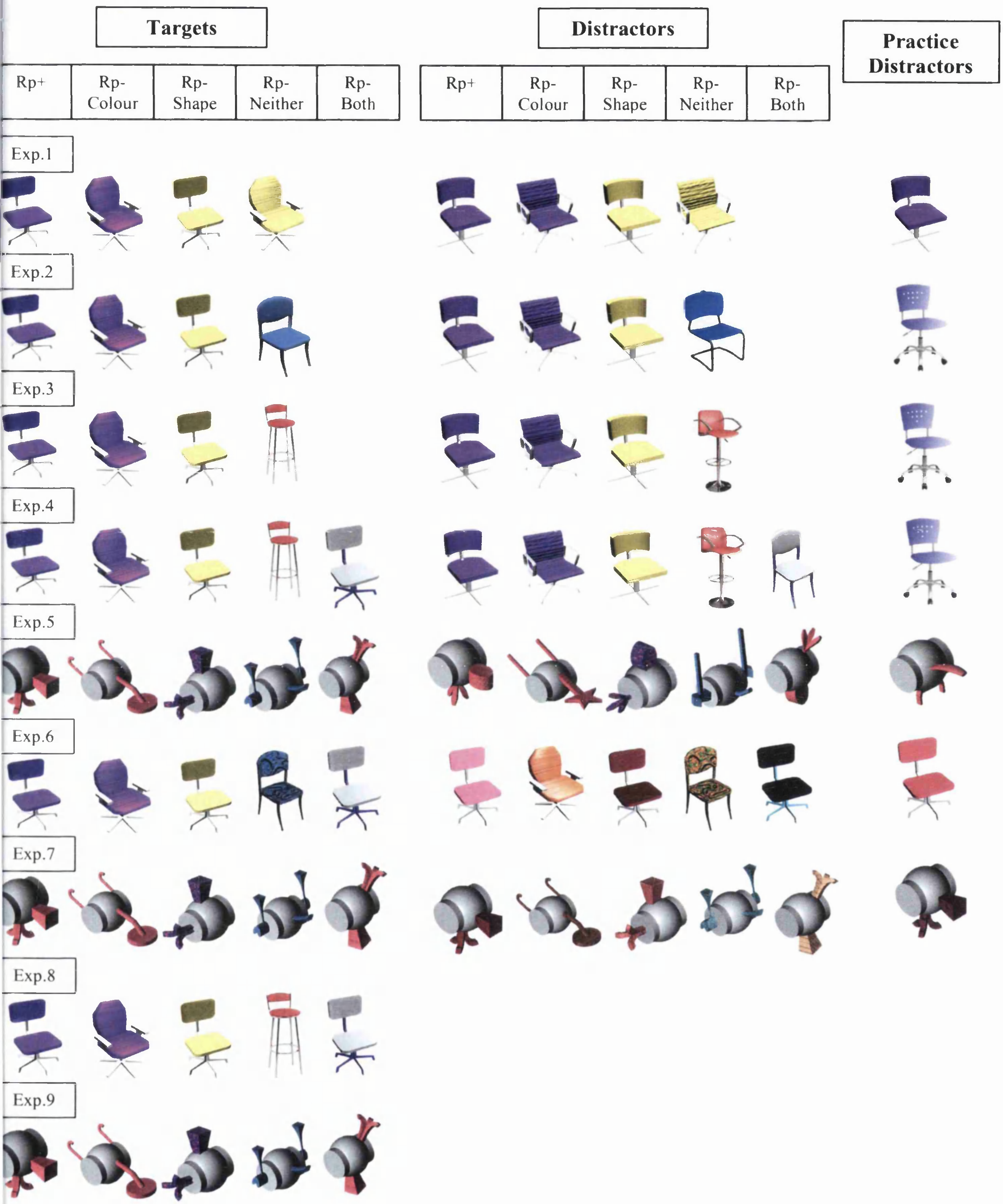

Figure 1a: Summary of key stimulus manipulations across all 9 Experiments.

Chapter Three

The Representation of Object Colour in Recognition Memory for Familiar Objects

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3.1 Experiment 1: Familiar Objects I

3.1.1 Introduction and Predictions

Experiment 1 examined whether object colour is represented in long-term episodic memory for familiar objects (e.g., tables, chairs). In order to examine the role and potential representation of object colour in memory for objects, Experiment 1 examined the contribution of shape and colour information in their ability to elicit retrieval-induced forgetting (RIF), when both colour and shape were varied within the same object category. Hence the current method had the potential to provide evidence from converging operations regarding whether colour information is a represented visual attribute in object memory.

The current studies used a variant of the retrieval-practice paradigm (Anderson et al., 1994). Participants studied objects from different categories that appeared in different shapes and colours (Figure 1b) and then practiced a subset of the objects (Rp+ objects). For each practiced object there were three different types of unpracticed objects (Rp- objects):- Rp-Shape objects shared only shape information with the practiced objects, while Rp-Colour objects shared only colour, and Rp-Neither objects were from the same category but shared neither shape nor colour information with the practiced objects.

The issue of independent representation of colour and shape information has been examined previously with somewhat mixed results. Some studies have found that shape and colour information might be represented and accessed independently in memory (e.g., Cave et al., 1996; Hanna & Remington, 1996; Stefurak & Boynton, 1986), while others have shown that the two object attributes may be represented separately but are strongly interconnected leading to effects suggesting that the two are bound in an integrated representation (e.g., Nicholson & Humphrey, 2003; Price & Humphreys, 1989). The experimental design allowed for comparison of any RIF induced by colour alone against any RIF induced by shape alone, along with a baseline for comparison of RIF induced by objects that shared only category with the practiced object. Discovering RIF for objects that share shape only or colour only with the practiced objects, would demonstrate that such properties can have independent contributions to long-term episodic memory representations of objects.

The application of the RIF paradigm in the current thesis involved the novel use of object stimuli, rather than words as is typical for the retrieval-practice paradigm, and employed a recognition task during the practice phase, as opposed to the typically used cued recall. The use of a recognition practice task in producing RIF was expected to succeed, as Anderson (2003) has suggested that how Rp+ items are practiced should not affect the observation of RIF as long as the Rp- items compete to a strong enough level. Strength of competition was encouraged by the use of non-speeded recognition, the use of unstudied items/or distractors (new items) that were similar to the studied objects/or targets (old items), and the use of feedback during the practice phase (see Chapter 1 for discussion). Although prior RIF demonstrations have occasionally used recognition tasks during the test phase (e.g., Anderson et al., 1997; Gómez-Ariza et al., 2005; Hicks & Starns, 2004; Radvansky, 1999; Spitzer & Bäuml, 2007; Verde, 2004), the current research was the first to examine whether a recognition task at practice is sufficient to induce memory competition and elicit RIF.

Assuming that the Old/New recognition practice task employed here was sufficient to elicit RIF, the magnitude of RIF in the different object conditions would be diagnostic of the contributions and presence of different object attributes in object memory. Significant RIF for both the Rp-Colour and the Rp-Shape objects would suggest that, like shape, colour information is a core component in the representations of episodic memory for objects, and not merely an additional (or secondary) property only utilised when a discrimination between objects that are high in colour diagnosticity is required. Such a finding would add to the limited existing evidence that colour is represented even for non-colour diagnostic objects (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003), and significant RIF for colour would extend existing evidence for colour effects to an accuracy-based dependent measure (e.g., Hanna & Remington, 1996; Stefurak & Boynton, 1986). Furthermore, the use of the modified RIF paradigm allowed conclusions regarding the representation of colour to be free of any encoding specificity explanations to account for a decrement in performance for Rp-Colour objects, as these objects remained in the same colour between study and test.

Finally, RIF was expected for Rp-Neither objects as they shared category with the practiced (Rp+) objects. However, as Rp-Neither objects did not share shape (part shape + part configuration) or colour with the practiced objects, they were not expected to produce as much RIF as the Rp-Colour and Rp-Shape objects. The added sharing of visual properties, if fundamental components of object representations, would be expected to cause increased interference and greater levels of RIF than the Rp-Neither objects.

3.1.2 Method

Participants

Fifty-six Swansea University students (29 males and 27 females), 28 in the Experimental Group (recognition-practice) and 28 in the Control Group (no recognition-practice), were given participant pool credits for their participation. Participants were aged between 18 and 49 *(M* =

25, *SD* = 8.11). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The Experiment was run on a Dell OptiPlex GX520 computer connected to a 15.5- inch LCD monitor. Stimulus presentation, trial randomisation, and recording of responses and response times were controlled via the experimental software package E-prime (version 2.0). The stimuli were pictures of everyday objects, belonging to four different categories: Tables, Chairs, Lamps and Pots (Figure 1b). In total there were 64 images of familiar objects taken from Art Explosion 750,000 and the World Wide Web. The images were modified (Strata 3D pro and Adobe Photoshop) to approximately 10x10cm in size and 355x420 pixels, with a resolution of 71 dpi.

In each object category there were two sets of objects (see Figure 1b). In each set there were 4 target and 4 distractor objects. Therefore, for each category there were 8 target and 8 distractor objects, yielding a total 32 targets and 32 distractors. Following the procedures of previous work (e.g., Ciranni & Shimamura, 1999) it was deemed sufficient to include four items in each of the key conditions. Furthermore, pilot work using the objects did show that RIF could emerge with 4 items per condition, showing that participant performance levels were adequate with this number of items. For each set of objects the Rp+ object was the object chosen to be practiced – e.g., top left Chair in Figure 1b. Corresponding Rp-Shape objects were created by colouring the chosen Rp+ object with a different colour (or different colour combinations for multi-part objects) but had the same texture as the Rp+ objects. The Rp-Colour objects were different in overall shape from the Rp+ objects, but were given the same colour (or colour combinations and texture). Finally, the Rp-Neither objects shared neither shape nor colour with Rp+ objects. In Experiment 1 only, Rp-Neither objects had the same shape as the Rp-Colour objects and the same colour as the Rp-Shape objects. The implication of this design of the Rp-Neither objects is discussed in the Discussion section of Experiment 1. Once all of the target (old or studied) objects had been created, distractor (new or unstudied) objects were made for each target object. The main constraint was that they were identical to targets in terms of colour (or colour combinations), different from the targets in the shape of their parts, and similar to the targets in terms of overall shape configuration (Figure 1b).

Design

Experiment 1 employed a mixed factorial design manipulating one within- and two between-participant factors. The within-participants factor was Item Type (Figure 1b), with five levels: Rp+ (Practiced objects), Rp- Shape (objects sharing shape with Rp+ objects), Rp- Colour (objects sharing colour with Rp+ objects), Rp- Neither (objects that did not share shape or colour with Rp+ objects), and Nrp (Non-recognition practice - non-practiced objects from non-practiced categories). Categories Practiced was a between-participant factor with two levels (Tables and Chairs or Lamps and Pots). For the participants who practiced a subset of the Tables and Chairs, Lamps and Pots were the Nrp objects; and vice versa. The other between-participants factor was Key Response with two levels (Left vs. Right hand 'Yes' response).

The dependent variable was the test phase recognition accuracy, expressed in terms of *A'* (a-prime). *A'* scores were computed from hits and false alarms (B''_D scores were also computed and are reported in Appendix A). The data from a Control Group with no recognition practice phase served as the between-participant baseline for the Rp conditions (Nrp was the within-participants baseline). Control Group data were used to ensure that there were no systematic differences between Rp conditions in the absence of recognition practice that could explain any effects found in the Rp conditions in the Experimental Group.

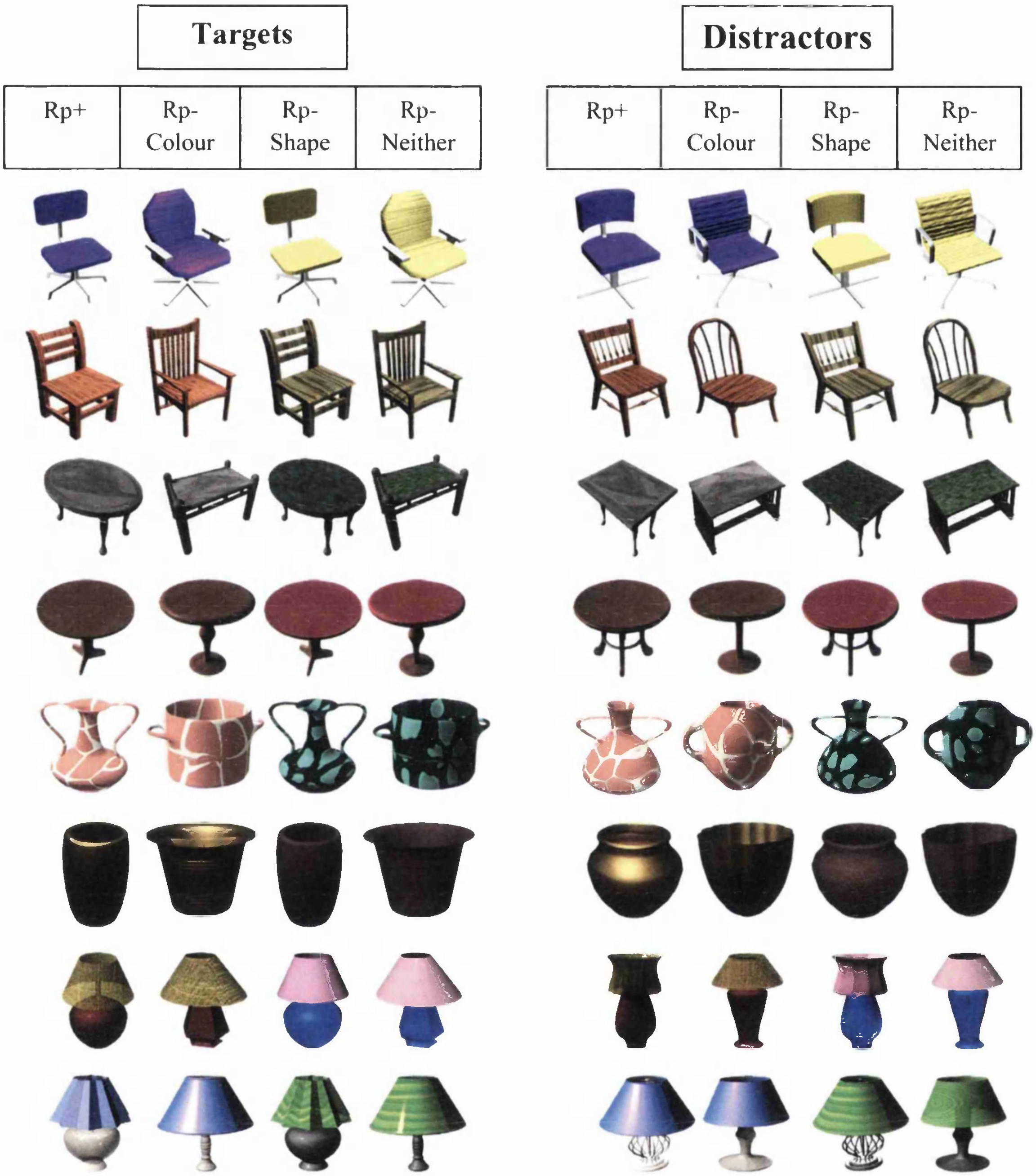

Figure 1b: Target and distractor objects used as stimuli in Experiment 1.

Procedure

Participants were seated individually in a quiet room approximately 60 cm from the computer monitor. Participants in the Experimental Group completed a study phase, three recognition-practice phases separated by extra filler tasks, and a test phase. Control Group participants completed the study phase, filler tasks and a test phase, thereby lacking recognition practice.

Study phase. The study phase consisted of learning 32 objects. In a random order, participants rated each target object once for attractiveness on a scale from 1 (not at all attractive) to 5 (very attractive) by pressing the corresponding number on the computer keypad until all target objects were rated. Object category names were never mentioned to the participants.

Recognition-practice phases. Consistent with most RIF experiments, the Experimental Group participants completed three recognition practiced phases (e.g., Anderson et al., 1994; Jakab & Raaijmakers, 2009). In each recognition-practice phase four objects were practiced (two objects from each of the object categories, e.g. two Tables and two Chairs) with recognition-practice phases separated by filler tasks. In each phase the same four pre-specified Rp+ targets and their corresponding distractors were presented one at a time sequentially and in random order at screen centre. The objects were presented in a different random order in each of the three practice phases. Participants were asked to indicated whether each object had been rated for attractiveness or not, by pressing Q and P on a QWERTY keyboard. Half of the participants responded 'Yes' by pressing P with their right hand and 'No' by pressing Q with their left hand, with the key to press reversed for the other half of the participants. Correct responses were followed by a 'Correct' message on the screen for 1 second, and incorrect responses were followed by an 'Incorrect' message on the screen for 1 second and a beep sound. Incorrect trials were not replaced. Traditionally, RIF has been studied without the use of feedback at practice, however, given the nature of the recognition task it was deemed necessary to provide feedback in order to ensure that participants learned the correct Rp+ objects. The practiced categories for half of the participants (Tables and Chairs) were the un-practiced categories (or Nrp) for the other half of participants (Lamps and Pots), and vice versa.

Filler tasks. For the Experimental Group participants, filler tasks separated the recognition practice phases. The first and second filler tasks lasted for 2 minutes and the third lasted for 5 minutes. Filler tasks required participants to list as many words as they could for each letter of the alphabet, for a range of categories (e.g., girls' names, animals, capital cities, etc.). Participants in the Control Group did not receive recognition-practice; but were required to do the filler tasks for 15 minutes, as this was how long it took the participants in the recognition-practice condition to complete their recognition-practice and filler tasks.

Test phase. All objects presented in the study phase, as well as their distractors were presented sequentially and in a random order at screen centre. The task was identical to that of the recognition-practice phase with participants indicating whether they had seen each object before or not. Participants were encouraged to respond as quickly and as accurately as possible. After Experimental Group participants responded, they were asked to rate how confident they were that their response was correct on a scale from 1 (definitely wrong) to 6 (definitely correct). Feedback was presented following each entry of the confidence rating (Experimental Group participants) or the recognition response (Control Group participants). If the recognition response was correct then a 'Correct' message was shown on the screen for 1 second. If they were incorrect then and 'Incorrect' message was shown on the screen for 1 second with a beep sound.

3.1.3 Experiment 1: Results

The data analysis procedure for all experiments in the thesis is explained here, and a note is made in the appropriate sections where analyses deviate from this procedure.

Dependant measures: For each experiment, the *A'* measure of discriminability (Snodgrass, Levy-Berger, & Haydon, 1985) and its associated response bias B''_D (Donaldson, 1992) were calculated from the hit and false alarm rates, both for the Experimental and the Control Groups. The *A'* measure of discriminability was chosen as it can be calculated even with hit values of 1 and 0, which were expected in the current paradigm. *A'* and B''_D scores were calculated by adding 0.5 to each Hit and False Alarm count value, dividing by the number of trials in each condition and adding 1. For clarity and economy of exposition, only *A'* scores are reported, while means and analyses on hits, false alarms, and B''_D are reported in Appendix A.

Test phase analysis

Experimental Group analysis. Participants in the Experimental Group who completed the recognition practice phases were scored on the number of Rp+, Rp-, and Nrp objects they had correctly recalled in the Test Phase. It was possible for Experimental Group participants to correctly recall 32 objects: 16 Nrp objects, 4 Rp+ objects, 4 Rp-Shape objects, 4 Rp-Colour objects, and 4 Rp-Neither objects.

Mixed model ANOVA

A 5 (Item Type: Nrp, Rp+, Rp-Shape, Rp-Colour and Rp-Neither) X 2 (Category Practiced: Tables and Chairs vs. Lamps and Pots) X 2 (Key Response: Left or Right) mixed model ANOVA is reported on *A'*. Item Type was manipulated within-participants, while Category Practiced and Key Response were manipulated between-participants. [The same

ANOVAs were also carried out for hit, false alarm rates, and B''_D which are reported in Appendix A]. The ANOVA was carried out and reported mostly for completeness, but also to ensure that the two factors of secondary interest, Category Practiced and Key Response, did not interact with the variable of primary interest, which was Item Type. Item Type was collapsed across Category Practiced and Key Response, when it did not interact significantly with these factors. When the Item Type by Category Practiced interaction was significant, then RIF and facilitation are also reported separately per Item Type and per Category Practiced.

The mixed model ANOVA for Experiment 1 revealed only a significant main effect of Item Type (see Table 1a). Table 1b shows the mean *A'* scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Figure 1c shows the mean *A'* per Rp condition for the Experimental Group. Figure 1d shows the mean *A'* for the Experimental and Control Groups per Rp condition.

RIF analysis. The magnitude of RIF in each Rp- condition was assessed in two ways. *Within-participant RIF* was examined by contrasting, via paired-samples t-tests[1], recall of Rp- conditions with the Nrp condition of the Experimental Group (e.g., Anderson et al., 1994). Therefore within-participant RIF was evaluated completely among within-participant conditions. For instance, to find out whether colour was represented in memory, for say Tables, required

[1] The current experiments tested hypotheses with specific predictions and stated the direction of those predictions. Therefore, given that the t-tests in the current experiments were decided *a-priori,* it was decided not to conduct Bonferroni corrections on the data. There are generic objections to the practice of adopting Bonferroni corrections (see discussions in see Nakagawa, 2004 and Perneger, 1998).

comparison of the Rp-Colour Table with the same participant's accuracy to objects whose category had not received any practice (e.g., Nrp Lamps).

Similarly, *between-participant RIF* was assessed by comparing, via independent-samples t-tests (see footnote 1), each of the Rp- conditions of the Experimental Group with corresponding Rp- conditions of the Control Group (e.g., MacLeod, 2002). For instance, experimental participants' accuracy for the Rp-Colour Tables was compared with the control participants' accuracy for the same object, to yield an assessment of RIF produced by the repetition practice manipulation that the Control Group lacked. Sometimes, within- and between- participant RIF showed the same pattern of results.

In Experiment 1 there was significant between-participant RIF for each of the three unpracticed conditions (Rp- Colour, Rp- Shape and Rp- Neither), though corresponding within-participants RIF effects were absent (see Table 1b). There were no significant differences between Experimental Group objects (Rp- Colour, Rp- Shape and Rp- Neither).

Facilitation analysis. To ensure that recognition practice was successful in enhancing the memory of the practiced objects, facilitation was reported for each experiment. As with RIF, facilitation was examined both within participants (i.e., comparing Rp+ and Nrp conditions of the Experimental Group), and between participants (i.e., comparing the Experimental Group Rp+ objects with the Control Group Rp+ objects). Both within- and between- participants facilitation was expected for all experiments, however, there have been reports of RIF without significant facilitation (e.g., Tempel & Frings, 2013). For Experiment 1, neither within- nor between-participants facilitation was significant: Experimental Group Rp+ objects did not show higher A' than Nrp objects, or than Control Group A' (see Experiment 1 discussion section).

<u>Table 1a:</u> Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiments 1 – 3 (Exp 1, Exp 2 and Exp 3 respectively).

		Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
	Dependent measure	*F* (4, 96)	*MSE*	*F* (1, 24)	*MSE*	*F* (1, 24)	*MSE*	*F* (4, 96)	*MSE*	*F* (4, 96)	*MSE*	*F* (1, 24)	*MSE*	*F* (4, 96)	*MSE*
Exp 1	*A'*	2.69*	0.02	0.04	0.04	1.97	0.04	0.23	0.02	0.15	0.02	0.07	0.04	1.41	0.02
Exp 2	*A'*	7.75**	0.01	4.29*	0.03	7.93*	0.03	3.27*	0.01	0.96	0.01	2.55	0.03	1.89	0.01
Exp 3	*A'*	12.71**	0.02	0.11	0.01	1.75	0.01	2.04	0.02	0.37	0.02	0.04	0.01	2.43	0.02

*$p<0.05$, **$p<0.001$

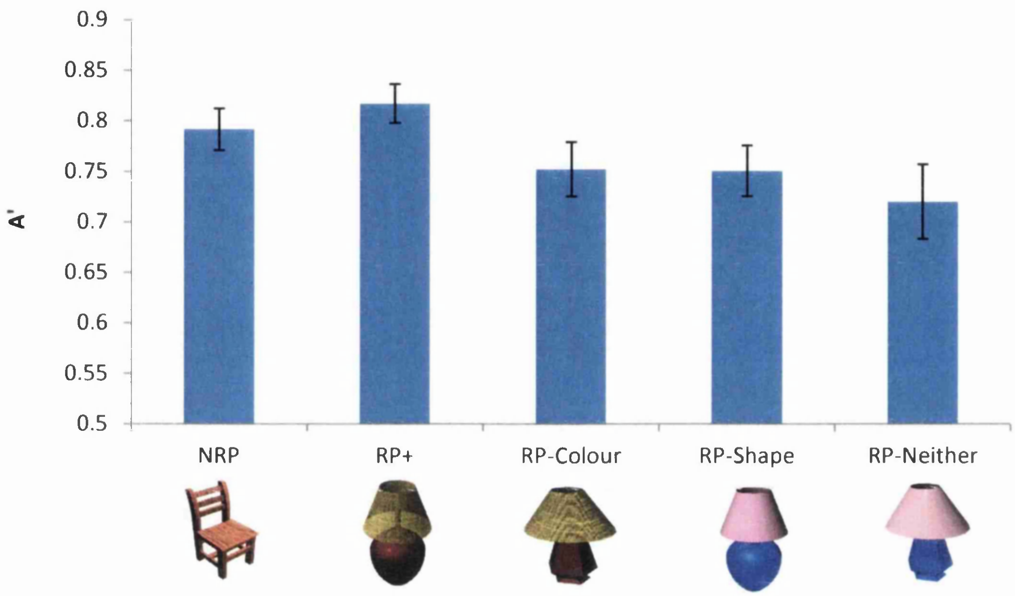

Figure 1c: Mean *A'* for each of the Rp conditions in the Experimental Group in Experiment 1. Error bars indicate standard error of the mean.

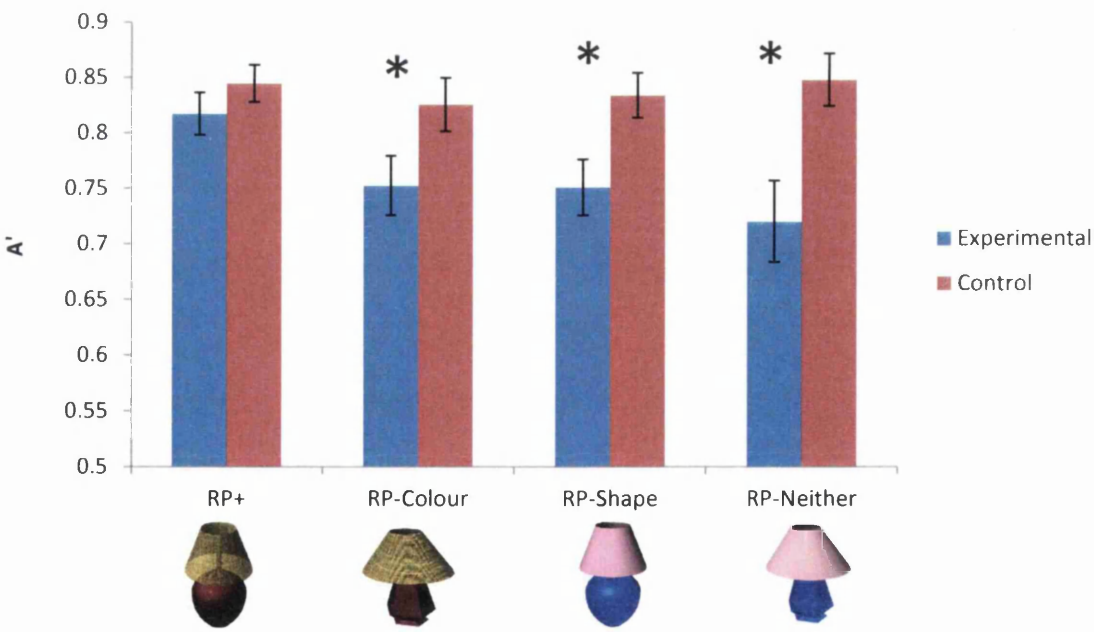

Figure 1d: Mean *A'* for the Experimental and Control Groups per Rp condition in Experiment 1. Asterisks indicate a significant difference between the Groups (between-participant RIF). Error bars indicate standard error of the mean.

Table 1b: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* scores from Experiment 1 Test Phase. *A'* scores are presented by Item Type collapsed across Category Practiced and Key Response.

		A' scores							
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
Experimental Group	*M*	0.79	0.81	0.75	0.75	0.72			
	SD	*(0.11)*	*(0.10)*	*(0.14)*	*(0.13)*	*(0.19)*			
Control Group	*M*		0.84	0.83	0.83	0.85			
	SD		*(0.09)*	*(0.13)*	*(0.11)*	*(0.13)*			
Within comparisons	$t(27)=$		-1.11	1.60	1.78	1.34	0.05	0.78	-0.87
	$p=$		*ns*^{f}	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comparisons	$t(54)=$	-3.56	1.08	2.03	2.56	2.92			
	$p=$	.001*$^\Delta$	*ns*^{f}	.05*	.01*	.005*			

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^\Delta$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp- Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp- Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp- Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

Control Group Analysis

Control Group *A'* scores were analysed (as well as hits, false alarms, and B''_D), with the full analyses reported in Appendix A. The presence of any significant main effects or interactions is made within the main document.

Given the visual complexity of the objects used in the current studies, the analysis of the Control Group data could give insights about any differences in memory for different object categories when there was no recognition practice manipulation. This would ensure that without the practice manipulation, there would be no difference in discriminability between the critical Item Type conditions of Rp-Colour and Rp-Shape.

Participants in the Control Group (no recognition practice) were scored on total correct objects recalled in the final test phase (32 objects). The Control Group data were also broken down by Category Practiced (Tables and Chairs or Lamps and Pots) and by Item Type (Rp+, Rp-Shape, Rp-Colour, and Rp-Neither). Although the Item Type factor was not applicable for the Control participants, the objects remained sub-divided into the different Rp categories to allow calculation of between-participant RIF and facilitation, as described earlier. It was possible for Control Group participants to correctly recall 8 Rp+ objects, 8 Rp-Shape objects, 8 Rp-Colour objects, and 8 Rp-Neither objects.

Two analyses involving the Control Group data are reported:

Control Group mean Vs. Experimental Group Nrp. In order to examine whether there was a difference between the two baselines used to assess RIF and facilitation, independent-samples t-tests on *A'* were carried out between the Control Group overall mean and the Experimental Group Nrp condition. If these conditions were different, it may suggest that Nrp objects were potentially susceptible to cross-category RIF – that is, performing recognition practice on, say Tables and Chairs, may cause forgetting not only for other Tables and Chairs (Rp- objects) but also for the Nrp category Lamps and Pots, perhaps by virtue of those Nrp objects being, for instance, other man-made items of furniture (e.g., Anderson & Bell, 2001; Anderson & Spellman, 1995, MacLeod & Saunders, 2005; Macrae & MacLeod, 1999; Saunders & MacLeod, 2002, 2006; Shaw, Bjork, & Handal, 1995), or by virtue of having been studied in the same experimental session (e.g., Koutstaal et al., 1999). This would lead to the underestimation of RIF using the Nrp baseline.

In Experiment 1 Control Group *A'* was significantly higher than Experimental Group Nrp *A'* (Table 1b), suggesting potential cross-category RIF for Experimental Group Nrp objects.

Repeated-measures ANOVA. It was important to ensure that the pattern of results in the Control Group – especially the pattern of *A'* in the Rp- conditions, did not resemble that of the Experimental Group. If the pattern of *A'* is the same in the two groups, it would suggest that any differences between conditions (especially between Nrp and the Rp- conditions) were due to attributes of the stimuli per se (e.g., some more memorable than others), and not to the competition among their representations induced by the practice manipulation. Furthermore, if the pattern of the two critical conditions (Rp-Colour and Rp-Shape) do not differ from each other in the Control Group, then it would suggest that there is no difference in discriminability between them, thus any differences or lack of differences in the Experimental Group cannot be accounted for solely as differences in discriminability. If, however, there is a difference between Rp-Colour and Rp-Shape in the Control Group, and a difference in discriminability between the two conditions in the Experimental Group in the same direction, then the pattern can be said to be due to differences in discriminability. Finally, if there are differences between Rp-Colour and

Rp-Shape in the Control Group but no differences between the two conditions in the Experimental Group, then they cannot be solely due to discriminability.

For Control Group participants, a 4 (Item Type: Rp+, Rp-Shape, Rp-Colour and Rp-Neither) x 2 (Category: Tables and Chairs vs. Lamps and Pots) repeated-measures ANOVA was carried out on *A'* scores (Appendix A – Table 1e). The factor of Key Response was not included in any of the Control Group analyses. For Experiment 1, there were no significant main effects or interactions, confirming that the observed differences between Item Types in the Experimental Group were due to the recognition practice manipulation.

Additional analyses

A number of additional analyses were carried out and are reported in Appendix A, as they were not of primary interest. These include: the speed-accuracy trade-off analysis, the Experimental Group confidence ratings analysis, and the recognition practice phase analysis. A full description of what these analyses show is given at the beginning of Appendix A.

3.1.4 Experiment 1: Discussion

Experiment 1 examined whether RIF, assuming it could be induced by recognition practice, can be used to examine the representation of object colour in episodic memory for familiar objects. The finding of (between-participant) RIF in Experiment 1 has significant empirical and theoretical implications. Empirically, the finding of RIF using recognition practice is important because this is the first time that RIF was induced using a recognition task at practice. Previous attempts have been unsuccessful in finding a RIF effect when tasks other than cued-recall (e.g., re-study) have been used during practice (e.g., Anderson & Spellman, 1995; Anderson et al., 2000; Anderson & Bell, 2001; Bäuml, 2002; Bäuml & Aslan, 2004, Ciranni & Shimamura, 1999; Hanslmayr et al., 2010; Saunders et al., 2009; Dobler & Bäuml, 2013). Furthermore, there have been reported failures to find a RIF effect when a recognition task was employed during the test phase (Koutstaal et al., 1999). Finding significant RIF using recognition practice, suggests there can be greater flexibility and diversity in the use of this paradigm than previously thought. RIF with recognition could therefore potentially be used to examine memory for a wide range of stimuli, such as objects, which do not easily lend themselves to recall tasks.

Theoretically, the finding of significant RIF in both Rp-Shape and Rp-Colour conditions suggests that object shape and object colour are encoded in object representations and drive competition in memory. This occurs even for objects that are not strongly associated with a specific colour – such as the non-colour diagnostic objects used in the current experiment. These findings extend existing literature in a number of ways.

First, the current study found evidence for colour representation in accuracy. Previous studies using Old/New recognition tasks, have examined whether changes in colour information between study and test had a negative impact on recognition performance (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003). In those studies although recognition latencies, when recorded (e.g., Nicholson & Humphrey, 2003), invariably show an advantage of colour being present at both study and test (as opposed to being only present at study and not at test), recognition accuracy almost invariably has not shown such an effect (e.g., Cave et al., 1996; Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986). Finding colour effects in response time but not in accuracy has led theorists to conclude that shape and colour may be represented separately but are strongly associated, with colour only accessed when the corresponding shape information is accessed (e.g., Nicholson & Humphrey, 2003; Price & Humphreys, 1989).

The current finding of significant RIF for Rp-Colour objects challenges those conclusions. This finding suggests that colour is encoded and competes for retrieval even when it is presented on a different object – colour therefore, has an independent contribution from shape to competition effects in episodic memory. This is in contrast to the findings by Nicholson and Humphrey (2003) who showed that false alarms to 'new' objects that had the same colour combinations as 'old' objects, were not significantly higher than false alarms to 'new' objects which had colour combination that had not been used during study. This led them to propose, that colour and shape are integrated in memory for objects, and that colour does not have an influence on performance unless the correct shape is also activated (Nicholson & Humphrey, 2003, p. 351). Instead, Experiment 1 showed that objects that had the same colour combinations as the practiced object competed for retrieval and were susceptible to RIF, even if they appeared on a different shape (Rp-Colour objects). This suggests that shape and colour are both represented features in object representations held in memory (e.g., Brady et al., 2012; Hanna & Remington, 1996; Stefurak & Boynton, 1986), and can drive competition effects in memory independently of each other.

The lack of significant within-participant RIF (i.e., RIF assessed by comparing the Nrp baseline and each of the Rp- conditions) was somewhat unexpected. The cause may have been the low accuracy for Nrp objects (confirmed by the significantly lower *A'* scores in the Experimental Nrp compared to the Control group's total scores). Practice of the Rp+ objects, say Tables and Chairs, may have impacted recognition memory not only of other objects related to the practiced category at the basic level (e.g., other Tables and Chairs), but also of objects related either via a super-ordinate category label (e.g., other furniture, such Lamps and Pots) or via a common study episode (i.e., they were all studied together). Similar outcomes have been reported by Koutstaal et al. (1999) who have shown significant RIF for events (photographs of action shots) following practice of events studied in the same experimental episode, without any other common characteristics. The issue of low Nrp discriminability was addressed in Experiments 2 and 3.

The lack of difference in recognition accuracy between Rp-Neither objects and the Rp-Shape and Rp-Colour objects was not expected. Performance for Rp-Neither objects was predicted to be significantly better than Rp-Shape and Rp-Colour objects, i.e., Rp-Neither objects were expected to show less RIF than Rp-Shape and Rp-Colour objects. One explanation of the low Rp-Neither performance may be due to the design of the Rp- Neither objects: although they did not share shape or colour with the practiced objects, they shared shape with Rp-Colour objects and colour with the Rp-Shape objects (see Figure 1b). Therefore, recognition performance for the Rp-Neither objects may have been driven not by their competition with the practiced objects but by their association to the other two types of Rp- objects (e.g., Anderson & Spellman, 1995; Anderson, Green, & McCulloch, 2000). This issue was addressed in Experiment 2 where the Rp-Neither objects did not share shape or colour with any of the other Rp- objects.

Finally, the lack of facilitation for Rp+ objects (both when compared with the Experimental Group Nrp baseline and with Control Group scores) was unexpected, given previous evidence that repeated exposure should lead to significantly better accuracy for Rp+ objects compared to Nrp objects (e.g., Anderson et al., 1994; Hicks & Starns, 2004). One explanation is that the Rp+ distractors used during the practice phase of the experiment were also used as Rp+ distractors during the test phase. Therefore, during the test phase when the Rp+ distractors were shown again, participants may have been more likely to respond 'Yes' to having previously seen them, even though the question specifically asked whether the object was shown during the study (attractiveness) phase. This possibility is supported by the generally high hit rates for Rp+ target objects coupled with the high false alarm rates for Rp+ distractor objects relative to the Control Group. Therefore, the low discriminability (as gauged by *A'*) of the Rp+ target objects was possibly due to the learning of the Rp+ distractor objects. This possibility was addressed in Experiment 2.

3.2 Experiment 2: Familiar Objects II

3.2.1 Introduction and Predictions

The aim of Experiment 2 was to replicate the significant RIF found for Rp-Colour and Rp-Shape objects, using the recognition practice task, but also to specifically address two issues that arose from Experiment 1. The first concerned the source of significant RIF in the Rp-Neither condition, and the second concerned the lack of facilitation for Rp+ objects.

In Experiment 1, Rp-Neither objects shared colour with Rp-Shape objects and shared shape with Rp-Colour objects. One possibility is that RIF in the Rp-Neither condition resulted not from competition between Rp-Neither and Rp+ objects, but by the spreading of RIF from the other two object types (Rp-Colour and Rp-Shape) to the Rp-Neither objects. To examine this possibility, Rp-Neither objects were modified in Experiment 2 to ensure that they did not share shape or colour with any other Rp object in the stimulus set. If the RIF for Rp-Neither objects in Experiment 1 arose due to competitor-competitor interference, then by abolishing the source of such interference, memory for Rp-Neither objects would improve over the other two Rp- objects.

To address the issue of possible learning of Rp+ distractors during the practice phase, eight new Rp+ distractors were created only for the recognition-practice phase. Therefore, Rp+ distractors shown during the recognition-practice phase differed from those during the final recognition test phase. It was expected that this manipulation would lead to the reduction of Rp+ false alarms, and the increase in *A'* of Rp+ objects. The stimuli, design and procedure of Experiment 2 was identical to Experiment 1, except for the new Rp-Neither objects and the use of different Rp+ distractors between the recognition-practice phase and the final test phase. Therefore, for Experiment 2, significant facilitation for Rp+ objects and significant RIF for Rp-Shape and Rp-Colour objects was predicted. Regarding Rp- Neither objects, if RIF in that condition was caused by a spreading of RIF from the other two conditions (Rp-Colour and Rp-Shape), then RIF for Rp-Neither objects in Experiment 2 would be significantly less.

3.2.2 Method

Participants

A different group of fifty-six Swansea University students (6 males and 50 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 56 ($M = 22$, $SD = 6.01$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The stimuli and apparatus used were the same as in Experiment 1, except the 16 new (8 target and 8 distractor, taken from the Art explosion corpus and the World Wide Web) Rp-Neither objects did not share shape or colour with the other Rp- objects nor with the Rp+ objects (Figure 2a). Also, 8 new objects were used as distractors in the recognition practice phase only (bottom of Figure 2a).

Design, Procedure, and Data Analysis Procedure

Those were identical to Experiment 1.

Figure 2a: Target and distractor objects used as stimuli in Experiment 2.

3.2.3 Experiment 2: Results

Test Phase Analyses

Experimental Group Analyses

Mixed model ANOVA. The mixed model ANOVA (Table 1a), showed a significant main effect of Item Type. There was a significant main effect of Category Practiced, with higher *A'* for Lamps and Pots compared to Tables and Chairs. There was also a significant main effect of Key Response, with participants who responded 'Yes' with their left hand performing significantly better than those who responded 'Yes' with their right hand. Finally, there was a significant Item Type by Category Practiced interaction. Given the significant Item Type by Category Practiced interaction, RIF and facilitation were calculated and reported (here and in subsequent experiments where there was an Item Type by Category Practiced interaction) separately for each category[2]. However, RIF and facilitation effects are also reported for each Item Type collapsed across Category Practiced, because those comparisons were the most theoretically relevant.

Table 2 shows the mean *A'* for the Experimental and Control Group participants, as well as within- and between-participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 2.

Figure 2b shows the mean *A'* per Rp condition for the Experimental Group. Figure 2c shows the mean *A'* per Rp condition and per Category Practiced for the Experimental Group. Figure 2d shows the mean *A'* for the Experimental and Control Groups per Rp condition.

[2] Corrections were not applied to the Item Type comparisons within each Category Practiced as the pattern of facilitation for Rp+ objects and RIF for Rp-Colour, Rp-Shape, and Rp-Neither objects was still predicted to emerge.

RIF. There was significant within-participant RIF for Rp-Shape and Rp-Colour objects, but no significant within-participant RIF for Rp-Neither objects. There was no significant between-participant RIF for any of the three Rp- objects (Experimental vs. Control Group Rp-Colour, Rp-Shape and Rp-Neither).

For the Tables and Chairs category, there was significant within-participant RIF for all of the Rp- objects, and no difference between them. There was no significant between-participant RIF for any of the three experimental Rp- objects.

For the Lamps and Pots category, within-participant RIF was only significant for the Rp-Colour objects. There was no difference between Rp-Colour and Rp-Shape objects, while those conditions had significantly lower *A'* than Rp-Neither objects. In fact, for Rp-Neither Lamps and Pots there was significant within-participant facilitation instead of RIF. There was no significant between-participant RIF for any of the three Rp- conditions.

Facilitation. There was no within-participant facilitation for Rp+ objects. However, there was significant between-participant facilitation for Rp+ objects.

For the Tables and Chairs category there was neither within- nor between- participant facilitation for Rp+ objects. While for the Lamps and Pots category, facilitation was significant both for within- and between- participant comparisons (see discussion section).

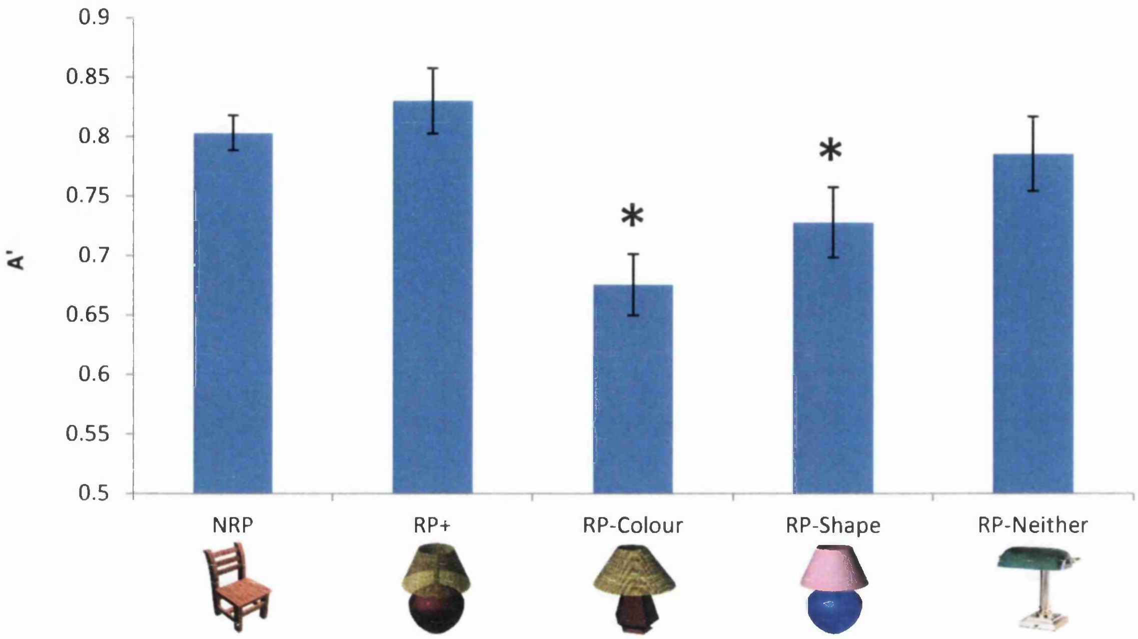

Figure 2b: Mean *A'* for each of the Rp conditions in the Experimental Group in Experiment 2. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF). Error bars indicate standard error of the mean.

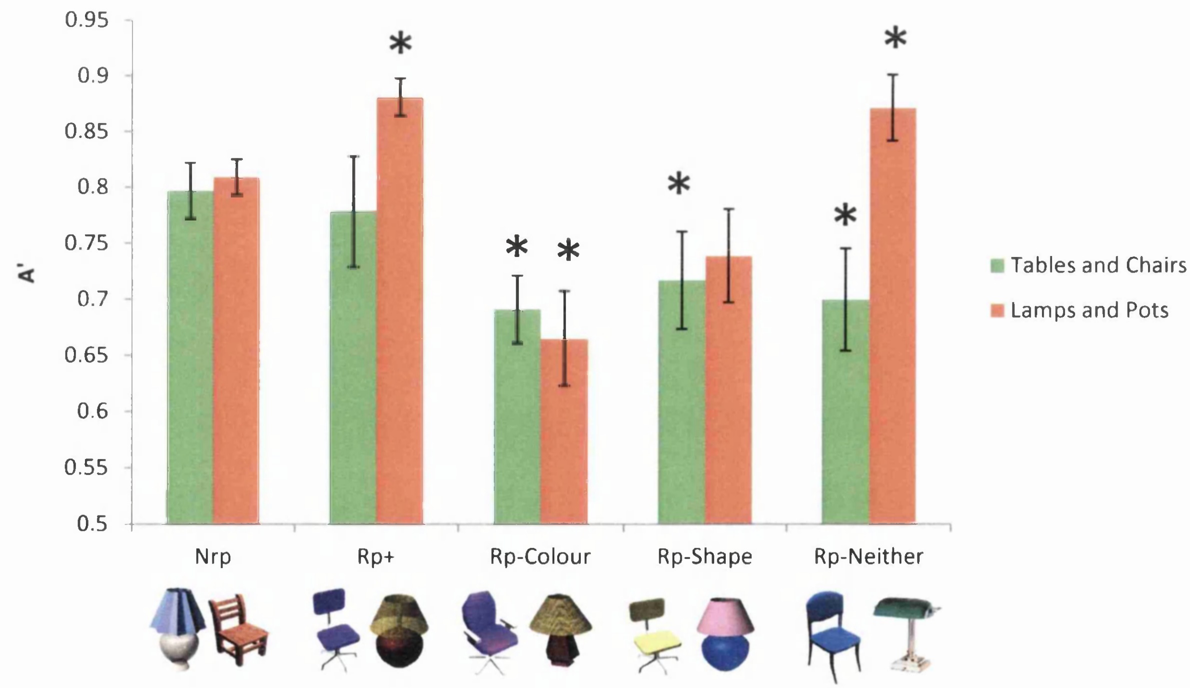

Figure 2c: Mean *A'* per Category Practiced and Rp condition in the Experimental Group in Experiment 2. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF or facilitation). Error bars indicate standard error of the mean.

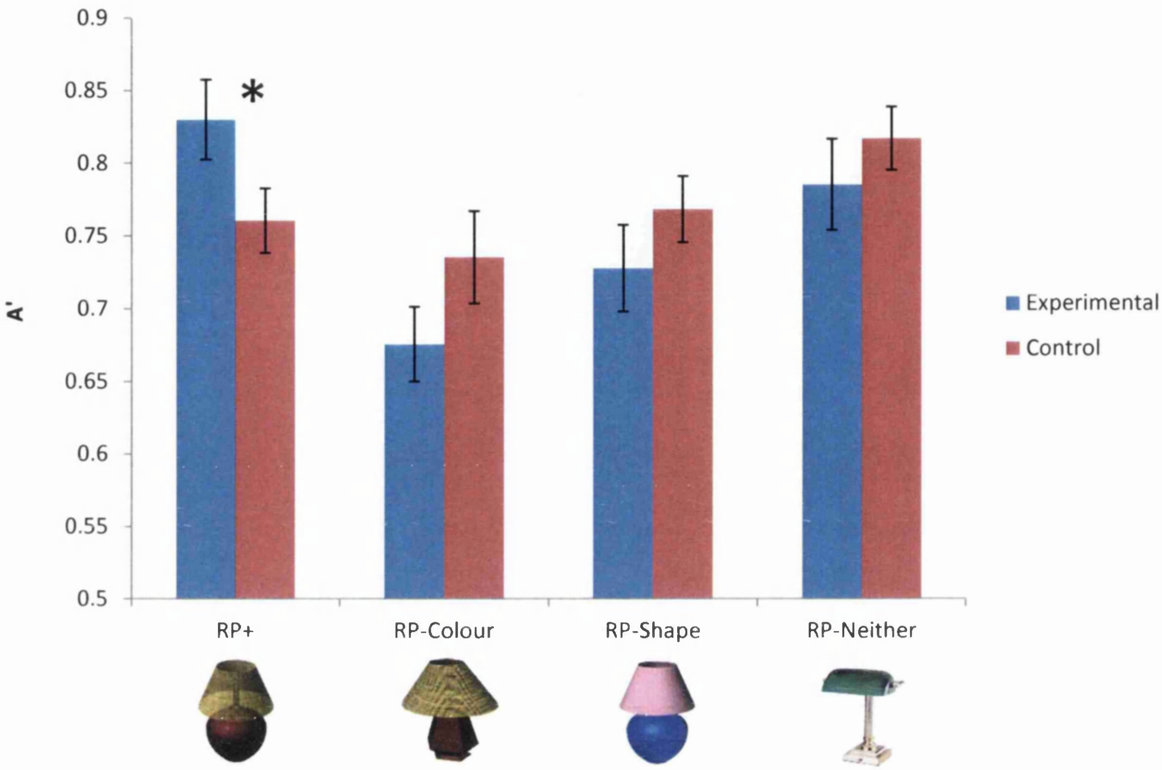

Figure 2d: Mean *A'* for the Experimental and Control Groups per Rp condition in Experiment 2. Asterisk indicates a significant difference between the Groups (between-participant facilitation). Error bars indicate standard error of the mean.

Table 2: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* scores from Experiment 2 Test Phase. *A'* scores are presented by Item Type collapsed across Category Practiced and Key Response, as well as by Item Type per Category Practiced collapsed across Key Response.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
Total *A'*									
Experimental	*M*	0.80	0.83	0.68	0.73	0.79			
Group	*SD*	*(0.83)*	*(0.15)*	*(0.14)*	*(0.16)*	*(0.17)*			
Control	*M*		0.76	0.74	0.77	0.82			
Group	*SD*		*(0.09)*	*(0.12)*	*(0.09)*	*(0.09)*			
Within	$t(27)$=		1.10	4.38	2.72	0.61	1.31	2.58	1.42
comparisons	p=		*ns*[f]	.0001**	.011*	*ns*	*ns*	.02*	*ns*
Between	$t(54)$		2.13	1.71	1.18	0.88			
comparisons	p=		.04*[f]	*ns*	*ns*	*ns*			
***A'* scores for Tables and Chairs**									
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
Experimental	*M*	0.80	0.77	0.69	0.72	0.70			
Group	*SD*	*(0.09)*	*(0.19)*	*(0.11)*	*(0.16)*	*(0.17)*			
Control	*M*		0.74	0.76	0.75	0.76			
Group	*SD*		*(0.14)*	*(0.16)*	*(0.08)*	*(0.16)*			
Within	$t(13)$=		0.51	3.04	2.40	2.34	-0.52	-0.18	-0.37
comparisons	p=		*ns*[f]	.009*	.03*	.04*	*ns*	*ns*	*ns*
Between	$t(40)$	-0.70	0.78	1.34	0.87	1.18			
comparisons	p=	*ns*[Δ]	*ns*[f]	*ns*	*ns*	*ns*			
***A'* scores for Lamps and Pots**									
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
Experimental	*M*	0.81	0.88	0.66	0.74	0.87			
Group	*SD*	*(0.06)*	*(0.06)*	*(0.15)*	*(0.16)*	*(0.11)*			
Control	*M*		0.78	0.72	0.79	0.87			
Group	*SD*		*(0.10)*	*(0.17)*	*(0.16)*	*(0.07)*			

Within	$t(13)=$		2.59	3.14	1.55	2.31	1.25	3.58	2.13
comparisons	$p=$		.02*^{f}	.008*	*ns*	.04*^{f}	*ns*	.003*	.05*
Between	$t(40)=$	-0.70	3.49	0.91	0.95	0.01			
comparisons	$p=$	*ns*$^{\Delta}$	.001**^{f}	*ns*	*ns*	*ns*			

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp- Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp- Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp- Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp: There was no difference between the Experimental Group Nrp and the overall mean of the Control Group (Table 2). Therefore, in Experiment 2 there was no evidence for cross-category inhibition of Experimental Group Nrp objects.

Repeated-measures ANOVA: The repeated-measures ANOVA on the Control Group showed a significant main effect of Item Type, a significant main effect of Category, and a significant Item Type by Category interaction (Appendix A – Table 2e). There were no differences between any of the Rp- conditions in the Tables and Chairs category. However, in the Lamps and Pots category, the Rp-Neither objects were remembered significantly better than all the other Rp objects. This difference in the pattern of results between the two categories was most likely due to the differences in design of the Rp-Neither objects, and will be discussed in more detail later.

Collapsed across Category, there was significantly higher accuracy for Rp-Neither objects compared to Rp+, Rp-Colour, and Rp-Shape (marginal) objects. There were no significant differences between the Rp+, Rp-Colour, and Rp-Shape objects (Appendix A – Table 2f), suggesting that any differences found for the critical Rp-Colour and Rp-Shape Item Types in the Experimental Group were the result of competition induced during recognition practice[3].

[3] For this Experiment, and all subsequent Experiments where there was a significant main effect of Item Type and/or a significant interaction between Item Type and Category, all Control Group comparisons between Item Types (per Category and collapsed across Category) were Bonferroni corrected, given that no differences between the Item Types were predicted.

3.2.4 Experiment 2: Discussion

Apart from replicating the pattern of RIF found in Experiment 1 for Rp-Colour and Rp-Shape objects, Experiment 2 was designed to remedy the lack of facilitation in Experiment 1, and to examine the source of RIF in the Rp-Neither condition, i.e., whether it was due to sharing Category with the Rp+ objects or to sharing perceptual features with the Rp-Colour and Rp-Shape objects.

Replicating Experiment 1, Experiment 2 showed significant RIF for objects that shared colour only (Rp-Colour) with the practiced object. This finding augments that of Experiment 1, in suggesting that colour is a represented object feature that can drive competition independently of the object on which it appears.

Regarding the issue of facilitation, the use of different distractors between the practice and the final test phase was effective in eliciting significant facilitation, albeit only for the Lamps and Pots and not for the Tables and Chairs. The reason for this difference is unclear, but one possibility is the difference in the stimulus sets of the two categories. Recall that Lamps and Pots were remembered overall better than the Tables and Chairs category (by the Experimental Group participants). Also, recall that facilitation for the Tables and Chairs group, was calculated by subtracting the mean Nrp accuracy (Nrp for the Tables and Chairs group was the Lamps and Pots category) from the Rp+ Tables and Chairs accuracy. As the accuracy for Lamps and Pots was high, any facilitation in memory for the practiced (Rp+) Tables and Chairs may have been obscured, leading to lack of significant facilitation for the Rp+ Tables and Chairs.

Regarding the Rp-Neither objects, Experiment 2 was designed to examine the source of significant RIF for Rp-Neither objects in Experiment 1. If the source of RIF was competition with the Rp+ objects, then the pattern of RIF would remain the same in Experiment 2. If however, the source of RIF was competitor-competitor interference coming from sharing features with the Rp-Colour and Rp-Shape objects, then RIF was expected to lessen. The results of Experiment 2, offered a mixed picture regarding the Rp-Neither condition. For the Tables and Chairs objects, Experiment 2 replicated the pattern of RIF in Experiment 1 (Rp-Colour = Rp-Shape = Rp-Neither). This was despite Rp-Neither objects no longer sharing the same colour or shape with any of the other two Rp- object types. This result suggests that RIF was unlikely to be due to competitor-competitor interference.

So, where did RIF come from for the Tables and Chairs Rp-Neither objects? The most likely possibility is that it came from competition with the Rp+ objects via sharing *some* perceptual features with them. Although Rp-Neither objects did not share colour and did not have identical shape with the Rp+ objects, they often shared material or texture with the Rp+ objects (e.g., they were both wooden or metal based); the shape of some parts (e.g., in a subset of Chairs the Rp-Neither chair has an almost identical seat with the Rp+ chair); overall configuration (e.g., in a subset of the Tables and Chairs); and in some case both texture and shape properties (e.g., in a subset of Tables both the Rp+ and the Rp-Neither objects have a *round wooden* top). Indeed, apart from the undisputed role of shape properties to object perception (both part shape and part configuration; Arguin & Saumier, 2004; Behrmann, Peterson, Moscovitch, & Suzuki, 2006), texture is also a represented object feature (e.g., Cant et al., 2008; Rossion & Pourtois, 2004). Therefore, significant RIF for the Rp-Neither condition could have arisen from sharing either shape or texture/material with the Rp+ objects.

Supporting the explanation above, Rp-Neither Lamps and Pots objects, which did not share any shape (e.g., part shape) or surface property (e.g., texture or material) with the Rp+

objects, did not show any RIF. Interestingly, the Rp-Neither Lamps and Pots showed significant facilitation. Data from the Control Group also confirmed that Rp-Neither Lamps and Pots were remembered better than all other objects in the Control Group, even though no objects were practiced. The better recognition memory for Rp-Neither Lamps and Pots objects may have been due to the *distinctiveness* of those objects. One reason for their distinctiveness may be that the Rp-Neither Lamps and Pots differed in texture from the other Rp objects in that category – in one Lamps and Pots subset the Rp-Neither object was metal when the rest in that subset were clay-based; in another subset the Rp-Neither Pot was made of glass, while the others were bronze; and so on. In contrast, the texture of the Rp-Neither Tables and Chairs objects was kept the same as the other Rp objects in that category (See Figure 2a). For instance, one of the Rp-Neither Chairs was wooden, as were all the other Rp objects in that Chair category.

Finally, although there was a trend towards significant RIF for the Rp-Shape Lamps and Pots objects, this was not significant. One possible reason for the lack of RIF for Rp-Shape objects could be that they were simply better remembered than the Rp-Colour objects. However, the Control Group data showed no difference in discriminability between the two conditions, countering the possibility that Rp-Shape objects were better remembered than Rp-Colour objects. A more likely possibility is related to the high level of accuracy of the Lamps and Pots objects. The reasoning is the same as that put forward to explain the lack of facilitation for the Rp+ Tables and Chairs. Recall that RIF for the Rp- objects in the group of participants who practiced the Lamps and Pots, was calculated by comparing accuracy in the Nrp condition (those were the Tables and Chairs objects) and accuracy in each of the Rp- Lamps and Pots objects. As accuracy was high in the Lamps and Pots objects, any RIF for those objects is potentially obscured by the high *A'* in that category.

If however, the explanation above is correct, why was there no significant RIF for Lamps and Pots Rp-Shape objects but significant RIF for Rp-Colour objects? One reason may be related to the nature of the distractors during the practice task. Say for instance, that participants were practicing recognition of the previously studied Rp+ chair (top left of Figure 2a). During the practice phase, both the studied chair and its associated distractor (see Figure 2a) appeared and participants had to say 'Yes' to the studied chair, and 'No' to the distractor. Note that the distractor object of the Rp+ top left chair has the same colour but different shape. It is possible, that during this practice phase participants learnt a category rule to say 'No' to objects that have the same colour but different shape from the studied objects. This rule learning might have subsequently (during the final test phase) disadvantaged the studied Rp-Colour objects, which have the same colour but different shape from the Rp+ objects. Therefore, the Rp-Colour objects may not only have lower accuracy due to their competition with the Rp+ objects (on the basis of sharing colour with them), but also have an extra bias associated with them, that was induced in the practice phase. This extra bias may have led to RIF being significant for the Rp-Colour Lamps and Pots objects, while RIF was obscured for the Rp-Shape Lamps and Pots. The significant response bias (in terms of B''_D – see Appendix A) for Rp-Colour Lamps and Pots but not for Rp-Shape Lamps and Pots supports this explanation. This issue will be brought up again and examined in Experiments 6 and 7.

3.3 Experiment 3: Familiar Objects III

3.3.1 Introduction and Predictions

In Experiment 2, participants who practiced the Lamps and Pots showed significantly higher accuracy for the Rp-Neither objects, compared to the accuracy on Rp-Neither objects of the participants who practiced the Tables and Chairs objects. Results from the Control Group data suggested that the Rp-Neither Lamps and Pots may have been seen as more distinct than the Rp-Neither Tables and Chairs.

In Experiment 3, in order to standardise the design of the Rp-Neither objects for both Categories Practiced, a set of new and more distinct Rp-Neither Tables and Chairs were created for the participant group who practiced the Tables and Chairs objects. It was expected that this manipulation would lead to Rp-Neither Tables and Chairs being no different in recognition memory accuracy from the Rp-Neither Lamps and Pots objects. In all other respects, predictions for Experiment 3 remained the same as in Experiments 1 and 2. That is, significant facilitation was expected for Rp+ objects, due to their repeated exposure in the recognition-practice phase, and for Rp-Neither objects due to their distinctive qualities. The predictions regarding RIF for Rp-Colour and Rp-Shape objects remained the same as in Experiments 1 and 2.

3.3.2 Method

For the Experimental Group in Experiment 3, only the Tables and Chairs condition was run (i.e. all 14 participants in the Experimental Group only practiced Tables and Chairs during the practice phase). The data from the 14 Tables and Chairs Experimental Group participants in Experiment 3 were then analysed together with the data from the 14 Lamps and Pots Experimental Group participants in Experiment 2. This was also the case for the Control Group, and it was ensured that an equal number of left and right hand 'Yes' responses were used when amalgamating the data. It should be noted here that although the Rp-Neither Tables and Chairs stimuli were different between Experiments 2 and 3, the combination of the data for the analysis was unlikely to be a problem. The Rp-Neither Tables and Chairs from Experiment 2 only contributed to ¼ of the Nrp items against which the Lamps and Pots Rp+ and Rp- objects were measured. The Lamps and Pots category could have been re-run with the more distinct Rp-

Neither Tables and Chairs objects, however, this was deemed unnecessary as analysing the data from the two categories together would not have impacted on the overall accuracy for the Rp+, Rp-Colour, Rp-Shape, and Rp-Neither conditions.

Participants

Twenty-eight Swansea University students (6 males and 22 females), 14 in the Experimental Group and 14 in the Control Group, were given participant pool credits for their participation. Participants were aged between 18 and 40 (M =23, SD = 5.03). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The same apparatus was used as in the previous experiments. The stimuli used (shown in Figure 3a) were exactly the same as in Experiments 1 and 2, except for the Rp-Neither objects in the Tables and Chairs group. In Experiment 3 the Rp-Neither Tables and Chairs were substituted with new ones (Figure 3a). The 8 new (4 targets and 4 distractors) Rp-Neither Tables and Chairs were taken from furniture websites and were chosen because they did not share any property with any of the other Rp conditions, and because similarly shaped objects with the same colours were also available on those websites that could be used as distractors (Figure 3a).

Design and Procedure

Those were the same as in Experiments 1 and 2.

Figure 3a: Target and distractor objects used as stimuli in Experiment 3

3.3.3 Experiment 3: Results

Test Phase Analysis

Experimental Group Analyses

Mixed model ANOVA. The mixed model ANOVA (Table 1a) revealed only a significant main effect of Item Type.

Table 3 shows the mean *A'* scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 3.

Figure 3b shows the mean *A'* per Rp condition for the Experimental Group. Figure 3c shows the mean *A'* for the Experimental and Control Groups per Rp condition.

RIF. There was significant within-participant RIF for Rp-Colour and Rp-Shape objects, and no difference between them. For Rp-Neither objects, there was significant within-participant facilitation (not RIF), and *A'* in this condition was significantly higher than Rp-Colour and Rp-Shape objects.

There was no between-participant RIF for either Rp-Colour or Rp-Shape objects, but there was significant between-participant facilitation for Rp-Neither objects.

Facilitation. There was significant within- and between- participant facilitation for Rp+ objects.

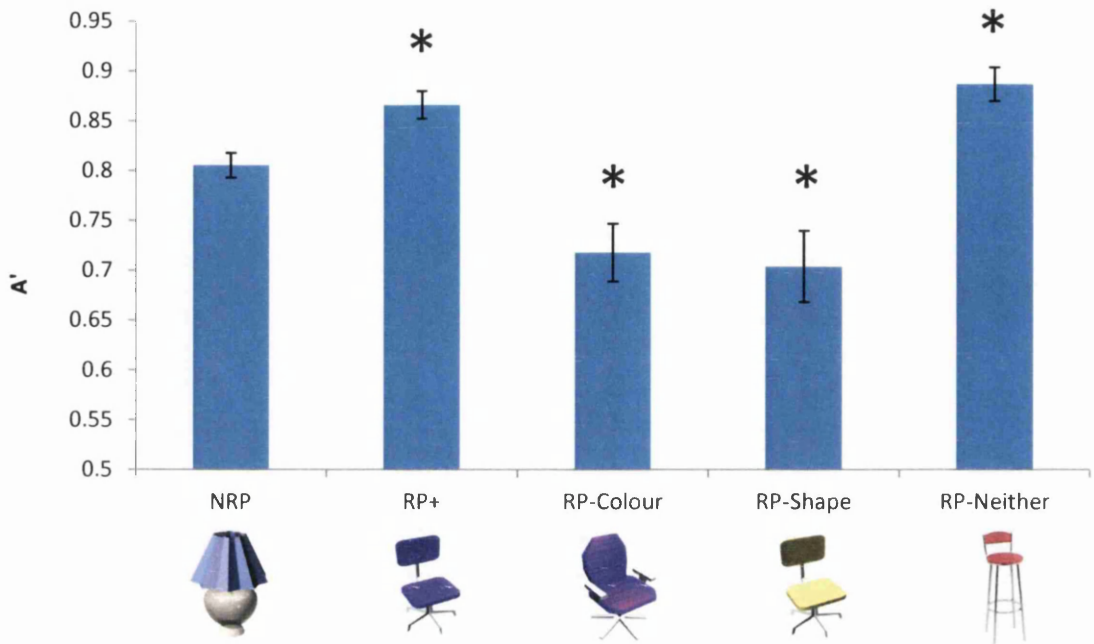

Figure 3b: Mean A' for each Rp condition in the Experimental Group in Experiment 3. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

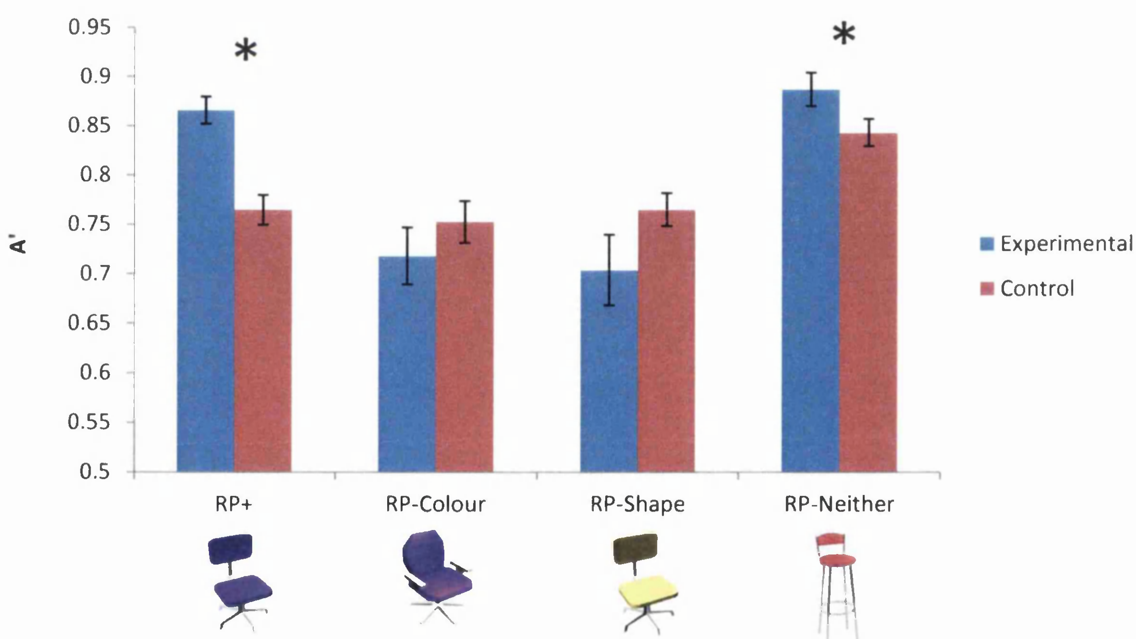

Figure 3c: Mean A' in the Experimental and Control Groups in Experiment 3. Asterisk denotes a significant difference between the groups (between-participant RIF and facilitation). Error bars indicate standard error of the mean.

Table 3: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* scores from the Experiment 3 Test Phase. *A'* scores are presented per Item Type only.

	A' scores								
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
Experimental Group	*M*	0.81	0.87	0.72	0.70	0.89			
	SD	*(0.07)*	*(0.07)*	*(0.15)*	*(0.19)*	*(0.09)*			
Control Group	*M*		0.76	0.75	0.76	0.84			
	SD		*(0.08)*	*(0.11)*	*(0.88)*	*(0.07)*			
Within comparisons	*t(27)=*		3.36	2.61	2.81	4.22	0.30	4.94	4.03
	p=		.002*^{f}	.02*	.009*	.0001**^{f}	*ns*	.0001**	.0001**
Between comparisons	*t(54)=*	1.80	4.91	0.96	1.55	1.98^{f}			
	p=	*ns*$^{\Delta}$	.0001**^{f}	*ns*	*ns*	.05*			

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp- Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp- Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp- Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. There was no significant difference between the Control Group scores and the Experimental Group Nrp scores (See Table 3), thus excluding the possibility of cross-category inhibition of the Experimental Group Nrp objects.

Repeated-measures ANOVA. The repeated-measures ANOVA on the Control Group showed a significant main effect of Item Type and a significant Item Type by Category interaction (Appendix A - Table 3e). For Tables and Chairs, Rp-Colour objects were better remembered than Rp-Shape objects, and Rp-Neither objects were better remembered than Rp+ and Rp-Shape objects. For the Lamps and Pots, Rp-Neither objects were better remembered than Rp+ and Rp-Colour objects.

Collapsed across Category, there was significantly higher accuracy for Rp-Neither objects compared to all other Rp objects, and no significant difference between the Rp+, Rp-Colour, and Rp-Shape objects. Therefore, the pattern in the Control Group for the critical Rp-Colour and Rp-Shape Item Types did not resemble the pattern of the Experimental Group (Appendix A - Table 3f).

3.3.4 Experiment 3: Discussion

Apart from the main theoretical aim, which was to examine whether colour is represented in memory for objects and the extent to which it is represented, Experiment 3 specifically addressed an issue regarding Rp-Neither objects that arose from Experiment 2. In Experiment 3 new Rp-Neither Tables and Chairs were used in an effort to eliminate the differences in discriminability found between them and the Rp-Neither Lamps and Pots (found in Experiment 2). The results showed that the change in the design of Rp-Neither Tables and Chairs led to the elimination of

RIF in that condition. Instead the Rp-Neither objects for both categories showed significant facilitation. At first glance this finding would suggest that when objects do not share shape or colour properties with the practiced objects they are not likely to compete during recognition practice and are therefore not susceptible to RIF. However, it must be taken into consideration that the Rp-Neither Tables and Chairs objects were systematically designed to look more distinct than all other Rp objects in order to be standardised with the Lamps and Pots Rp-Neither objects that were susceptible to facilitation. Therefore, at this stage we cannot conclude that objects sharing only category and no visual properties with practiced objects do not compete during recognition practice. This issue will be re-examined in Experiment 6.

Two further findings emerged in Experiment 3. First, there was significant facilitation for Rp+ objects, suggesting that their repeated exposure led to better discriminability. Second, there was significant RIF for Rp-Colour and Rp-Shape objects. This finding of significant RIF in both conditions, suggests that both properties were likely to be competing with Rp+ objects during the recognition-practice phase. The findings of Experiment 3 are discussed in conjunction with those of Experiments 1 and 2 in the following section.

3.4 Interim Discussion for Experiments 1-3

The results of Experiments 1-3 revealed that practice with objects that share shape only and/or colour only, with objects in memory, can potentially lead to forgetting – RIF – of the objects in memory. Significant RIF for Rp-Colour and Rp-Shape objects suggests that at least for this set of man-made familiar objects, both object attributes are represented and can drive competition effects independently in episodic object memory.

As discussed earlier (Experiment 1 Discussion), the results from Experiments 1-3 complement the limited previous evidence showing that object colour is part of the representation of even non-colour diagnostic objects. Most importantly, the current findings extend previous evidence by showing that object colour influences performance not only when the associated shape is also activated (e.g., Nicholson & Humphrey, 2003; Price & Humphreys, 1989), but also under circumstances like those in the current experiments, it can guide memory retrieval and competition effects in memory, independently of shape.

Previous findings showing colour to be a represented feature in object memory are often complicated by possible encoding specificity effects (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986). When there have been some efforts to exclude encoding specificity as a plausible explanation for the detrimental effects of colour change between study and test (e.g., Nicholson & Humphrey, 2003), it could not be completely excluded as contributing to memory performance, as there has never been a condition where colour remains the same between study and test. In the current experiments objects presented during the study phase remained in their exact same shapes and colours in the test phase, therefore, any decrement in performance of the Rp-Colour objects could be attributed directly to the forgetting of those objects due to competition with the Rp+ objects during practice and not due to any visual property changes.

Chapter Four

Rp-Both Experiments and the Effect of Distractors

Findings from Experiments 1-3 have shown that episodic representations for familiar objects make explicit information about both shape and colour. More specifically, results from Experiments 1-3 showed that RIF is sensitive to object shape, regardless of sharing the same colour, and sensitive to object colour regardless of sharing the same shape. These findings suggested that the two visual properties are indeed represented and can drive competition effects in memory independently. One question arising from this finding relates to whether memory performance would be different for an object sharing both properties (e.g., by recombining colour and shape in a novel way to make a new object) with the practiced object. This question was examined in Experiments 4 -7.

The other issue examined in Chapter 4 was the possible effect that the distractors may have on recognition memory accuracy and specifically on the pattern on RIF. It was speculated in the discussion of Experiment 2 that the nature of the distractors *may* have influenced the magnitude (or even the presence) of RIF for the Rp-Colour objects, thus potentially undermining any conclusions regarding the representation of colour in object memory. This issue was examined in the comparison between Experiments 4 and 5 (which used distractors that shared the same colours as the targets but differed in shape) and Experiments 6 and 7 (which used distractors that shared the same shape as the targets but had different colours).

4.1 Experiment 4: Familiar Objects IV (Different Shape Distractors)

4.1.1 Introduction and Predictions

In Experiment 4 the design of Experiments 1-3 was augmented to include a new condition where unpracticed objects shared the same shape *and* colour as the practiced object – this was named the Rp-Both condition (Figure 4a). It was predicted that sharing both properties with a practiced object might lead to greater RIF than the Rp-Shape and Rp-Colour objects given that the Rp-Both objects share both visual properties (shape and colour) with the practiced object and may compete to a greater level during practice.

4.1.2 Method

Participants

Fifty-six Swansea University students (14 males and 42 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 50 ($M = 21$, $SD = 4.33$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Stimuli and Apparatus

The stimuli and apparatus used were the same as in Experiment 3 except for the addition of 16 new Rp-Both objects (4 in each of the 4 categories; 8 used as targets and 8 used as distractors), and the change in some of the original objects from Experiment 3 that needed modification in order to accommodate to the creation of the new Rp-Both condition designs. For instance, some of the Rp+ objects from Experiment 3 only had one colour; therefore they were assigned two different colours in order to reverse the colours to make the Rp-Both objects (See difference between Figures 3a and 4a). Eighty-eight objects were used in total (40 targets, 40 distractors in the test phase, and an additional 8 Rp+ distractors for the practice phase).

Design

Experiment 4 had the same design as Experiments 1-3 with the exception that the Rp-Both level was added to the Item Type factor. Therefore, Experiment 4 employed a mixed factorial design manipulating one within- and two between-participant factors. The within-participant factor was Item Type, with six levels: Rp+ (Practiced objects), Rp- Shape (objects that shared the same shape with the Rp+ object), Rp- Colour (objects that shared the same colour with the Rp+ object), Rp- Neither (objects that did not share shape or colour with the Rp+ object), Rp-Both (objects that shared both the same shape and the same colour with the Rp+ objects) and Nrp (Non-practiced objects from non-practiced categories). One of the between-participant factors was Category Practiced, with two levels: Tables and Chairs or Lamps and Pots. The other between-participant factor was Key Response, again with two levels: Left hand 'Yes' response or Right hand 'Yes' response. The same dependant measures were employed in Experiment 4 as in Experiments 1-3.

Procedure

The procedure was identical to Experiments 1-3.

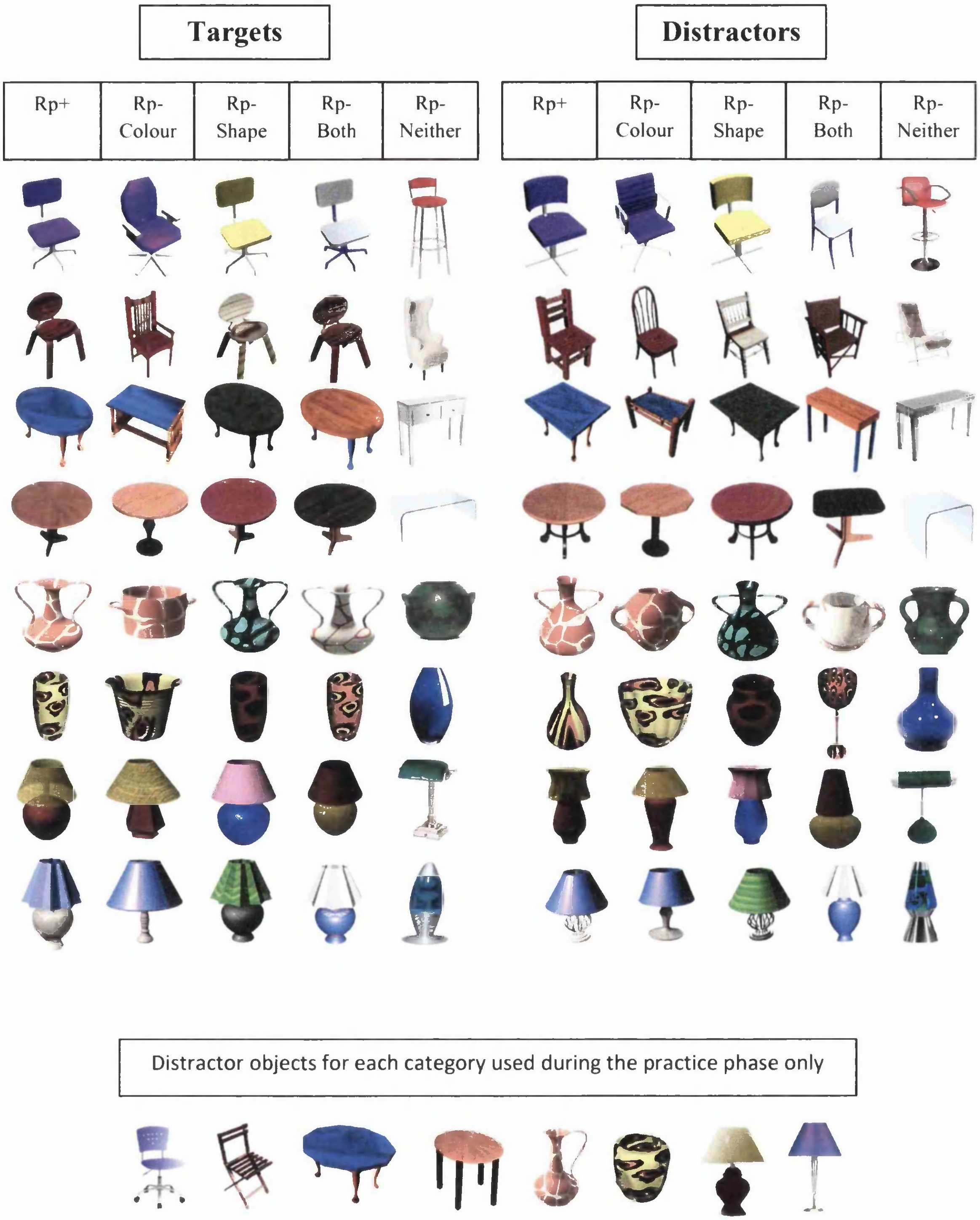

Figure 4a: Target and distractor objects used as stimuli in Experiment 4.

4.1.3 Experiment 4: Results

The data analysis procedure was identical to Experiments 1-3, with changes noted below.

Test Phase Analyses

Participants in the Experimental Group (recognition-practice) were scored on the recognition of 40 objects in the test phase: 20 Nrp, 4 Rp+, 4 Rp-Shape, 4 Rp-Colour, 4 Rp-Both, and 4 Rp-Neither objects.

Experimental Group Analyses

Mixed Model ANOVA: A 6 (Item Type: Nrp, Rp+, Rp-Shape, Rp-Colour, Rp-Both, and Rp-Neither) X 2 (Category Practiced: Tables and Chairs vs. Lamps and Pots) X 2 (Key Response: Left or Right) mixed model ANOVA, with Category Practiced manipulated between-participants, were reported on *A'* scores. The same ANOVAs were also carried out for hit, false alarm rates, and $B''_{D,}$ which are reported in Appendix A.

For Experiment 4, the mixed model ANOVA (Table 4a) showed a significant main effect of Item Type and a significant Item Type by Category Practiced interaction. The main effect of Category Practiced was not significant.

Table 4b shows the mean *A'* for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 4.

Figure 4b shows the mean *A'* per Rp condition for the Experimental Group. Figure 4c shows the mean *A'* per Rp condition and per Category Practiced for the Experimental Group. Figure 4d shows the mean *A'* for the Experimental and Control Groups per Rp condition.

Table 4a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiments 4 (Familiar objects) and 5 (Novel objects).

		Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
	Dependent measure	*F* *(5, 120)*	*MSE*	*F* *(1,24)*	*MSE*	*F* *(1, 24)*	*MSE*	*F* *(5, 120)*	*MSE*	*F* *(5, 120)*	*MSE*	*F* *(1, 24)*	*MSE*	*F* *(5, 120)*	*MSE*
Exp 4	*A'*	17.53**	0.01	1.98	0.02	0.19	0.02	4.49*	0.01	0.51	0.01	0.40	0.02	1.76	0.01
Exp 5	*A'*	2.20*	0.02	0.05	0.05	0.30	0.05	0.80	0.02	0.65	0.02	0.85	0.05	0.06	0.02

*$p<0.05$, **$p<0.001$

RIF analysis: RIF was calculated in the same way as in Experiments 1-3, with the only difference that within and between RIF was calculated for the Rp-Both condition, alongside the Rp-Colour, Rp-Shape, and Rp-Neither conditions.

Overall, there was significant within-participant RIF for Rp-Shape and Rp-Colour objects, with no significant difference between them. There was no significant within-participant RIF for Rp-Both and Rp-Neither objects. There was no significant between-participant RIF for any of the four Rp- objects.

For the Tables and Chairs category, there was significant within-participant RIF only for Rp-Colour and Rp-Shape objects, with no significant difference between them, or between any of the other Rp- conditions. Experimental and Control Group comparisons revealed significant between-participant RIF for Rp-Colour, Rp-Shape and Rp-Both objects, but not for Rp-Neither objects.

For the Lamps and Pots category there was significant within-participant RIF only for Rp-Colour objects, which had significantly lower *A'* compared to the Rp-Shape, Rp-Both, and Rp-Neither objects. There was no significant between-participant RIF for any of the Rp- objects.

Facilitation. There was significant within- and between- participant facilitation for Rp+ objects.

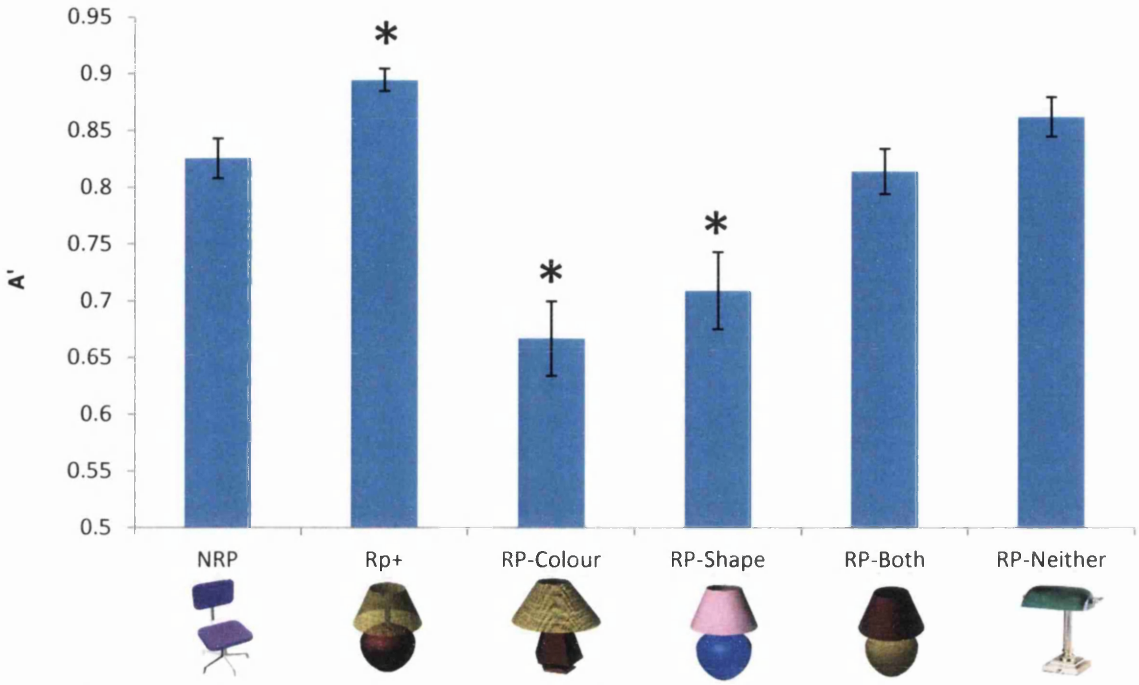

Figure 4b: Mean A' for each of the Rp conditions in the Experimental Group in Experiment 4. Asterisks denote significant difference compared to the Nrp condition (significant within-participant RIF and facilitation). Error bars indicate standard error of the mean.

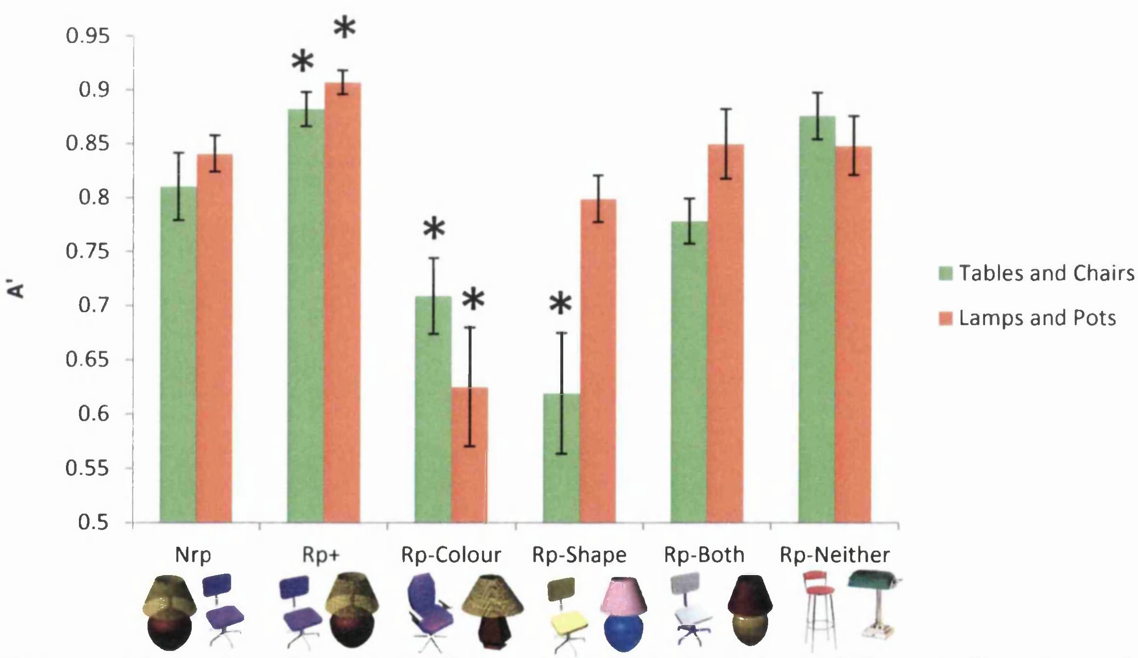

Figure 4c: Mean A' per Category and Rp condition in the Experimental Group in Experiment 4. Asterisks denote significant difference compared to Nrp (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

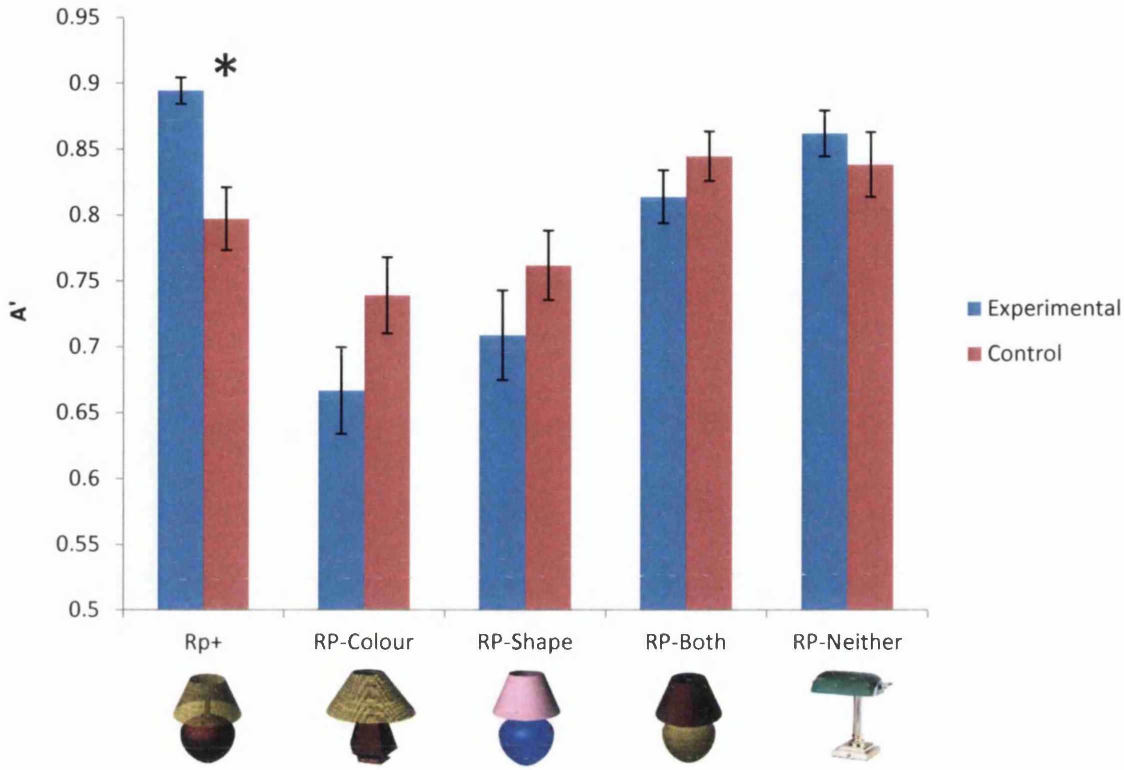

Figure 4d: Mean *A'* for the Experimental and Control Groups per Rp condition in Experiment 4. Asterisk indicates a significant difference between the Groups (between-participant facilitation). Error bars indicate standard error of the mean.

Table 4b: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* scores from Experiment 4 Test Phase. *A'* scores are presented by Item Type collapsed across Category Practiced and Key Response, as well as by Item Type per Category Practiced collapsed across Key Response.

						Total *A'*							
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental Group	*M*	0.83	0.89	0.67	0.71	0.81	0.86						
	SD	*(0.09)*	*(0.05)*	*(0.17)*	*(0.18)*	*(0.11)*	*(0.09)*						
Control Group	*M*		0.80	0.74	0.76	0.84	0.84						
	SD		*(0.10)*	*(0.14)*	*(0.10)*	*(0.08)*	*(0.10)*						
Within comparisons	$t(27)=$		3.45	4.20	3.87	0.54	1.65	0.84	4.14	5.50	2.88	3.76	2.06
	$p=$		.002*[f]	.0001*	.001*	*ns*	*ns*	*ns*	.0001*	.0001*	.008*	.001*	.05*
Between comparisons	$t(54)=$	1.25	4.70	1.74	1.37	1.25	0.90						
	$p=$	*ns* $^{\Delta}$	.0001*[f]	*ns*	*ns*	*ns*	*ns*						

						A' scores for Tables and Chairs							
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental Group	*M*	0.81	0.88	0.71	0.62	0.78	0.88						
	SD	*(0.12)*	*(0.06)*	*(0.13)*	*(0.21)*	*(0.08)*	*(0.08)*						
Control Group	*M*		0.79	0.82	0.77	0.84	0.84						
	SD		*(0.13)*	*(0.10)*	*(0.14)*	*(0.10)*	*(0.15)*						
Within comparisons	$t(13)=$		3.45	2.00	4.40	0.92	1.70	1.27	1.69	4.30	2.76	4.19	2.90
	$p=$		.002*[f]	.07 *[m]	.001*	*ns*	*ns*	*ns*	*ns*	.001*	.02*	.001*	.01*
Between comparisons	$t(40)=$	1.25	2.40	3.05	2.68	2.13	0.83						
	$p=$	*ns* $^{\Delta}$	.02*[f]	.004*	.01*	.04*	*ns*						

						A' scores for Lamps and Pots							
	Statistic	Nrp	Rp+	Rp- Colour	Rp- Shape	Rp- Both	Rp- Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental	*M*	0.84	0.91	0.62	0.80	0.85	0.85						
Group	*SD*	*(0.06)*	*(0.04)*	*(0.20)*	*(0.08)*	*(0.12)*	*(0.10)*						
Control	*M*		0.80	0.66	0.76	0.85	0.84						
Group	*SD*		*(0.12)*	*(0.20)*	*(0.14)*	*(0.10)*	*(0.11)*						
Within	$t(13)$=		3.45	4.05	1.31	0.36	0.37	3.26	4.39	3.72	1.22	1.28	0.05
comparisons	p=		.002*^{f}	.001**	*ns*	*ns*	*ns*	.006*	.001**	.003*	*ns*	*ns*	*ns*
Between	$t(40)$=	1.25	3.15	0.48	1.02	0.07	0.30						
comparisons	p=	*ns* $^\Delta$	.003*^{f}	*ns*	*ns*	*ns*	*ns*						

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^\Delta$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participant comparisons (independent-samples t-tests) between Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour as the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape as the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour as the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

Control Group Analyses

The analysis procedure for the Control Group's test phase data was the same as in Experiments 1-3, with the addition of the Rp-Both condition. Using the same reasoning as in Experiment 1, participants in the Control Group (no-recognition-practice) were scored on total correct objects recalled in the test phase (40 objects). It was possible for Control Group participants to correctly recall 8 Rp+, 8 Rp-Shape, 8 Rp-Colour, 8 Rp-Both, and 8 Rp-Neither objects. Therefore, a 5 (Item Type: Rp+, Rp-Shape, Rp-Colour, Rp-Both, and Rp-Neither) X 2 (Category: Tables and Chairs vs. Lamps and Pots) repeated-measures ANOVA was reported on *A'* scores. The full analysis of the Control Group data (including analysis of hits, false alarms, and B''_D) is presented in Appendix A.

Control Group mean Vs. Experimental Group Nrp: There was no difference between the Control Group mean and Experimental Group Nrp (See Table 4b), suggesting no cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA: The repeated-measures ANOVA on Control Group (Appendix A - Table 4e) showed a significant main effect of Item Type, a significant main effect of Category, and a significant Item Type by Category interaction. Within the Tables and Chairs category paired samples t-tests revealed significantly higher accuracy for Rp-Both objects compared to Rp-Shape objects. Within the Lamps and Pots Category there was significantly higher accuracy for Rp+ objects compared to Rp-Colour objects, significantly higher accuracy for Rp-Both objects compared to Rp-Colour and Rp-Shape objects, and significantly higher accuracy for Rp-Neither objects compared to Rp-Colour objects (Appendix A -Table 4f).

Collapsed across Category, there was significantly higher accuracy for Rp-Neither objects compared to Rp-Colour and Rp-Shape objects. This was expected given the distinctive design of the Rp-Neither objects. There was also significantly higher accuracy for Rp-Both objects compared to Rp+, Rp-Colour, and Rp-Shape objects. These comparisons appear in Appendix A – Table 4f.

4.1.4 Experiment 4: Discussion

Apart from the main theoretical aim regarding whether object colour is represented in long-term episodic memory for familiar objects, Experiment 4 examined whether RIF for objects sharing *both* shape and colour with the practiced objects would be different in magnitude from RIF for objects sharing only shape or only colour information with the practiced objects.

The following main findings emerged in Experiment 4. Complementing the findings in Experiments 1-3, Experiment 4 showed significant within-participant RIF for Rp-Colour objects. This finding strengthens the conclusion that objects sharing colour only with the practiced objects (Rp-Colour) can drive competition during recognition practice and induce significant RIF. As expected, there was significant facilitation for Rp+ objects, suggesting that recognition practice led to better recognition of those objects, and there was no RIF (or facilitation) for Rp-Neither objects.

As in Experiment 2, the presence of RIF for Rp-Shape objects was moderated by object category: while there was significant RIF for Rp-Shape Tables and Chairs, there was no RIF for Lamps and Pots. Overall, the Lamps and Pots category were less susceptible to RIF effects - the Lamps and Pots category showed significant within-participant RIF only for the Rp-Colour objects, with no other evidence for within- or between- participant RIF.

In Experiment 2, it was suggested that the reason behind the modulation of RIF for Rp-Shape by object category may lie in the nature of the Lamps and Pots category per se. That is, objects in that category may be better remembered overall, due to their distinctiveness, thus obscuring effects of RIF. Indeed, during the recognition practice phase, Lamps and Pots were remembered better compared to Tables and Chairs (See Appendix A). Furthermore, Control Group participants showed overall better memory for Lamps and Pots compared to Tables and Chairs, and a similar trend (although non-significant) was observed in the Experimental Group participants. As also suggested in Experiment 2, one reason that the better memory for Lamps and Pots possibly obscured RIF for Rp-Shape and Rp-Both, but not for Rp-Colour objects might be the fact that there is an extra response bias against Rp-Colour coming from a categorisation rule in the practice phase – i.e., participants, during the recognition practice phase learned to say 'No' to the objects (distracters) that had the same colour but different shape than the target objects. This issue was addressed in Experiments 6 and 7.

There was significant RIF for Rp-Both objects (in the between-participant comparisons for Tables and Chairs only), but it was not greater than the RIF observed for Rp-Colour and Rp-Shape objects. Instead, discriminability for Rp-Both objects was significantly higher than discriminability for Rp-Colour and Rp-Shape objects. The high levels of discriminability for Rp-Both objects might be due to a spread of facilitation from Rp+ objects to Rp-Both objects (e.g., Anderson et al., 2000; Anderson & Spellman, 1995). That is, because the Rp-Both objects share both shape and colour with the Rp+ object, the memory trace of Rp-Both objects may be strengthened due to the high similarity to the practiced objects. Coupled with a decrement in performance due to sharing common properties, RIF may have been underestimated in that condition. This issue will be further explored in the remaining experiments.

Finally, Control Group participants had lower discriminability scores in the Rp-Colour and Rp-Shape conditions compared to the Rp-Both condition. This is the first time that the Control Group participants showed lower discriminability of Rp-Colour and Rp-Shape objects compared to another Rp condition (except in Experiments 2 and 3 where the Rp-Neither objects were distinct). The most likely cause of such pattern is that the encoding and subsequent memory of the Rp-Both objects was boosted by the high resemblance to the Rp+ objects, since the objects in those two conditions shared the same features (shape and colour).

4.2 Experiment 5: Novel Objects I (Different Shape Distractors)

4.2.1 Introduction and Predictions

Experiment 5 examined the same theoretical question as Experiments 1-4, but with novel objects. Previous studies using novel objects as stimuli have suggested that colour information is automatically encoded in the long term perceptual memory representations of objects (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003). However, these studies showed that such colour effects arise only when the associated shape is also activated, and any colour effects were only reported in response latencies and not in accuracy. Based on the current findings in Experiments 1-4, and assuming that the effects obtained in the previous experiments were due to perceptual object representations, it was expected that there would be significant RIF for Rp-Shape and Rp-Colour objects in Experiment 5.

Examining the representation of shape and colour in novel objects was important for many reasons. For instance, for familiar objects colour effects may be mediated by verbal labels, which bind colour and shape information, and not by the representation of colour as an independent perceptual feature. For example, in Tanaka, Weiskopf, and Williams' (2001) Shape + Surface model of object recognition an object is represented by the perceptual inputs of shape and colour, but also by the object name which includes a bi-directional relationship with visual and verbal colour knowledge. It has been suggested that verbal labels may preserve binding so that features such as shape and colour are bound to the correct object during retention (e.g., Wheeler & Treisman, 2002). Paivio's Dual Code theory (e.g., Paivio, 1971, 1986, 1991; Paivio & Csapo, 1973; Paivio et al., 1968) suggests that there are two codes for pictures: a visual and verbal code. The theory recognises that pictures have perceptual information (i.e. colours and shape) but also verbal information (i.e. this is a picture of a *"lamp"*). For familiar recognisable objects, verbal labels are often automatically elicited and are therefore connected with the visual information. The use of novel objects should not elicit a verbal category label, and therefore, should preclude the use of a verbal coding strategy (e.g., Nicholson & Humphrey, 2003). This should then allow for the examination of the representation of colour in object memory as a perceptual feature.

The use of novel objects in the current study allowed the examination of two further important issues. The first one concerns the interpretation of RIF for Rp-Colour and the second concerns the Rp-Shape and Rp-Both objects in Experiments 1-4. Regarding the Rp-Colour objects, one might have suggested that the significant RIF for the Rp-Colour in Experiments 1-4 was induced from competition of those objects via sharing overall configuration with the Rp+ objects in some cases (e.g., in the case of Lamps, Tables or Chairs), sharing some of the parts in other cases (e.g., round table top), or even sharing common texture. The same argument may also be applied to explain Rp-Shape RIF. For instance, RIF in Rp-Shape objects may come from sharing the same material or texture with the Rp+ objects. The use of novel objects allowed a much greater control over stimulus design (as changing the configuration of the familiar objects would render them unrecognisable). For instance, it would now be possible to have Rp-Colour objects sharing the same colours as the Rp+ objects, but without having the same parts or the same configuration.

Regarding the Rp-Shape and Rp-Both condition, the use of novel objects allowed examination of the issue of shape. Previous empirical evidence from the visual search paradigm has demonstrated that both the component parts and their spatial configuration are explicit in object representations (e.g. Arguin & Saumier, 2004; Behrmann et al., 2006). For instance, Arguin and Saumier (2004) used a visual search task with complex 3-D objects constructed of volumetric parts. During a trial, participants had to indicate whether a target was present or absent amongst an array of other distractor objects. Distractors would share with targets: (a) same parts and same configuration; (b) same parts in a different configuration; (c) different parts in the same configuration; (d) different parts and a different configuration. They found that both the sharing of parts only and the sharing of spatial configuration only between targets and distractors increased search times additively. Their results suggested that object parts and their spatial configuration are explicit in the object representation, and mediated by different processes: one concerned with the properties of higher-order constituent parts and another concerned with the spatial configuration of parts.

In multi-part objects like those used in the current studies, the term shape can therefore refer to (a) the shape of the individual parts of the object (e.g., two objects would have the same shape if they are both composed of the exact same parts regardless of the configuration of those parts); (b) the overall configuration of their parts (e.g., two objects would have the same shape if they both have the same overall spatial layout, for example both ballerina-looking, regardless of the shape of their individual parts); or (c) both the shape of the parts *and* the overall configuration of parts.

In all previous experiments (Experiments 1-4), shape referred to option C - that is, Rp-Shape objects had exactly the same shaped parts in exactly the same configuration (but were different in colour) to the Rp+ objects. In Experiment 5, the Rp-Shape objects shared only parts, but not part configuration with the Rp+ objects. Based on previous findings (e.g., Arguin & Saumier, 2004; Behrmann et al., 2006) it was expected that RIF would be significant for Rp-Shape objects on the basis of sharing parts, and despite not sharing part configuration. Finding significant RIF for Rp-Shape objects, despite the differences in the manipulation of shape in Rp-Shape objects between the familiar objects experiments and the novel objects experiment of Experiment 5 would suggest that RIF in that condition was not specific to the familiar objects used in Experiments 1-4, but can generalise to other types of objects.

Similarly, in Experiment 4, Rp-Both objects shared the same colour and the same shape as described in option C above (same parts + same configuration) as practiced objects. That condition showed RIF only for a subset of data point (between-participants RIF for Tables and Chairs only), and it was proposed that the high level of similarity between Rp-Both and Rp+ objects may have been the reason for the lack of stronger evidence for RIF. In Experiment 5, Rp-Both objects would share the same colour and the same parts as Rp+ objects, but not the same configuration. This would reduce the degree of similarity in terms of overall shape between the Rp+ and the Rp-Both objects, but would not reduce their similarity in terms of their component parts and colour (both object types would still share the same colour and the same object parts). If the similarity explanation proposed in Experiment 4 for the observed RIF in the Rp-Both condition is correct, then more RIF would be predicted for Rp-Both objects in Experiment 5, because of the reduced overall similarity between Rp+ and Rp-Both objects, compared to Experiment 4.

4.2.2 Method

Participants

Fifty-six Swansea University students (9 males and 47 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 49 ($M = 22$, $SD = 6.25$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The apparatus used was exactly the same as in Experiments 1-4. The stimuli used were pictures of novel objects (adapted from Michael Tarr's stimulus database found on: titan.cog.brown.edu). They were created in Strata 3D Pro and modified in Adobe Photoshop (Version GS2). The novel objects were created so they could be grouped (through the shape of the central components) into four different informally labelled categories: Ballerinas, Mowers, Probes and Tubes (Figure 5a). These names were made up and were never mentioned to the participants. The central component of all objects in all categories were kept the same (grey) in order to reduce any confounding effects that may have emerged if the central components for each of the categories had been given their own colour. The sizes of the images presented during the experiment were roughly 10x10 cm and 355x420 pixels, with a resolution of 71 dpi. An effort was made to make the Rp-Shape objects different in texture from the Rp+ objects. Also, the Rp-Shape and Rp-Both objects differed from the Rp+ objects in terms of part configuration, while Rp-Colour and Rp-Neither objects differed from the Rp+ objects both in terms of part shape and part configuration.

Eighty-eight objects were used in total (40 targets, 40 distractors in the test phase, and 8 Rp+ distractors for the practice phase). The Rp-Colour, Rp-Shape, and Rp-Neither objects were created in the same way as for Experiments 1-4. However, in Experiment 5, the Rp-Both objects were created by changing the configuration of the parts of the Rp+ objects in Strata 3D (Figure 5a). Therefore, for the Rp-Both objects sharing the same shape as the Rp+ objects meant sharing the shape of the component parts and not the spatial configuration of the parts (as is the case for the Rp-Shape objects).

Design

Experiment 5 employed a mixed factorial design manipulating one within- and two between-participant factors. The within-participant factor was Item Type, with six levels: Rp+ (Practiced objects), Rp- Shape (objects that shared the same shape with the Rp+ object), Rp- Colour (objects that shared the same colour with the Rp+ object), Rp- Neither (objects that did not share shape or colour with the Rp+ object), Rp-Both (objects that shared both the same shape and the same colour with the Rp+ objects) and Nrp (Non-practiced objects from non-practiced categories). One of the between-participant factors was Category Practiced, with two levels: Ballerinas and Mowers vs. Probes and Tubes. The other between-participant factor was Key Response, again with two levels: Left hand 'Yes' response or Right hand 'Yes' response. The dependent variable was recognition accuracy in the test phase.

Procedure

The procedure was identical to Experiments 1-4, with the exception that there were two consecutive study phases (as opposed to only one as was the case in Experiments 1-4). This was deemed necessary because novel objects were used in Experiment 5, and participants may have required the additional viewing of the objects given their unfamiliarity and complex structure. Data analysis procedure was the same as in Experiment 4.

Figure 5a: Target and distractor objects used as stimuli in Experiment 5.
Note: The central components of all objects within a category in Experiment 5 (as well as in Experiments 7 and 9) were the same, but the size and shading appear to be different here because of re-sizing.

4.2.3 Experiment 5: Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVA. The mixed model ANOVA showed only a significant main effect of Item Type (see Table 4a). Planned comparisons to examine facilitation and RIF are reported by total collapsed across Category Practiced. Those comparisons appear in Table 5.

Table 5 shows the mean *A'* scores for the Experimental and Control Group participants, as well as within- and between-participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 5.

Figure 5b shows the mean *A'* per Rp condition for the Experimental Group. Figure 5c shows the mean *A'* for the Experimental and Control Groups per Rp condition.

RIF. There was significant within-participant RIF only for Rp-Colour and Rp-Shape objects, with no significant difference between the two conditions, or between any of the other Rp- conditions.

There was no significant between-participant RIF for any of the Rp- objects.

Facilitation. There was significant between-, but no significant within- participant facilitation.

Table 5: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* from the Experiment 5 Test Phase. *A'* is presented by Item Type only.

		A' scores											
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental Group	*M*	0.82	0.83	0.74	0.75	0.79	0.79						
	SD	*(0.11)*	*(0.12)*	*(0.17)*	*(0.14)*	*(0.15)*	*(0.15)*						
Control Group	*M*		0.76	0.76	0.78	0.81	0.79						
	SD		*(0.11)*	*(0.13)*	*(0.10)*	*(0.10)*	*(0.11)*						
Within comparisons	$t(27)$=		0.54	2.72	2.01	0.96	1.07	0.40	1.16	1.85	0.88	1.13	0.11
	p=		*ns*^{f}	.01*	.05*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comparisons	$t(54)$=	0.57	2.41	0.48	0.74	0.57	0.03						
	p=	*ns*$^{\Delta}$	.02*^{f}	*ns*	*ns*	*ns*	*ns*						

*p<0.05, **p<0.001, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

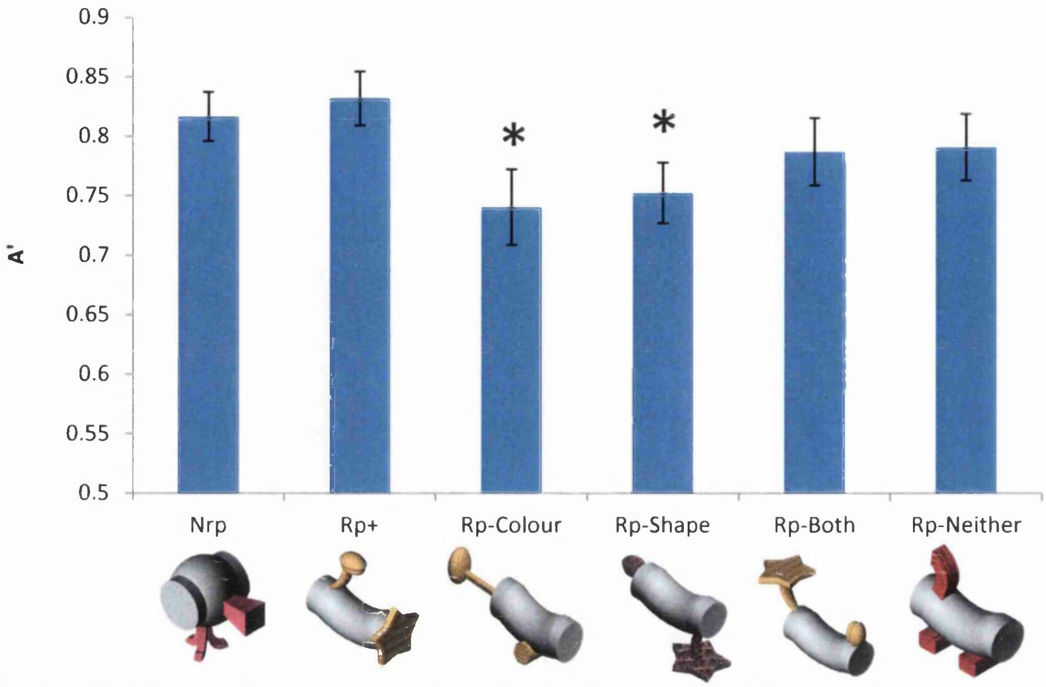

Figure 5b: Mean *A'* in each Rp condition for the Experimental Group in Experiment 5. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF). Error bars indicate standard error of the mean.

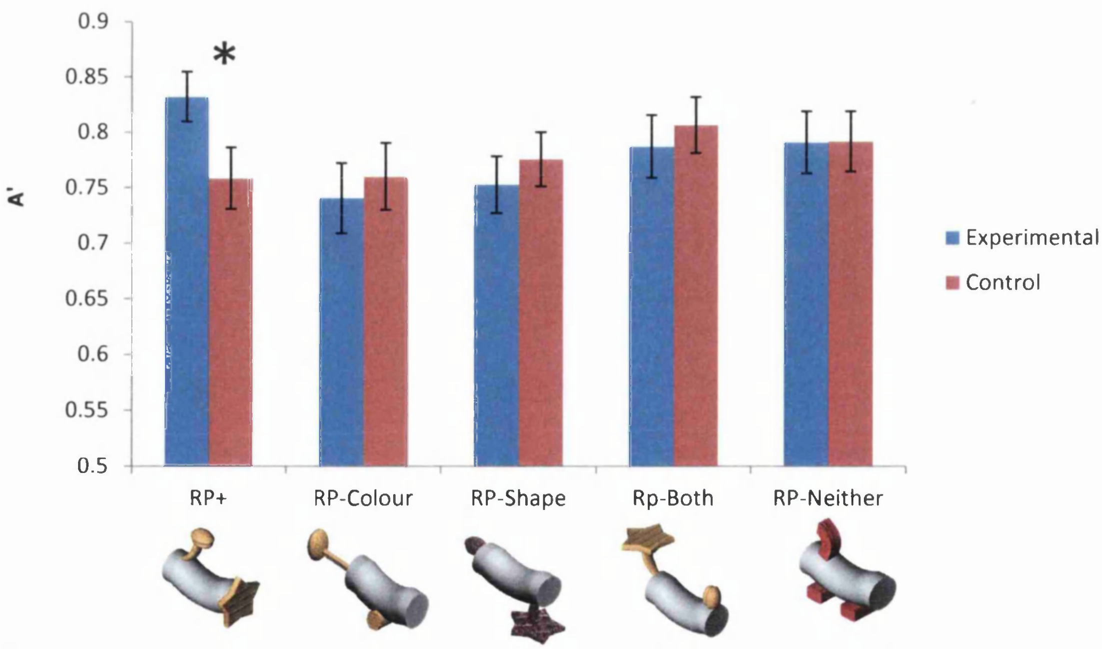

Figure 5c: Mean *A'* for the Experimental and Control Groups per Rp condition in Experiment 5. Asterisks indicate a significant difference between the Groups (between-participant facilitation). Error bars indicate standard error of the mean.

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. There was no significant difference between the Control Group overall *A'* scores and the Experimental Group Nrp *A'* scores (See Table 5), suggesting no cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA. The repeated-measures ANOVA on Control Group *A'* scores revealed no significant main effects and no significant interaction (Appendix A - Table 5e).

4.2.4 Experiment 5: Discussion

Experiment 5 examined whether colour is a represented property for novel objects. The rationale was that if the colour effects in Experiment 1-4 reflected the representation of colour and were not due to verbal coding potentially facilitating the binding of an object's shape and colour, then RIF would be observed for Rp-Colour in Experiment 5 as well.

Experiment 5 results revealed significant RIF for Rp-Colour objects, confirming that, as with familiar objects, perceptual representations in memory for novel objects that have no prior semantic or verbal associations between shape and colour, and no colour or shape diagnosticity, make explicit object colour information. Furthermore, RIF for Rp-Colour objects was significant despite the fact that in Experiment 5 (unlike in Experiments 1-4) those objects only shared colour and no shape properties (not part shape or part configuration) with the Rp+ objects.

The significant RIF for Rp-Colour and Rp-Shape objects suggests that for novel objects, as for familiar objects, both colour and shape drive competition effects in episodic memory. The novel objects in Experiment 5 were not associated with a prior category name, therefore, any effects of colour associated with them cannot be due to access to semantic memory or to a category name. That is, although the parts of the novel objects could be named (e.g., the star on one of the Tube objects could be named as a star), there was no universal prior category label as for familiar objects (e.g., a chair). The finding of colour-related RIF in novel objects is compatible with previous evidence showing colour effects using novel objects, suggesting that both shape and colour are encoded automatically in long-term memory (e.g., Nicholson & Humphrey, 2003).

Significant RIF was observed for the Rp-Shape condition in Experiment 5, despite the fact that objects in that condition shared the same part shape but not configuration with the practiced object (unlike the Rp-Shape condition in Experiments 1-4, where objects shared part shape and part configuration). The Rp-Shape objects showed significant within-participant RIF, despite the fact that they shared part shape but not texture and overall configuration with the Rp+ objects. This suggests that the shape of individual parts is made explicit in the object representation, and that interference arises not only at the level of part configuration but also at the level of local part shape, complementing similar evidence from different paradigms (e.g., Arguin & Saumier, 2004; Behrmann et al, 2006).

When objects did not share any part shape or part colour properties (other than the central component in order to group the objects) with the practiced objects – as was the case with the Rp-Neither objects, then no significant RIF was observed. This result confirms the explanation provided in Experiment 2 for the presence of RIF in the Rp-Neither condition – that it was due to the sharing of some shape properties in some cases.

Regarding Rp-Both objects, it was suggested that one possible reason for the lack of RIF for this condition in Experiment 4, may have been the spread of facilitation from Rp+ objects to

Rp-Both objects (e.g., Anderson et al., 2000), cancelling out any RIF. That is, because the Rp-Both objects shared both shape (parts and configuration) and colour with the Rp+ object, practice with the Rp+ object may have strengthened the memory of the Rp-Both objects. Therefore, on the one hand Rp-Both may have been susceptible to RIF due to competition at recognition, while also receiving facilitation due to the similarity with the Rp+ object, with the two effects cancelling each other out. The explanation for the lack of RIF in Rp-Both objects in Experiment 5 should be the same as in Experiment 4 –possible combined effects of facilitation and RIF cancelling each other out. This issue is revisited and discussed in more detail in the discussion of Experiment 7.

4.3 Interim Discussion for Experiments 4 and 5

Experiments 4 (familiar objects) and 5 (novel objects) showed significant RIF for Rp-Colour and Rp-Shape objects. Critically, in both experiments there was no significant difference in discriminability between these two conditions (except in Lamps and Pots category of Experiment 4 where Rp-shape objects were remembered significantly better than Rp-Colour objects). This suggests that, on the whole, for familiar and novel objects both shape and colour information can drive competition in memory independently of each other.

Interestingly, the findings of significant overall RIF for Rp-Colour and Rp-Shape and the overall lack of RIF for Rp-Both was found in both Experiment 4 and 5 despite the differences in design of the objects between the two experiments. First, RIF for Rp-Colour objects remained significant in Experiment 5, where those objects shared only colour (and no parts or overall configuration) with the Rp+ objects. Second, RIF for Rp-Shape objects remained significant in Experiment 5 despite the fact that those objects only shared part shape (and not configuration) with the Rp+ objects. This result suggests that part shape must be encoded in object memory independently of part configuration (e.g., Arguin & Saumier, 2004). The similarities in the pattern of RIF between the two experiments, despite their differences in stimuli, suggests that the experiments were truly tapping into the representations of shape and colour in object memory, as both properties are able to compete during recognition-practice despite the changes in location of local part shape and local part colour.

One possibility that was raised earlier, was that the significant RIF found for Rp-Colour objects, did not necessarily reflect the forgetting of Rp-Colour objects but may instead have been an artefact of the Old/New recognition design and its use of distractor objects. This issue was explored in Experiments 6 (familiar objects) and 7 (novel objects).

4.4 Experiment 6: Familiar Objects V (Different Colour Distractors)

4.4.1 Introduction and Predictions

One issue that arose in Experiments 1 and 4 concerned the presence of RIF for Rp-Colour objects, in the absence of RIF for Rp-Shape objects. One possibility suggested earlier was that significant RIF in the Rp-Colour condition may have been due to the nature of the task, and in particular the distractors, during the recognition practice phase. That is, during the recognition practice phase, participants had to accept (say 'Yes' to) the studied objects (targets) and reject (say 'No' to) stimuli that had a different shape but the same colour as the studied objects (distractors). Thus, they learn to reject objects that shared the same colour but had a different shape from the target objects. As suggested in the Experiment 2, this rule learning may have disadvantaged performance for the studied Rp-Colour objects (that also shared colour but had different shape from the targets). If this is true then it could undermine the conclusion drawn from the significant RIF in the Rp-Colour condition, about the representation of object colour in memory.

Therefore, Experiment 6 was run with new distractor objects, which shared the same part shape and part configuration with the target objects, but had a different colour from the targets (Figure 6a). If colour is encoded in the object representation then RIF would be observed, despite the change in the nature of the distractors – that is, the same pattern of results would be observed in Experiment 6 as in Experiments 1-4, with significant RIF for Rp-Shape and for Rp-Colour objects. However, if the RIF for Rp-Colour objects was due to the nature of the distractors biasing responses against Rp-Colour objects, then RIF for Rp-Colour objects would be reduced or eliminated.

4.4.2 Method

Participants

Fifty-six Swansea University students (10 males and 46 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 38 ($M = 21$, $SD = 3.18$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Stimuli and Apparatus

The stimuli and apparatus used was exactly the same as in Experiment 4, except for the distractors and the Rp-Neither objects. In all previous experiments, distractors shared the same colour as the targets but differed in terms of shape. For Experiment 6 new distractors were designed that shared the same shape (same overall configuration) as the targets, but differed from the target in terms of colour or colour combinations (Figure 6a).

In order to create Rp-Neither distractor objects for Experiment 6 it was necessary to keep the shape of the object the same and to change the colour. It was not possible to do this with the Rp-Neither objects taken from the World Wide Web as they could not be manipulated in the computer software programme, to alter their colours without compromising the appearance of the shape. Therefore, a new set of Rp-Neither objects (targets and distractors) was created. Some of the Rp-Neither objects used in Experiment 6 were recycled from previous experiments. The shape of the bottom two Rp-Shape Lamp distractors from Experiment 1 (see Figure 1b) were used as Rp-Neither targets and distractors in Experiment 6. Also, three of the Rp-Neither targets and one Rp-Neither distractor from the Tables and Chairs category that were used in Experiment 2 were now used as Rp-Neither target and distractor objects in Experiment 6 (see Figure 2a). Finally, two new Rp-Neither Pots were created for Experiment 6 (See Figure 6a).

Design and Procedure

Design and Procedure were identical to Experiment 4.

Figure 6a: Target and distractor objects used as stimuli in Experiment 6.

4.4.3 Experiment 6: Results

Test phase analysis

Experimental Group analysis

Mixed model ANOVA. The mixed model ANOVA showed a significant main effect of Item Type (see Table 6a). There was also a significant Category Practiced X Key Response interaction, which was not theoretically significant and was not explored further.

Table 6b shows the mean *A'* scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 6.

Figure 6b shows the mean *A'* per Rp condition for the Experimental Group. Figure 6c shows the mean *A'* in the Experimental and Control Groups per Rp condition.

RIF. There was significant within-participant RIF for all four Rp- objects. Within-participant comparisons showed that accuracy for Rp-Shape objects were significantly lower than for Rp-Colour and Rp-Both objects.

There was significant between-participant RIF for Rp-Shape and Rp-Neither objects, but no significant between-participant RIF for Rp-Colour and Rp-Both objects.

Facilitation. There was significant within-participant facilitation, but no significant between-participant facilitation.

Table 6a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiments 6 (Familiar objects) and 7 (Novel objects).

		Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
	Dependent measure	*F* *(5, 120)*	*MSE*	*F* *(1, 24)*	*MSE*	*F* *(1, 24)*	*MSE*	*F* *(5, 120)*	*MSE*	*F* *(5, 120)*	*MSE*	*F* *(1, 24)*	*MSE*	*F* *(5, 120)*	*MSE*
Exp 6	*A'*	16.24**	0.02	0.12	0.03	0.35	0.03	1.51	0.02	0.35	0.02	4.84*	0.03	1.71	0.02
Exp 7	*A'*	4.65*	0.02	5.15*	0.05	0.09	0.05	0.40	0.02	0.39	0.02	3.01	0.05	1.23	0.02

*$p<0.05$, **$p<0.001$

Table 6b: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* from the Experiment 6 Test Phase. *A'* scores are presented by Item Type collapsed across Category Practiced and Key Response.

		A' scores											
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental Group	*M*	0.80	0.90	0.73	0.58	0.73	0.65						
	SD	*(0.08)*	*(0.07)*	*(0.18)*	*(0.18)*	*(0.16)*	*(0.20)*						
Control Group	*M*		0.87	0.79	0.71	0.77	0.78						
	SD		*(0.07)*	*(0.09)*	*(0.12)*	*(0.10)*	*(0.10)*						
Within comparisons	$t(27)$=		4.87	2.20	6.91	2.78	4.07	2.92	0.02	1.80	4.14	1.15	1.51
	p=		.001**[f]	.04*	.001**	.01*	.001**	.007*	*ns*	*ns*	.001**	*ns*	*ns*
Between comparisons	$t(54)$=	2.03	1.80	1.76	3.09	1.33	2.99						
	p=	.05*[Δ]	*ns*	*ns*	.003*	*ns*	.004*						

*$p<0.05$, **$p<0.001$, [f] = facilitation. [Δ] = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

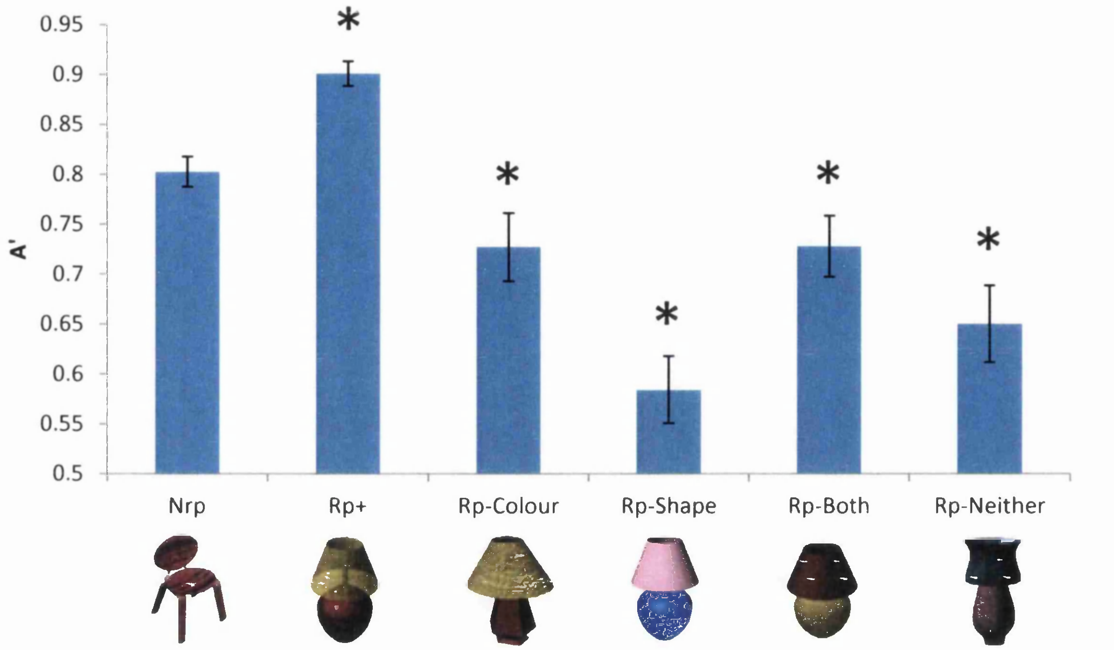

Figure 6b: Mean *A'* for each Rp condition in the Experimental Group in Experiment 6. Asterisks denote significant difference from the Nrp condition (within-participant facilitation and RIF). Error bars indicate standard error of the mean.

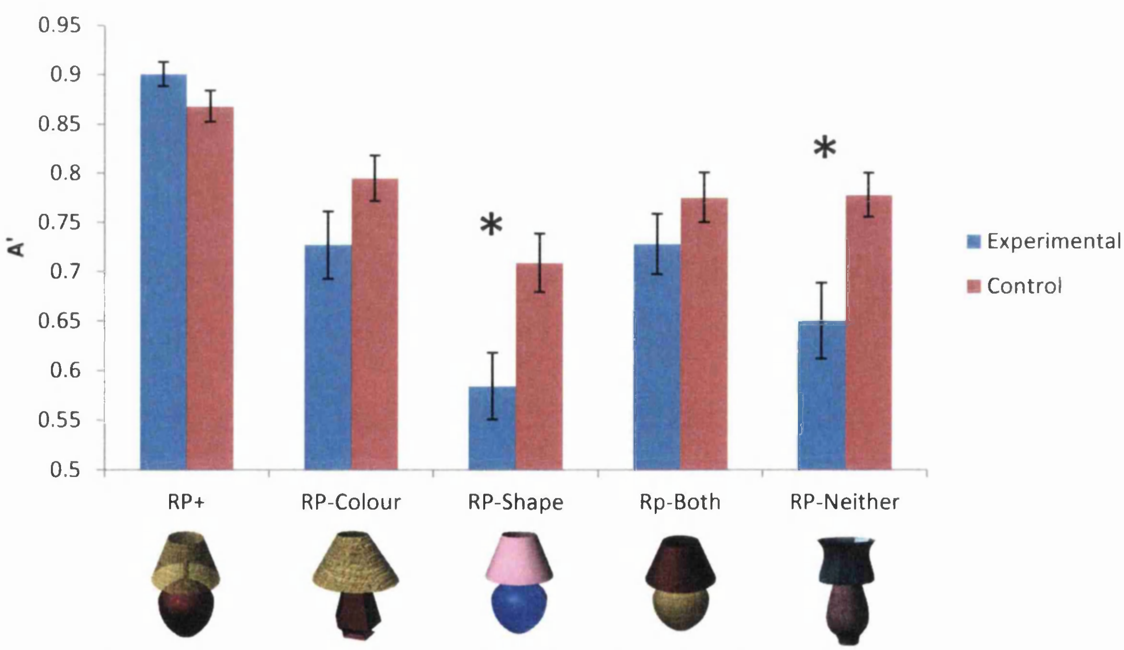

Figure 6c: Mean *A'* in the Experimental and Control Groups per Rp condition in Experiment 6. Asterisks indicate a significant difference between the Groups (between-participant RIF). Error bars indicate standard error of the mean.

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Total Control Group scores were higher than Experimental Group Nrp scores (See Table 6b), suggesting potential cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA. The repeated-measures ANOVA on Control Group *A'* scores revealed a significant main effect of Item Type and a significant Item Type by Category interaction (Appendix A - Table 6e). Within the Tables and Chairs category paired samples t-tests revealed significantly higher discriminability for Rp+ objects compared to Rp-Shape and Rp-Neither objects, significantly higher discriminability for Rp-Colour objects compared to Rp-Shape objects, and significantly higher discriminability for Rp-Both and Rp-Neither objects compared to Rp-Shape objects. For the Lamps and Pots category there was significantly higher discriminability for Rp+ objects compared to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects (Appendix A - Table 6f).

Collapsed across Category, there was significantly higher discriminability for Rp+ objects compared to all other Rp- objects. There was also significantly lower discriminability for Rp-Shape objects compared to Rp-Colour objects (Appendix A – Table 6f).

4.4.4 Comparison between Experiments 4 and 6

Because Experiment 6 was designed to examine the possibility that the previously observed RIF for Rp-Colour, and the occasional lack of RIF for Rp-Shape, was due to the nature of the distractors in the previous experiments, a mixed model ANOVA was carried out on RIF magnitude with Experiment (4 vs. 6) as the between-participants factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both and Rp-Neither) as the within-participants factor. There was a significant main effect of Experiment, $F\ (1, 54) = 5.47, p = .02$, a significant main effect of Rp-condition, F (3, 162) = 8.50, $p < .0001$, and a significant interaction, F (3, 162) = 8.20, $p <.001$. There was significantly more RIF for Rp-Shape in Experiment 6 compared to Experiment 4, t (54) = -2.33, $p = 0.023$, while there was no significant difference in RIF for Rp-Colour objects between the two experiments, t (54) = 1.63, $p> 0.05$. Therefore, RIF for Rp-Colour remained significant, despite the change in the distractors. However, changing the distractors in Experiment 6 led to significantly more RIF in the Rp-Shape condition. For Rp-Neither objects, RIF magnitude was larger in Experiment 6 compared to Experiment 4, t (54) = 4.43, $p < 0.001$, while there was no difference in RIF magnitude between experiments for Rp-Both objects, t (54) = 1.84, $p > .05$

Finally, to ensure that any differences in RIF between the two experiments were not due to a change in task difficulty, a comparison of Nrp A' between the experiments was carried out, which showed no significant difference, t (54) = 0.99, $p > .05$. Similarly, there was no significant difference in total between the Control Groups of Experiment 4 and 6, t (54) = 0.79, $p > 0.05$.

4.4.5 Experiment 6: Discussion

Experiment 6 examined whether the significant RIF for Rp-Colour objects in Experiments 1-4, and the occasional lack of RIF for the Rp-Shape objects (Experiments 2 and 4 in the Lamps and Pots category) was a methodological artefact, related to the nature of the distractors used during the recognition task. Given that the distractors in Experiments 1-4 shared the same colour as the Rp-Colour objects, it was likely that the finding of significant RIF for Rp-Colour objects may have been due to the learning of a categorisation rule during the practice phase – i.e., say 'No' to objects with the same colour but different shape from the Rp+ objects (which were the objects they learnt to say 'Yes' to). The results of Experiment 6 disconfirmed this possibility. First, there was significant RIF for the Rp-Colour condition despite the change in distractors, which removed any previous disadvantage for that condition. Second, comparison between Experiments 4 and 6 revealed no difference in Rp-Colour RIF magnitude between the two experiments. This suggests that the RIF for Rp-Colour observed in Experiment 4 was not simply due to a disadvantage for that condition because of the nature of distractors; in other words it was not simply a methodological artefact.

The change in the nature of distractors, however, did have an impact on the Rp-Shape condition. Although Rp-Shape RIF was significant in Experiments 4 and 6, comparison between experiments revealed greater RIF in Experiment 6. Therefore, the nature of distractors –a methodological factor – influenced the magnitude of RIF for Rp-Shape objects: during recognition practice participants learned to say 'No' to objects sharing the same shape as the practiced objects (the Rp+ objects) to which they learned to 'Yes'. The same reasoning can be used to explain the significant RIF for Rp-Both objects in Experiment 6 and not in Experiment 4. Overall, therefore it appears that the nature of distractors can influence the magnitude of RIF via reducing the accuracy of studied objects (see Anderson, 2003 for discussion on distractors in recognition tasks). Critically, however, the nature of distractors did not influence *the presence of RIF* in the Rp-Shape and Rp-Colour conditions.

Unlike Experiment 4, Experiment 6 showed significant RIF for Rp-Neither objects, which was accompanied with a significantly more conservative bias compared to Experiment 4. One explanation for significant RIF in the Rp-Neither condition, is that in Experiment 6 the Rp-Neither objects occasionally shared some properties with the Rp+ objects. For instance, in the case of Tables and Lamps, Rp-Neither objects shared either a part with the Rp+ objects or overall configuration, on the basis of which they may have been able to compete during recognition practice, leading to significant RIF (see also Experiment 2).

Finally, discriminability in the Control Group was lower in the critical Rp-Colour and Rp-Shape conditions, relative to the Rp+ condition. This pattern was most likely driven by the increased discriminability of Rp+ objects due to the addition of the Rp-Both objects in Experiment 6. This possibility is supported by comparisons between Experiment 3 (where there was no Rp-Both condition) and Experiment 6 (where the Rp-Both was included), on Rp+, Rp-Colour, and Rp-Shape *A'* scores. Those between-experiment comparisons revealed that Rp+ *A'* scores were (marginally) higher in Experiment 6 than in Experiment 3. Meanwhile, there was no difference between the two experiments on the Rp-Colour and Rp-Shape *A'* scores. Furthermore, Rp-Shape objects were remembered significantly less than Rp-Colour objects suggesting that the change in the distractors affected the baseline (no recognition-practice) discriminability of the critical Item Types (Rp-Shape and Rp-Colour). Finally, the fact that the Rp-Neither objects were no longer remembered better than the other Rp- objects was expected given that in Experiment 6 they were no longer distinctive from the other object types (see Appendix A – Table 6g for relevant analyses comparing Rp conditions of Experiments 3 and 6).

4.5 Experiment 7: Novel Objects II (Different Colour Distractors)

4.5.1 Introduction and Predictions

As with Experiment 6, the purpose of Experiment 7 was to ensure that the significant RIF for Rp-Colour novel objects observed in Experiment 5 was not simply a methodological artefact related to the nature of the distractors. Experiment 7 was a replication of Experiment 5 with the exception that now distractor objects shared the same part shape and part configuration as their respective targets, but differed from their respective targets in terms of colour.

4.5.2 Method

Participants

Fifty-six Swansea University students (15 males and 41 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 50 ($M = 21$, $SD = 4.54$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Stimuli and Apparatus

The stimuli and apparatus used was exactly the same as in Experiment 5, except for the distractors. The new distractors shared the same shape (part shape and overall configuration) as the targets but differed in terms of colour (Figure 7a).

Design and Procedure

As in Experiment 5 there were two consecutive study phases. All other aspects of the Design and Procedure were the same as in Experiments 4-6.

Figure 7a: Target and distractor objects used as stimuli in Experiment 7.

4.5.3 Experiment 7: Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVA. The mixed model ANOVA showed a significant main effect of Item Type (see Table 6a), and a significant main effect of Category Practiced with significantly higher accuracy in the Probes and Tubes category.

Table 7 shows the mean *A'* scores for the Experimental and Control Group participants, as well as within- and between-participant RIF and facilitation (rows titled 'Within' and 'Between' respectively) in Experiment 7.

Figure 7b shows the mean *A'* per Rp condition for the Experimental Group. Figure 7c shows the mean *A'* in the Experimental and Control Groups per Rp condition.

RIF. There was significant within-participant RIF for Rp-Shape and Rp-Neither objects, and between-participant RIF for Rp-Colour and Rp-Neither objects. There was no significant difference between Rp-Colour and Rp-Shape objects. There was no within- or between-participant RIF for the Rp-Both objects.

Facilitation. There was no within- or between-participants facilitation.

Table 7: Experimental and Control Group mean, standard deviation, and t-test statistics for *A'* from the Experiment 7 (Novel objects) Test Phase. *A'* scores are presented by Item Type only collapsed across Category Practiced and Key Response.

		A' scores											
	Statistic	Nrp	Rp+	Rp- Colour	Rp- Shape	Rp- Both	Rp- Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Experimental Group	*M*	0.76	0.81	0.71	0.63	0.73	0.68						
	SD	*(0.10)*	*(0.18)*	*(0.20)*	*(0.20)*	*(0.14)*	*(0.19)*						
Control Group	*M*		0.78	0.80	0.72	0.80	0.77						
	SD		*(0.10)*	*(0.10)*	*(0.18)*	*(0.15)*	*(0.12)*						
Within comparisons	*t(27)=*		1.82	1.62	3.11	0.77	2.92	1.50	0.71	0.75	2.29	0.88	1.49
	p=		*ns* ^{f}	*ns*	.004*	*ns*	.007*	*ns*	*ns*	*ns*	.03*	*ns*	*ns*
Between comparisons	*t(54)=*	2.42	0.72	2.15	1.67	1.57	2.25						
	p=	.02*$^{\Delta}$	*ns*	.04*	*ns*	*ns*	.03*						

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group *A'* (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

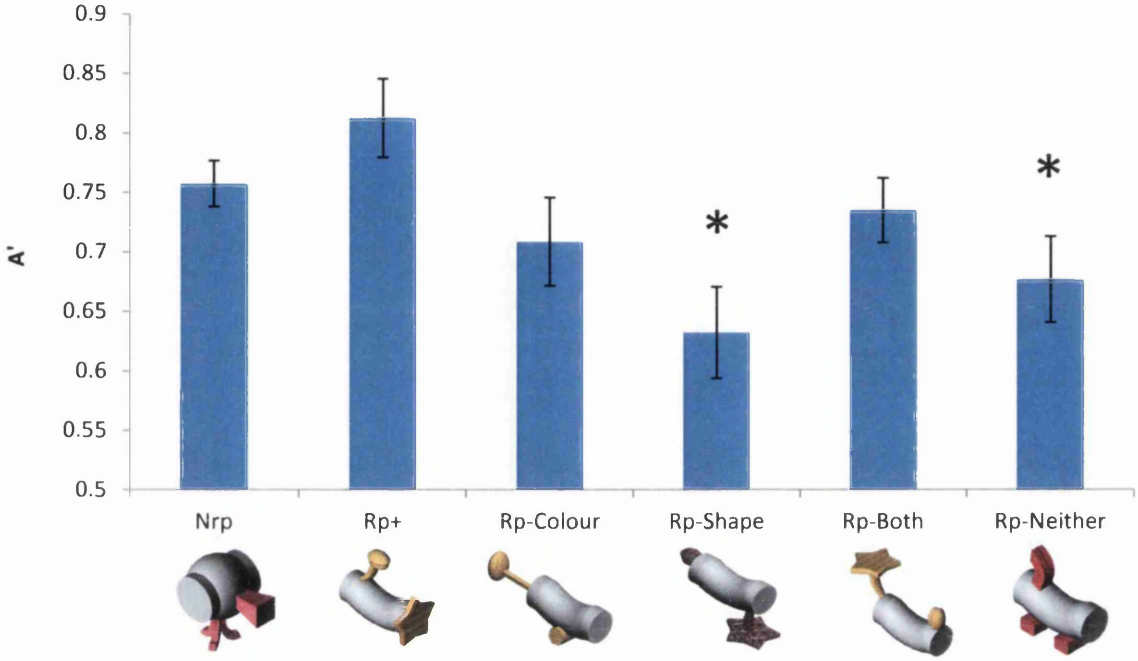

Figure 7b: Mean *A'* for each Rp condition in the Experimental Group in Experiment 7. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF). Error bars indicate standard error of the mean.

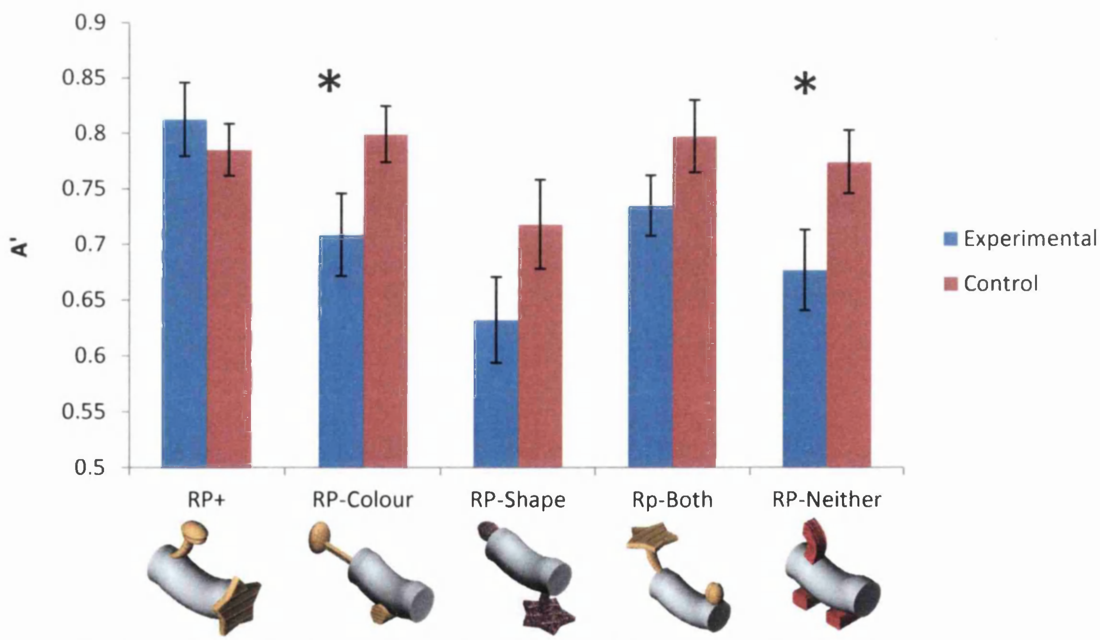

Figure 7c: Mean *A'* in the Experimental and Control Groups per Rp condition in Experiment 7. Asterisks indicate a significant difference between the Groups (between-participant RIF). Error bars indicate standard error of the mean.

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Control Group *A'* was significantly higher than Experimental Group Nrp *A'* (Table 7), suggesting potential cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA. The repeated-measures ANOVA on the Control Group showed a significant main effect of Item Type and a significant Item Type by Category interaction (Appendix A - Table 7e). Within the Ballerinas and Mowers category paired samples t-tests revealed no significant differences in discriminability. For the Probes and Tubes category there was significantly higher discriminability for Rp-Both objects compared to Rp-Shape objects (Appendix A - Table 7f).

Collapsed across Category (and following Bonferroni corrections), there were no significant differences in discriminability (Appendix A – Table 7f).

4.5.4 Comparison between Experiments 5 and 7

A mixed model ANOVA carried out on RIF magnitude with Experiment (5 vs. 7) as the between-participants factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both and Rp-Neither) as the within-participants factor, revealed no significant effects, suggesting that the change in distractors did not influence the magnitude of RIF overall.

Independent-samples t-tests to compare the Nrp *A'* between Experiments 5 and 7, showed significantly lower *A'* in the Nrp condition in Experiment 7, $t\,(54) = 2.10$, $p = 0.04$, suggesting that Experimental Group participants may have found the task in Experiment 7 more difficult than Experiment 5. However, there was no difference in mean *A'* between the Control Groups of Experiments 5 and 7, $t\,(54) = 0.37$, $p > .05$.

4.5.5 Experiment 7: Discussion

The results of Experiment 7 revealed significant between-participant RIF (and a trend but non-significant within-participant RIF) for Rp-Colour objects, despite the change in the nature of the distractors. Furthermore, the magnitude of within-participant RIF did not differ between Experiments 5 and 7. As with Experiment 6, this finding disconfirms the possibility that the significant RIF for Rp-Colour objects in Experiments 1-5 was a methodological artefact related to the nature of the distractors.

One explanation for the lack of within-participant RIF in the Rp-Colour condition may be the particularly low Nrp accuracy in Experiment 7, which combined with the lack of difference in RIF for Rp-Colour objects between Experiments 5 and 7, suggests that RIF was underestimated in the within-participant comparison of Experiment 7. Overall, therefore, Experiment 7 results have shown that the significant RIF for Rp-Colour novel objects was not simply a methodological artefact, but reflects reduced memory arising from the competition of objects sharing the same colour as the practiced objects.

There was also significant RIF for Rp-Shape objects, replicating the same finding in Experiment 5 –and in Experiments 4 and 6 which used familiar objects. Finding RIF for Rp-Shape novel objects suggests that those objects competed for retrieval during recognition practice on the basis of sharing part shape alone (without sharing part configuration).This finding supports previous evidence that part shape and part configuration are two independently represented properties of object shape (e.g., Arguin & Saumier, 2004).

With regards to Rp+ objects, although there was a trend for higher accuracy in the Rp+ condition compared to the Nrp condition, Experiment 7 was the first (apart from Experiment 1, where the same distractors for Rp+ objects were used during the practice and test phases) to show a complete lack of significant facilitation for practiced objects. Previous evidence has shown that RIF can occur without the facilitation of practiced objects (e.g., Tempel & Frings, 2013). However, an explanation as to why there was no significant facilitation for the Rp+ objects could be that participants did not learn the objects during the recognition practice phase. In fact, *A'* scores during the recognition practice phase were the lowest in Experiment 7 out of all the experiments, and a direct comparison of recognition practice scores between Experiments 5 (Novel objects) and 7 revealed significantly lower recognition in terms of *A'* in the recognition practice phase for Experiment 7 compared to Experiment 5, t (52) = 1.99, p = .05. If participants had not learned the target objects during the practice phase then it is likely that their memory for those objects would not have been enhanced during the test phase.

Finally, in Experiment 7, overall discriminability between the Item Types in the Control Group did not differ, thus confirming that the observed differences between Item Types in the Experimental Group were due to the recognition practice manipulation. However, as suggested in Experiment 6, there remains the possibility that the change in the distractors may have subsequently changed the overall baseline discriminability of the critical Item Types (Rp-Shape and Rp-Colour).

4.6 The Issue of Distractors

The different types of distractors had little (in the case of Rp-Shape) to no (in the case of Rp-Colour) impact on the presence of RIF in the critical Rp-Shape and Rp-Colour conditions. However, there were differences in the pattern of results in the Rp-Both and Rp-Neither conditions depending on whether the distractors shared the same shape (Experiments 4 and 5) or the same colour (Experiments 6 and 7) as the target objects. These differences across experiments depending on the nature of distractors, raises the question as to whether the observed RIF was a reflection of the *true impairment of memory for targets* or a combination of the nature of target representations being tapped and factors relating to methodology (distractors). Therefore, Experiments 8 and 9 were designed to examine RIF without using distractors at all (neither during the practice nor during the test phases).

Chapter Five

No Distractor Experiments

5.1 Experiment 8: Familiar Objects VI

5.1.1 Introduction and Predictions

Experiment 8 was a replication of Experiment 6, but without any distractors during the practice and test phases of the experiment. This was done in order to measure the pure competition among practiced and unpracticed studied objects, without any potential complications from the presence of distractors. This was a bold move, because during the test phase it would be possible for participants to be correct 100% of the time by simply pressing the 'Yes' key to all objects. However, if the memory of the Rp- objects is truly impaired following re-presentation of the Rp+ objects during the practice phase, then the pattern of results would be the same as in Experiment 6 – that is, significant RIF for Rp-Shape, Rp-Colour and Rp- Both objects. This would suggest that the pattern of results obtained in Experiment 6 was not an artefact of the distractors, but reflected the memory impairment of unpracticed objects.

Previous studies have observed memory impairment for target items at the test phase without using any distractors (e.g., Cox & Dobbins, 2011; Ley & Long, 1987, 1988; McKelvie, 1993; Wallace, 1978, 1982; Wallace, Sawyer, & Robertson, 1978). Not only have these distractor-free tasks been successful in measuring impairment for target items, but they also yield similar hit rates for targets items as the standard (target-distractor) recognition tests. Therefore, it seemed plausible that in Experiments 8 and 9, where there were no distractors, a similar pattern of results would emerge as in the previous experiments where distractors were present.

In Experiment 8, the practice phase consisted of presenting the Rp+ objects to participants and asking them to rate them on attractiveness, complexity, and usefulness, as opposed to performing a Yes/No recognition task. The reason for this manipulation was primarily due to the fact that there was a possibility that during the practice phase of the first seven experiments of the current research, where the task was to discriminate between targets and distractors, participants may have reasoned that seeing a particular colour object in any shape other than the one of the Rp+ target, should subsequently be responded to during the test phase as one that had not been previously seen during the study phase. Basing responses on a learning strategy to successfully complete the Yes/No recognition task at practice may have biased responses to certain objects (namely the Rp-Shape or Rp-Colour objects, depending on whether distractors shared shape or colour with targets) during the test phase. It could be argued that as there were no distractor objects presented during the test phase, a similar procedure could have been employed during the practice phase. However, it did not seem feasible to conduct a Yes/No recognition task at practice as all of the objects would be targets, and again it was not practical to utilise a memory retrieval task with pictures of objects.

Re-presenting a subset of studied objects during practice had potential shortfalls. For instance, previous evidence suggests that presentation alone of studied stimuli is not sufficient to induce competition in memory to subsequently produce significant RIF (e.g., Anderson, 2003; Anderson & Bell, 2001; Anderson & Spellman, 1995; Anderson et al., 2000; Bäuml, 2002; Bäuml & Aslan, 2004, Ciranni & Shimamura, 1999; Dobler & Bäuml, 2013; Hanslmayr et al., 2010; Saunders et al., 2009). According to the retrieval specificity assumption of the inhibitory theory of RIF (e.g., Anderson, 2003; Anderson & Spellman, 1995; Storm & Levy, 2012), if a target item is re-presented during practice then no activation or competition of non-target items occurs, therefore, non-practiced items will not receive any inhibition or be susceptible to RIF. Results from previous experiments suggest that RIF can only be caused by inhibitory control mechanisms operating during retrieval practice and not just from the increased competition arising from the strengthening of practiced items (Anderson & Spellman, 1995).

Recent evidence, however, suggests that RIF can emerge with the re-presentation of target items through non-competitive practice (Jonker & MacLeod, 2012; Raaijmakers & Jakab, 2012) and with additional study of target items during the practice phase (e.g., Verde, 2013). Specifically, Verde (2013) highlighted that RIF can emerge under some forms of study practice. He found that the presentation of the Rp+ items through additional study during practice did not lead to RIF, but when participants made category judgements about the Rp+ items, or decide how much they liked the Rp+ items, a significant RIF effect emerged for the Rp- items. This semantic processing of items (as opposed to passively viewing) may be what is required to induce RIF in a non-retrieval/non-recognition task.

In Experiments 8 and 9 of the current thesis, participants engaged in judgement tasks on Rp+ items during the practice phase. Based on previous evidence (e.g., Verde, 2013) it was expected that this type of practice would induce RIF for related unpracticed items. If the pattern of results in the previous experiments – and specifically the significant RIF for Rp-Colour and Rp-Shape objects – was due to the memory impairment of the unpracticed object's representation and not to the nature of the distractors, then the same pattern of results would emerge in Experiments 8 and 9 as in previous experiments.

5.1.2 Method

Participants

Fifty-six Swansea University students (22 males and 34 females), 28 in the Experimental Group (recognition-practice) and 28 in the Control Group (no recognition-practice), were given participant pool credits for their participation. Participants were aged between 18 and 58 (M = 24, SD = 6.71). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The stimuli and apparatus used was exactly the same as in Experiment 4, except that only the studied objects (targets) were used (Figure 8a). Forty objects were used in total.

Design

This was the same as Experiments 4 and 6, except the dependent variable was the test phase hit rate.

Figure 8a: Target objects used as stimuli in Experiment 8.

Procedure

Participants were seated individually in a quiet room approximately 60cm from the computer monitor. Participants in the Experimental Group completed a study phase, three practice phases separated by extra filler tasks and a test phase. Control Group participants completed the study phase, filler tasks and a test phase, thereby lacking the practice phase.

Study phase. The study phase consisted of learning of 40 objects, which appeared in random order. Participants rated each target object once for attractiveness on a scale from 1 (not at all attractive) to 5 (very attractive) by pressing the corresponding number on the computer keypad until all target objects were rated. As in all previous experiments, object category names were never mentioned to participants.

Practice phase. Consistent with most RIF experiments, the Experimental Group participants completed three practice phases (e.g., Anderson et al., 1994). In each practice phase four objects were seen (e.g., 2 Tables and 2 Chairs), with practice phases separated by filler tasks. In each practice phase the same four pre-specified Rp+ targets were presented at screen centre, one at a time and in random order. The Rp+ objects were presented three times during each phase. Therefore, each Rp+ object was presented nine times throughout the practice phase.

In the first practice phase participants were asked to indicate how attractive they thought the object was on a scale of 1 (not at all attractive) to 5 (very attractive). In the second practice phase participants were asked to indicate how useful they thought the object was on a scale of 1 (not at all useful) to 5 (very useful). Finally, in the third practice phase participants were asked to indicate how complex they thought the design of the object was on a scale of 1 (not at all complex) to 5 (very complex). There were no time limits imposed on participants during the practice phases, however, they were encouraged not to spend too much time thinking about each object. Following a response, the screen would automatically move on to display the next object. The practiced categories for half of the participants (Tables and Chairs) were the un-practiced categories for the other half of participants (Lamps and Pots), and vice versa.

Filler tasks. The filler tasks used (for the Experimental and Control Groups) were identical to Experiments 4 and 6.

Test phase. The test phase procedure was identical to Experiments 4 and 6, except there were no distractor objects.

5.1.3 Experiment 8: Results

There was no recognition-practice in Experiments 8 and 9, therefore, data was only analysed for Hit rates in the final test phase. The data analysis procedure for the final test phase was identical to that in Experiments 4-7.

Test phase analysis

Experimental Group Hit rate analysis

The mixed model ANOVA (Table 8a) revealed a significant main effect of Item Type, a significant main effect of Key Response, and a significant Item Type by Category Practiced interaction.

Table 8b shows the mean hit rates for the Experimental and Control Group participants by Category Practiced, as well as within- and between-participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Table 8a: Item Type X Category Practiced X Key Response ANOVA statistics for Experiments 8 (Familiar objects) and 9 (Novel objects).

		Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
	Dependant measure	*F* (5,120)	*MSE*	*F* (1, 24)	*MSE*	*F* (1, 24)	*MSE*	*F* (5,120)	*MSE*	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*
Exp 8	*Hits (%)*	33.94**	438	0.13	1205	7.00*	1205	3.76*	438	0.17	438	0.01	1205	0.28	438
Exp 9	*Hits (%)*	28.49**	335	1.80	888	1.11	888	3.90*	335	1.94	335	0.02	888	1.16	335

*$p<0.05$, **$p<0.001$

Figure 8b shows the mean Hit rate per Rp condition for the Experimental Group. Figure 8c shows the mean Hit rates per Rp condition and per Category Practiced for the Experimental Group. Figure 8d shows the mean Hit rates in the Experimental and Control Groups per Rp condition.

RIF. There was significant within-participant RIF for Rp-Shape and Rp-Colour objects only. There was significant within-participant facilitation for Rp-Neither objects. Comparison amongst the four Rp- conditions revealed significantly lower accuracy for Rp-Shape and Rp-Colour objects compared to Rp-Both and Rp-Neither objects, and significantly lower accuracy for Rp-Both compared to Rp-Neither objects. There was no significant difference between Rp-Shape and Rp-Colour objects. Finally, there was significant between-participant RIF for all four of the Rp- objects.

Given the significant Item Type by Category Practiced interaction, RIF was calculated and reported separately for each category. For the Tables and Chairs category there was significant within-participant RIF for Rp-Colour, Rp-Shape and Rp-Both objects. There was significant within-participant facilitation for Rp-Neither objects. There was significant between-participant RIF for all four Rp- objects. Finally, Experimental Group Rp- objects revealed significantly higher accuracy in hit rates for Rp- Colour and Rp-Both objects compared to Rp-Shape objects, and significantly higher accuracy for Rp-Neither objects compared to Rp-Colour, Rp-Shape, and Rp-Both objects.

For the Lamps and Pots category there was significant within-participant RIF for Rp-Colour and Rp-Shape objects. There was significant between-participant RIF for all the Experimental Rp- objects. Finally, paired-samples t-tests on the Experimental Group Rp- objects revealed no significant difference in hit rates between the Rp- Colour and Rp- Shape objects. Accuracy for Rp-Both and Rp-Neither objects was significantly higher than Rp-Colour and Rp-Shape objects.

Facilitation. For Rp+ objects there was significant within-participant facilitation, but no between-participant facilitation.

Control group Hit rates analyses

Control Group mean Vs. Experimental Group Nrp: Hit rates were significantly higher for the Control Group compared to the Experimental Group Nrp condition (See Table 8b), suggesting potential cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA: The repeated-measures ANOVA on the Control Group Hit rates revealed a significant main effect of Item Type and a significant Item Type by Category interaction (Appendix A – Table 8a). For Tables and Chairs, paired samples t-tests revealed significantly higher hit rates for Rp+ objects compared to Rp-Shape objects, significantly higher hit rates for Rp-Neither objects compared to Rp-Colour, Rp-Shape, and Rp-Both objects, and significantly higher hit rates for Rp-Colour objects compared to Rp-Shape objects. For Lamps and Pots, there was significantly higher hit rates for Rp+, Rp-Both, and Rp-Neither objects compared to Rp-Colour and Rp-Shape objects (Appendix A – Table 8b).

Collapsed across Category, Rp-Neither objects had higher hit rates compared to Rp-Colour, Rp-Shape, and Rp-Both objects. This was expected given that the Rp-Neither objects were distinct from all the other Rp objects. Rp+ hit rates were significantly higher than the Rp-Colour and Rp-Shape conditions. Finally, Rp-Shape objects had significantly lower hit rates than Rp-Colour and Rp-Both objects (Appendix A –Table 8b).

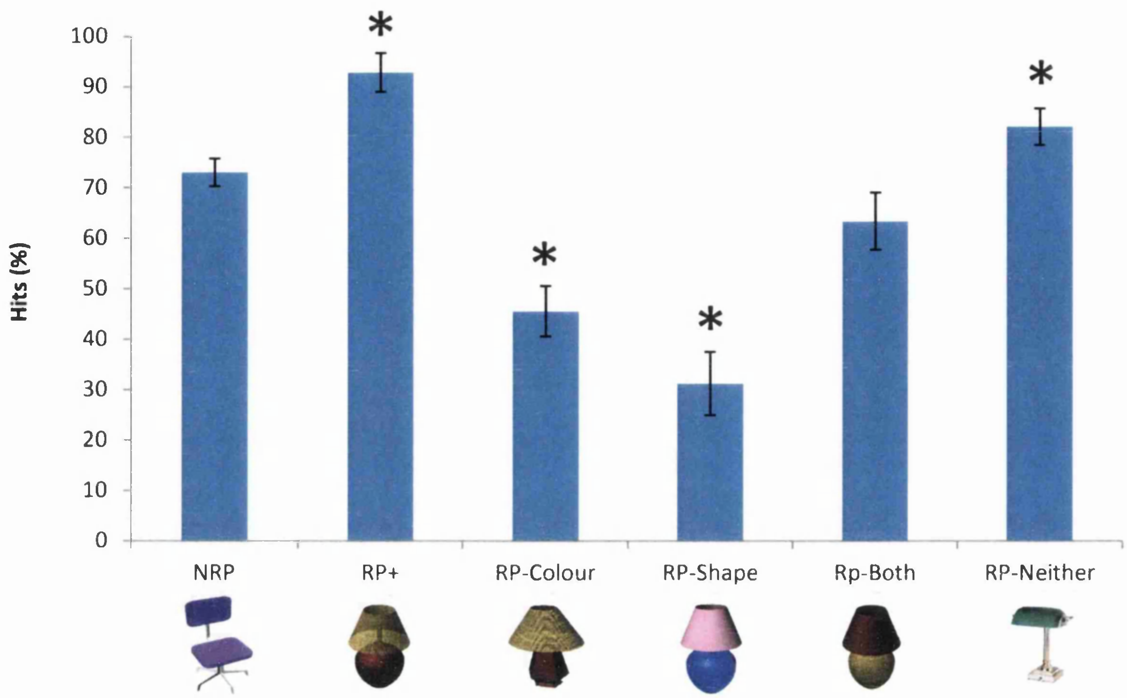

Figure 8b: Mean Hit rate for each Rp condition in the Experimental Group in Experiment 8. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

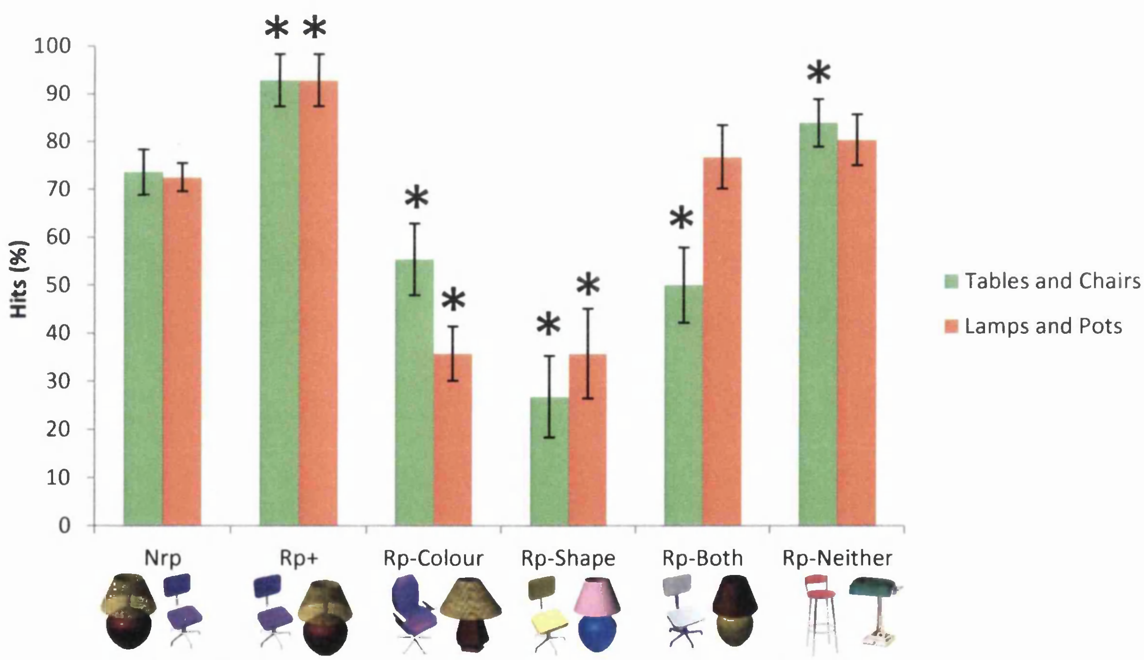

Figure 8c: Mean Hits per Category and Rp condition in the Experimental Group in Experiment 8. Asterisks denote significant difference compared to Nrp (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

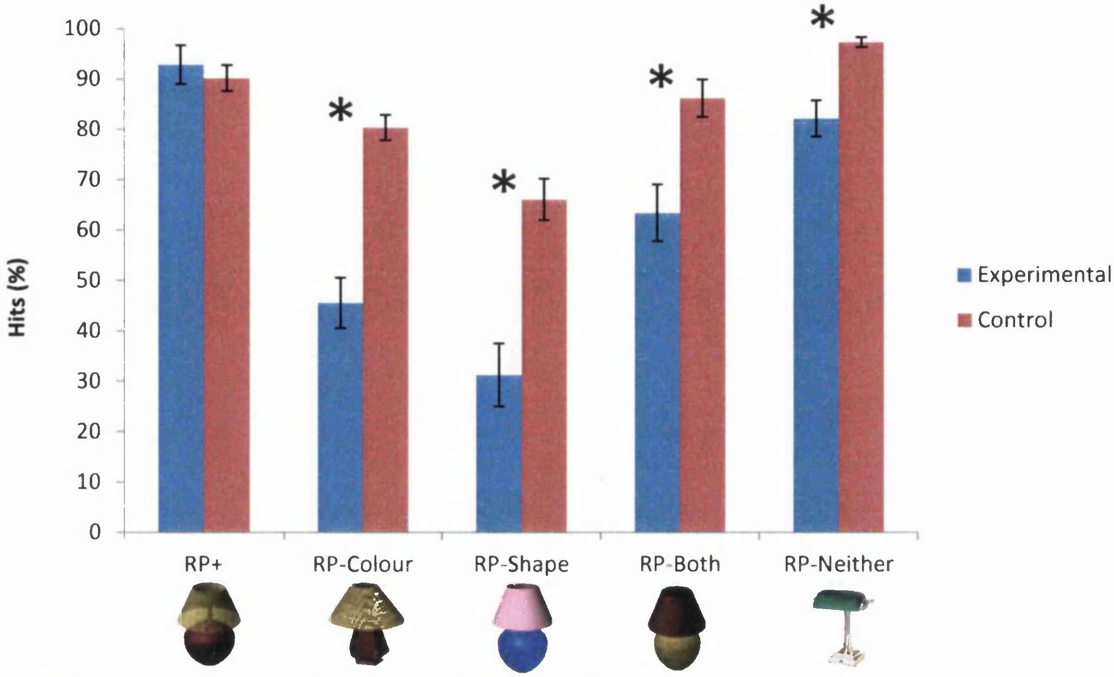

Figure 8d: Mean Hit rates in the Experimental and Control Groups per Rp condition in Experiment 8. Asterisks indicate a significant difference between the Groups (between-participant RIF). Error bars indicate standard error of the mean.

Table 8b: Experimental and Control Group mean, standard deviation, and t-test statistics for Hits (%) from the Experiment 8 Test Phase. Hit rates are presented by Item Type collapsed across Category Practiced and Key Response, as well as by Item Type per Category Practiced collapsed across Key Response.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Total Hits (%)							
Experimental	*M*	73.04	92.86	45.54	31.25	63.39	82.14						
Group	*SD*	*(14.49)*	*(20.25)*	*(26.40)*	*(33.07)*	*(30.03)*	*(19.07)*						
Control	*M*		90.18	80.36	66.07	86.16	97.32						
Group	*SD*		*(13.76)*	*(13.36)*	*(21.75)*	*(19.64)*	*(5.22)*						
Within	$t\ (27)=$		4.24	5.76	7.02	1.65	3.06	1.95	2.42	7.75	5.35	9.47	3.07
comparison	$p=$		.001**[f]	.001**	.001**	*ns*	.005*	*ns*	.02*	.001	.001**	.001**	.005*
Between	$t\ (54)=$	3.19	0.58	6.23	4.66	3.36	4.06						
comparison	$p=$	.002*[Δ]	*ns*	.001**	.001**	.001*	.001**						
						Hits (%) Tables and Chairs							
Experimental	*M*	73.57	92.86	55.36	26.79	50.00	83.93						
Group	*SD*	*(17.70)*	*(20.64)*	*(28.04)*	*(31.72)*	*(29.42)*	*(18.62)*						
Control	*M*		90.18	86.61	66.07	82.14	98.21						
Group	*SD*		*(19.65)*	*(15.93)*	*(27.40)*	*(27.10)*	*(6.56)*						
Within	$t\ (13)=$		4.24	2.45	5.80	2.73	2.68	2.66	0.53	3.89	2.62	7.51	3.65
comparison	$p=$		.001**[f]	.03*	.001**	.02*	.02*[f]	.02*	*ns*	.002*	.02*	.001**	.003*
Between	$t\ (40)=$	3.19	0.41	4.62	4.16	3.52	3.67						
comparison	$p=$	.002*[Δ]	*ns*	.001**	.001**	.001*	.001*						
						Hits (%) Lamps and Pots							
Experimental	*M*	72.50	92.86	35.71	35.71	76.79	80.36						
Group	*SD*	*(11.05)*	*(20.63)*	*(21.29)*	*(34.97)*	*(24.93)*	*(20.05)*						
Control	*M*		90.18	74.11	66.07	90.18	96.43						
Group	*SD*		*(15.72)*	*(20.95)*	*(28.23)*	*(14.17)*	*(8.91)*						
Within	$t\ (13)=$		4.24	7.22	4.16	0.70	1.69	0.00	6.62	8.33	5.34	5.96	0.62
comparison	$p=$		.001**[f]	.001*	.001*	*ns*	*ns*	*ns*	.001**	.001**	.001**	.001**	*ns*

Between comparison	t (40)=	3.19	0.47	5.57	3.03	2.23	3.62
	p=	.002*$^{\Delta}$	*ns*	.001**	.004*	.03*	.001*

*p<0.05, **p<0.001, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Within facilitation for Rp+ objects is collapsed across Category.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group Hit rates. Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

5.1.4 Comparison between Experiments 4 (Different shape distractors) and 8 (No distractors)

Independent samples t-tests on the magnitude of RIF in terms of hit rates for the Rp- conditions between Experiments 4 and 8 revealed no significant differences in the Rp- conditions [Rp-Colour, t (54) = 1.51, $p > 0.05$; Rp-Shape, t (54) = -1.26, $p > 0.05$; Rp-Both, t (54) = 0.49, $p > 0.05$; Rp-Neither, t (54) = 0.04, $p > 0.05$]. There was also no significant difference in Nrp baseline objects, t (54) = 0.82, $p > 0.05$.

5.1.5 Comparison between Experiments 6 (Different colour distractors) and 8 (No distractors)

Independent samples t-tests on the magnitude of RIF in terms of hit rates for the Rp- conditions between Experiments 6 and 8 revealed no significant differences in Rp-Colour, t (54) = -1.62, $p > 0.05$; Rp-Shape, t (54) = 0.64, $p > 0.05$; or Rp-Both, t (54) = 1.35, $p > 0.05$. There was a significant difference between the Rp-Neither objects of Experiments 6 and 8, t (54) = 6.86, $p = 0.0001$, with significantly more RIF for Rp-Neither objects in Experiment 6. This difference was attributed to the different Rp-Neither objects used in the two Experiments (See Figures 6a and 8a). There was no significant difference in Nrp baseline objects, t (54) = -0.58, $p > 0.05$.

5.1.6 Experiment 8: Discussion

The aim of Experiment 8 was to examine whether RIF shown in previous experiments of the current thesis was a reflection of the true impairment of memory for targets or whether it was an artefact of factors relating to experimental methodology. Specifically, it was postulated that the distractors themselves may have inadvertedly contributed to the pattern of results in the previous experiments. To address this concern, Experiment 8 used an engaging re-study task at practice (e.g., Verde, 2013) and a Yes/No recognition task without distractors at test; a methodology previously employed by others successfully (e.g., Cox & Dobbins, 2011).

The main findings of Experiment 8 were the significant facilitation for Rp+ objects and the significant RIF for Rp-Shape and Rp-Colour objects. These findings are very important for two reasons. Firstly, the task during the practice phase was to rate the Rp+ objects on various attributes (such as complexity) and not to engage in active retrieval or recognition. The fact that there was significant facilitation for Rp+ objects, and significant RIF for Rp- objects from the exposure of the objects during the practice phase suggests that engaging participants in an active task during practice that does not require retrieval is sufficient to induce competition in memory to subsequently produce significant RIF. This finding appears to contradict the retrieval specificity assumption of the inhibitory theory of RIF, according to which RIF is induced only by active retrieval of an item during the practice phase (e.g., Anderson & Bell, 2001; Bäuml & Aslan, 2004; Ciranni & Shimamura, 1999; Hanslmayr et al., 2010; Johansson et al., 2007). Instead, the significant RIF in Experiment 8 is in accordance with previous evidence showing significant RIF in non-competitive re-presentation (e.g., Raaijmakers & Jakab, 2012; Verde, 2013). The findings from Experiment 8 are critical for the RIF literature as they provide new evidence regarding the conditions with which competition in memory may arise. It may be the case that the RIF effect extends further than previously thought, as it may even operate implicitly in memory without active retrieval (this idea will be further discussed in the General Discussion).

Second, in Experiment 8 only target objects were shown during the test phase Yes/No recognition task. Participants should have responded 'Yes' to every object presented in the test phase as they were all objects presented in the study phase and no distractor objects were shown.

However, the fact that participants responded 'No' to objects sharing shape, colour, or both shape and colour with practiced objects which resulted in significant RIF, demonstrates that memory for those objects was truly diminished due to competition at practice and not due to any strategic responding or distractor interference. The results from Experiment 8 add to existing evidence showing memory impairment even with distractor-free recognition tasks (e.g., Cox & Dobbins, 2011; Ley & Long, 1987, 1988; McKelvie, 1993; Wallace, 1978, 1982; Wallace et al., 1978). Comparisons between Experiment 8 and the previous familiar object experiments of the current thesis that included distractors during the test phase of the Yes/No recognition task showed that the absence of distractors did not alter the pattern of results for the critical Rp-Colour and Rp-Shape conditions – RIF was significant regardless of whether memory for targets was tested against distractors sharing the same colour (Experiment 4), the same shape (Experiment 6), or against no distractors at all. The similarity in the pattern of results for the critical conditions tested here (Rp-Colour and Rp-Shape) despite the lack of distractors makes the modified paradigm introduced here much more usable. That is, eliminating the need of distractors in finding RIF using an Old/New recognition task eliminates methodological considerations for the design of appropriate distractors. The comparisons also corroborated with previous research that has found similar recognition rates when distractor-present and distractor-free tasks have been compared to one another (e.g., Cox & Dobbins, 2011; McKelvie, 1993; Wallace, 1982; Wallace et al., 1978).

Finally, as in previous experiments, the most likely cause of the high accuracy for Rp+ objects compared to Rp-Colour and Rp-Shape objects in the Control Group, is that the addition of the Rp-Both condition boosted the encoding and subsequently the memory of the Rp+ items, since the objects shared the same features (shape and colour). This possibility is supported by comparisons between Experiment 3 (where there was no Rp-Both condition) and Experiment 8 (where the Rp-Both was included) on Rp+, Rp-Colour, and Rp-Shape *A'* scores. Those between-experiment comparisons showed that Rp+ *A'* scores were higher (marginally significant) in Experiment 8 than in Experiment 3 (see Appendix A – Table 8c).

With regard to the lower accuracy for Rp-Shape objects compared to Rp+, Rp-Colour and Rp-Both objects in the Control Group, it may have been the case that the Rp-Shape objects were less well remembered due to the fact that they also shared the exact same shape as the Rp+ and Rp-Both objects, however, due to their difference in colour, participants may have reasoned that they needed to respond 'No' to some objects (as this was given as an option in the recognition task), therefore, the Rp-Shape objects may have been the likeliest of candidates. However, despite the difference in Control Group hit rates between Rp-Colour and Rp-Shape objects, there was no difference between the two conditions in terms of RIF in the Experimental Group. Therefore, the pattern of differences across the Rp-Colour and Rp-Shape conditions in the Control Group did not predict the pattern of differences in the Experimental Group.

5.2 Experiment 9: Novel Objects III

5.2.1 Introduction and Predictions

As With Experiment 8, the purpose of Experiment 9 was to measure the pure competition between target objects, without the complications from distractors, but this time using novel objects.

5.2.2 Method

Participants

Fifty-six Swansea University students (20 males and 36 females), 28 in the Experimental Group and 28 in the Control Group were given participant pool credits for their participation. They were aged between 18 and 58 ($M = 24$, $SD = 6.71$). All reported normal or corrected-to-normal vision and normal colour vision. All were native English speakers and naive to the purpose of the experiment.

Apparatus and Stimuli

The stimuli and apparatus used was exactly the same as in Experiment 5, except that only the studied objects (targets) were used (Figure 9a). Forty objects were used in total.

Design and Procedure

These were the same as Experiment 8. The only exception was that there were two consecutive study phases.

Figure 9a: Target objects used as stimuli in Experiment 9.

5.2.3 Experiment 9: Results

Test phase analysis

Experimental Group Hit rates analysis

The mixed model ANOVA (Table 8a) revealed a significant main effect of Item Type, and a significant Item Type by Category Practiced interaction.

Table 9 shows the mean hit rates for the Experimental and Control Group participants by Category Practiced, as well as within- and between-participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Figure 9b shows the mean hit rate per Rp condition for the Experimental Group. Figure 9c shows the mean hit rates per Rp condition and per Category Practiced for the Experimental Group. Figure 9d shows the mean hit rates in the Experimental and Control Groups per Rp condition.

RIF. There was significant within- and between- participant RIF for Rp-Shape, Rp-Colour, and Rp-Both objects. There was no significant within- or between- participant RIF for Rp-Neither objects. Comparison amongst the four Rp- conditions revealed significantly higher accuracy for Rp-Neither objects compared to Rp-Shape, Rp-Colour, and Rp-Both objects. There were no other significant differences between the Rp- conditions.

Given the significant Item Type by Category Practiced interaction, RIF (and facilitation) was calculated and reported separately for each category. For the Ballerinas and Mowers category there was significant within- and between- participant RIF for Rp-Shape and Rp-Both objects. There was no significant within- or between- participant RIF for Rp-Colour and Rp-Neither objects. Finally, paired-samples t-tests on the Experimental Group Rp- objects revealed significantly higher accuracy in hit rates for Rp- Colour objects compared to Rp- Shape and Rp-Both objects, and significantly higher hit rates for Rp-Neither objects compared to Rp-Both objects.

For the Probes and Tubes category there was significant within- and between- participant RIF for Rp-Colour and Rp-Both objects. There was only significant within-participant RIF for Rp-Shape objects. There was no significant within- or between- participant RIF for Rp-Neither objects. Finally, paired-samples t-tests on the Experimental Group Rp- objects only revealed significantly higher accuracy for Rp-Neither objects compared to the Rp- Colour, Rp- Shape, and Rp-Both objects.

Facilitation. There was significant within- and between- participant facilitation for Rp+ objects.

Control group Hit rates analyses

Control Group mean Vs. Experimental Group Nrp: There was no significant difference between Control Group hit rates and the Experimental Group Nrp hit rates (See Table 9), suggesting no cross-category RIF for the Nrp objects in the Experimental Group.

Repeated-measures ANOVA: The repeated-measures ANOVA on the Control Group hit rates revealed a significant main effect Item Type only (Appendix A – Table 9a), with significantly higher hit rates for Rp+ objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects, and significantly higher hit rates for Rp-Both objects compared to Rp-Shape and Rp-Neither objects (Appendix A – Table 9b).

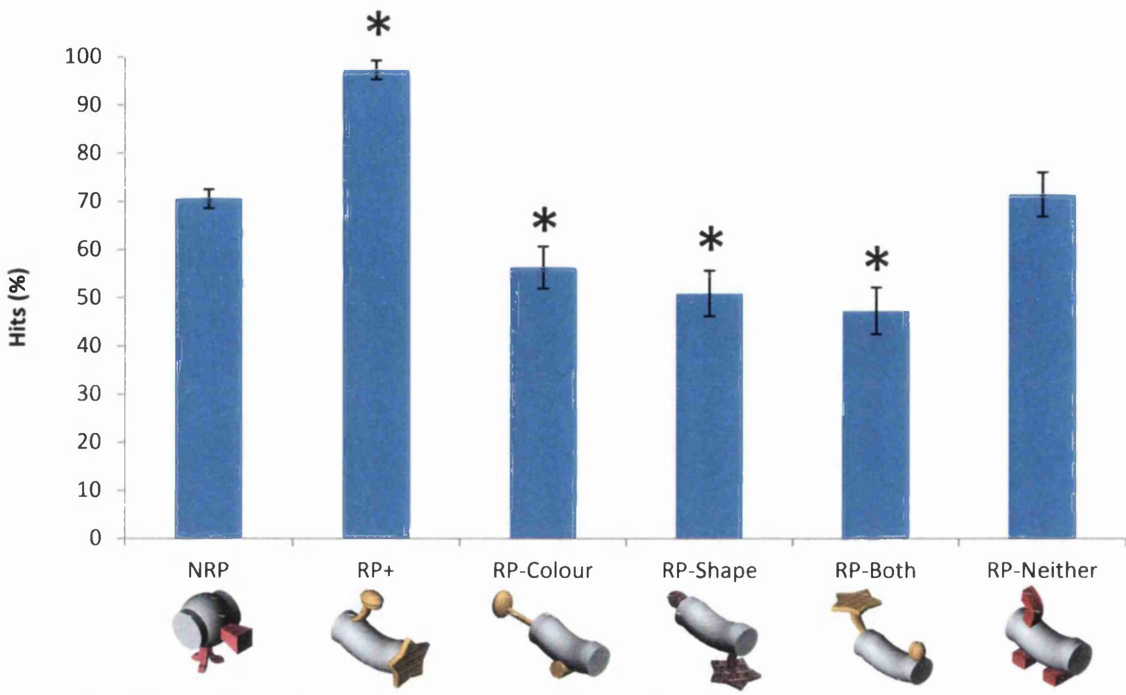

Figure 9b: Mean Hit rate for each Rp condition in the Experimental Group in Experiment 9. Asterisks denote significant difference compared to the Nrp condition (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

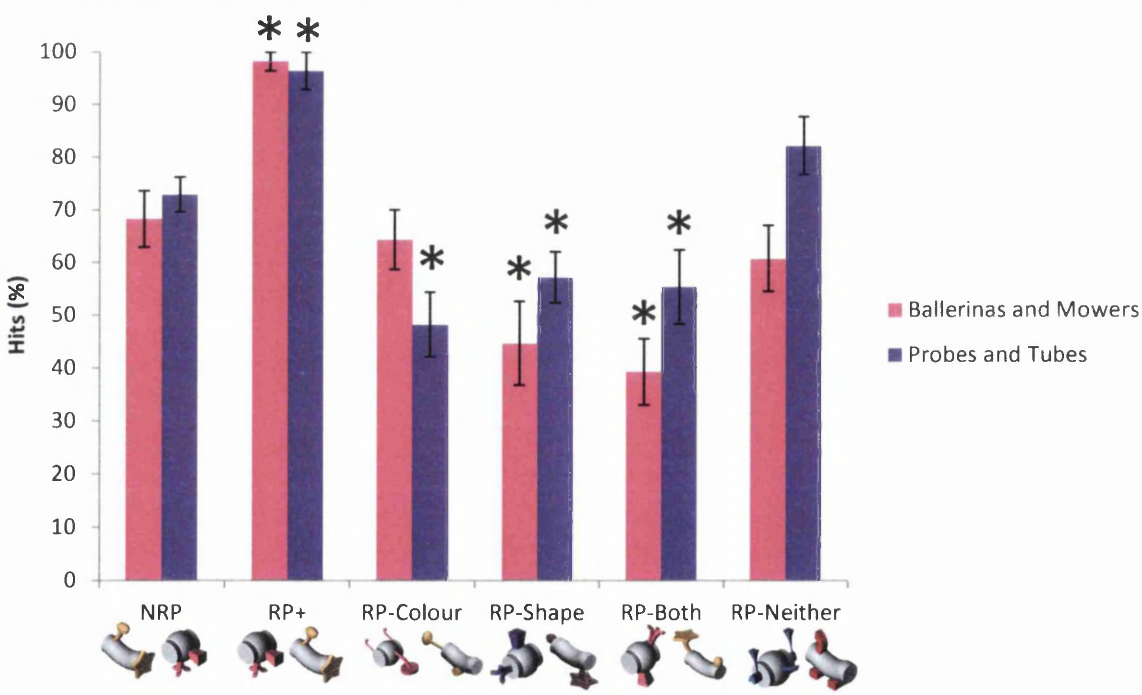

Figure 9c: Mean Hits per Category and Rp condition in the Experimental Group in Experiment 9. Asterisks denote significant difference compared to Nrp (within-participant RIF and facilitation). Error bars indicate standard error of the mean.

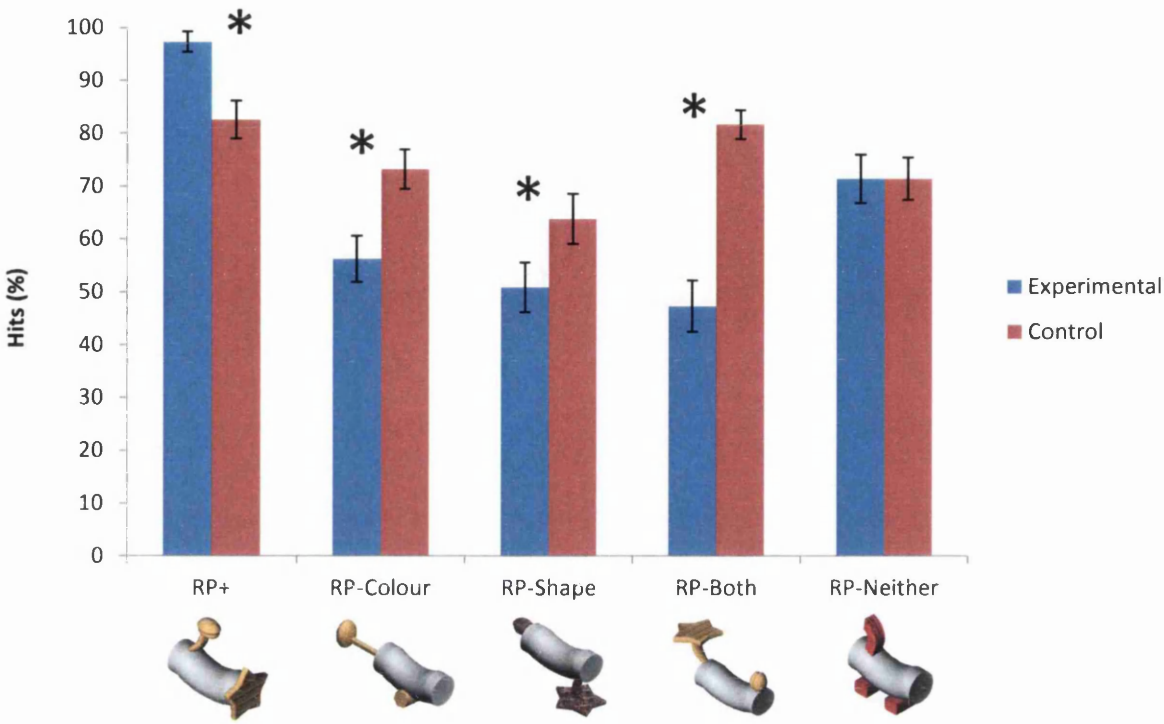

Figure 9d: Mean Hit rates in the Experimental and Control Groups per Rp condition in Experiment 9. Asterisks indicate a significant difference between the Groups (between-participant RIF and facilitation). Error bars indicate standard error of the mean.

Table 9: Experimental and Control Group mean, standard deviation, and t-test statistics for Hits (%) from the Experiment 9 Test Phase. Hit rates are presented by Item Type collapsed across Category Practiced and Key Response, as well as by Item Type per Category Practiced collapsed across Key Response.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Total Hits (%)													
Experimental	*M*	70.54	97.32	56.25	50.89	47.32	71.43						
Group	*SD*	*(16.52)*	*(10.41)*	*(23.20)*	*(24.98)*	*(25.77)*	*(24.26)*						
Control	*M*		82.59	73.21	63.84	81.70	71.43						
Group	*SD*		*(19.05)*	*(19.75)*	*(25.08)*	*(14.63)*	*(21.21)*						
Within	t (27)=		8.83	3.17	4.74	4.76	0.22	0.83	1.36	2.56	0.58	4.00	3.79
comparison	p=		.001**[f]	.004*	.001**	.001**	*ns*	*ns*	*ns*	.02*	*ns*	.001**	.001*
Between	t (54)=	0.94^{Δ}	3.59	2.95	1.94	6.14	0.00						
comparison	p=	*ns*	.001*	.005*	.05	.001**	*ns*						
Hits (%) Ballerinas and Mowers													
Experimental	*M*	68.21	98.21	64.29	44.64	39.29	60.71						
Group	*SD*	*(20.06)*	*(6.68)*	*(21.29)*	*(29.71)*	*(23.44)*	*(23.44)*						
Control	*M*		76.79	75.89	65.18	77.68	69.64						
Group	*SD*		*(25.39)*	*(20.95)*	*(28.33)*	*(22.91)*	*(27.52)*						
Within	t (13)=		8.83	0.74	4.12	4.39	1.69	2.24	3.89	0.52	0.68	1.98	2.75
comparison	p=		.001**[f]	*ns*	.001*	.001*	*ns*	.04*	.002*	*ns*	*ns*	*ns*	.02*
Between	t (40)=	0.94^{Δ}	3.09	1.68	2.18	5.08	1.04						
comparison	p=	*ns*	.004*	*ns*	.04*	.001**	*ns*						
Hits (%) Probes and Tubes													
Experimental	*M*	72.86	96.43	48.21	57.14	55.36	82.14						
Group	*SD*	*(12.36)*	*(13.36)*	*(22.92)*	*(18.16)*	*(26.27)*	*(20.64)*						
Control	*M*		88.39	70.54	62.50	85.71	73.21						
Group	*SD*		*(18.61)*	*(27.26)*	*(30.05)*	*(20.89)*	*(26.29)*						
Within	t (13)=		8.83	3.93	2.61	2.47	1.54	1.10	0.72	5.04	0.19	3.89	2.60
comparison	p=		.001**[f]	.002*	.02*	.03*	*ns*	*ns*	*ns*	.001**	*ns*	.002*	.02*

Between comparison	*t (40)*=	0.94^{Δ}	1.44	2.63	0.61	4.07	1.11
	p=	*ns*	*ns*	.01*	*ns*	.001**	*ns*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Within facilitation for Rp+ objects is collapsed across Category.

Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental Group Hit rates. Rp+ = Practiced objects from the practiced category. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object.

5.2.4 Comparison between Experiments 5 (Different shape distractors) and 9 (No distractors)

Independent samples t-tests on the magnitude of RIF in terms of hit rates for the Rp- conditions between Experiments 5 and 9 revealed no significant differences for the Rp-Colour, t (54) = -0.51, $p > 0.05$; Rp-Shape, t (54) = -0.66, $p > 0.05$; or Rp-Neither, t (54) = 0.24, $p > 0.05$ objects. There was a significant difference between the Rp-Both objects, t (54) = -2.85, $p = 0.006$, with greater RIF for Rp-Both objects in Experiment 9. This difference was attributed to the absence of distractors in Experiment 9, which meant Rp-Both objects were able to compete with Rp+ objects without the interference of the Rp-Both distractors that shared colour with them and may have potentially provided facilitation for them in Experiment 5 (See Figures 5a and 9a). There was no significant difference between Nrp baseline objects, t (54) = -0.49, $p > 0.05$.

5.2.5 Comparison between Experiments 7 (Different colour distractors) and 9 (No distractors)

Independent samples t-tests on the magnitude of RIF in terms of hit rates for the Rp- conditions between Experiments 7 and 9 revealed no significant differences for the Rp-Colour, t (54) = -1.42, $p > 0.05$; or Rp-Shape, t (54) = 0.44, $p > 0.05$ objects. The lack of difference in RIF levels of Rp-Colour and Rp-Shape objects between Experiments 7 and 9 in terms of hit rates provides further support that the lack of within-participant RIF for Rp-Colour objects in Experiment 7 was most likely driven by the distractors used and their interference in reducing competition between target objects.

There was a significant difference between Experiments 7 and 9 for Rp-Both objects, t (54) = -2.58, $p = 0.013$, with greater RIF in Experiment 9. Again, this difference was attributed to the absence of distractors in Experiment 9, which meant Rp-Both objects were able to compete with Rp+ objects without the interference of the Rp-Both distractors that shared shape with them and may have potentially provided facilitation for them in Experiment 7 (See Figures 7a and 9a). There was also a significant difference between the Rp-Neither objects of Experiments 7 and 9, t (54) = 2.50, p = 0.016, with significantly more RIF for Rp-Neither objects in Experiment 7. This difference was again attributed to the absence of distractors in Experiment 9, which meant Rp-Neither objects were able to compete with Rp+ objects on the basis of category without the interference of distractors. However, it is important to note here that there was no significant RIF for Rp-Neither objects in Experiment 7 or 9, therefore, the difference can only be applied to the level of accuracy. There was no significant difference in Nrp baseline objects, t (54) = -1.43, $p > 0.05$.

Overall, the lack of difference in accuracy for Nrp objects and the lack of difference in RIF magnitude for the critical Rp-Colour and Rp-Shape objects between Experiments 5 and 9, and between 7 and 9, suggests that despite the absence of distractors in Experiment 9, the modified paradigm used here remains valid as a means of assessing the contribution of shape and colour information in object recognition.

5.2.6 Experiment 9: Discussion

The aim of Experiment 9 was to examine whether RIF shown in previous novel objects experiments of the current thesis was a reflection of the true impairment of memory for targets or factors relating to experimental methodology. The results of Experiment 9 revealed significant facilitation for practiced objects, suggesting that their repeated presentation during practice led to better memory. Second, and most importantly, RIF was significant for Rp-Shape and Rp-Colour objects. These findings provide evidence to suggest that colour is represented in memory for novel objects. As with Experiment 8, finding significant RIF with the engaging re-presentation of Rp+ targets during the practice phase, and with a distractor-free Yes/No recognition task during the text phase, is of particular importance. The task in the test phase was such that participants would have achieved perfect performance if they responded 'Yes' in every trial. The fact that they did not suggests that the memory for the unpractised objects was indeed affected by competition during the practice phase.

Third, there was significant RIF for Rp-Both objects. The level of RIF for Rp-Both objects was similar to that of the Rp-Shape and Rp-Colour objects. This suggests that competition of an item sharing both visual properties does not induce greater RIF than either property on their own, which would suggest that the properties are able to compete independently during practice. Furthermore, the fact that RIF for Rp-Both was significant in Experiments 8 and 9 is interesting considering the design of the Rp-Both objects differed between these two experiments. For the familiar objects, the Rp-Both objects shared both parts and configuration of parts with the practiced objects. This was necessary in order for the objects to be recognisable. For the novel objects, Rp-Both objects shared the same parts but not the same spatial configuration of parts as the practised objects. This suggests competition can arise not only at global level representation, but also at the level of local part shape (e.g., Biederman, 1987; Arguin & Saumier, 2004).

With regards to Rp-Neither objects, again there was no significant RIF. This would suggest that sharing category with practiced objects does not induce competition. It may be the case that for novel objects, where there are no pre-existing verbal category labels associated with the objects, the visual representation of the central component of the objects (which aimed to denote which categories the objects belonged to) was not sufficient in producing competition as would a verbal/semantic representation of the objects, which was the case for familiar objects.

Unlike Experiment 8, where there was significant facilitation for Rp-Neither objects, in Experiment 9 there was neither RIF nor facilitation. The difference in accuracy for Rp-Neither objects between Experiments 8 and 9 could be attributed to a difference in the design of the objects. Rp-Neither objects in Experiment 8 (Familiar objects) were very distinct, therefore, instead of receiving inhibition due to competition from category sharing they were facilitated. In contrast the Rp-Neither objects in Experiment 9 (Novel objects) were not distinct enough from the other Rp- objects to elicit facilitation, and neither were they strong enough to compete with practiced objects on the basis of category sharing (see General Discussion for related suggestion regarding future research).

Finally, discriminability in the Control Group of Experiment 9 was lowest in the critical Rp-Colour and Rp-Shape conditions, relative to the Rp+ and Rp-Both (marginal difference between Rp-Both and Rp-Colour) conditions. As suggested in previous experiments (Experiments 4 and 6), this pattern was most likely driven by the addition of the Rp-Both objects, which boosted the encoding and subsequent memory of the Rp+ and Rp-Both objects, since the objects in those two conditions shared the same features (shape and colour). Given that there was no novel object experiment that did not include an Rp-Both condition, it was not possible to compare Rp+, Rp-Colour, and Rp-Shape conditions between experiments that did and did not include an Rp-Both condition.

Chapter Six

General Discussion and Conclusions

Studies examining recognition memory for objects (e.g., Cave et al., 1996; Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986; Vernon & Lloyd-Jones, 2003; Zimmer & Steiner, 2003) have shown that colour is a represented feature in object representations (e.g., for geometric shapes, familiar objects, or artificial objects). That is, when objects are studied in a certain colour or colour combinations, recognition memory is better when they appear in their studied colour(s) compared to when they appear in new colour(s) at test.

The positive evidence from previous recognition memory studies in favour of the representation of colour (e.g., Hanna & Remington, 1996; Nicholson & Humphrey, 2003; Stefurak & Boynton, 1986) is often complicated with effects of encoding specificity: memory performance was better when objects remained in the same colour between study and test compared to when objects changed colour from study to test. The difference in performance between the two conditions was either likely to be due to the changes in colour specifically, or simply to changes in context between encoding and retrieval. From the two studies that have attempted to distinguish the two, Hanna and Remington (1996) have found that encoding specificity effects interact with effects of colour change from study to test; while Nicholson and Humphrey (2003) have found evidence against an encoding specificity explanation of their data only in response latencies, but not in accuracy.

To examine the representation of colour and shape in object memory, the current thesis modified the retrieval-practice paradigm (Anderson et al., 1994). Participants studied a set of objects by rating them for attractiveness. Then, during the practice phase participants carried out an Old/New recognition task (Experiments 1-7) or re-studied (Experiments 8 & 9) a subset of the studied objects. Finally in the test phase, an Old/New recognition task (Experiments 1-7: with distractors; Experiments 8 & 9: with targets only) was carried out on all of the objects from the study phase. The objects remained the same between the study and final test phase, thus allowing the examination of the contribution of colour to object memory while minimizing possible encoding specificity effects. If only shape information is represented in object memory, then it was predicted that objects sharing shape only with the practiced objects would compete during practice and be susceptible to RIF, but objects sharing colour only would not. On the other hand, if colour information is represented in object memory then it too would be susceptible to RIF. Discovering RIF for objects sharing shape alone and sharing colour alone with the practiced objects, would suggest that the two properties can contribute independently of each to competition effects in memory.

Across nine experiments the main findings were that the use of a recognition task and a re-presentation task at the practice phase was sufficient to induce RIF effects, and that both colour and shape information independently led to a significant RIF effects. Overall the findings suggest that object colour and shape are explicit in the representations mediating object memory, and that RIF was sensitive to those representations.

Table 10: Summary of key findings from the 9 thesis experiments.

	Interaction	Rp+ Facilitation	Rp-Colour RIF	Rp-Shape RIF	Rp-Both RIF	Rp-Neither RIF
Exp. 1	No	No	Between	Between	N/A	Between
Exp. 2	Yes	Between	Within	Within	N/A	No
Exp. 3	No	Within + Between	Within	Within	N/A	Within (facilitation)
Exp. 4	Yes	Within + Between	Within	Within	No	No
Exp. 5	No	Between	Within	Within	No	No
Exp. 6	No	Within	Within	Within + Between	Within	Within + Between
Exp. 7	No	No	Between	Within	No	Within + Between
Exp. 8	Yes	Within	Within + Between	Within + Between	Between	Within (facilitation) + Between (RIF)
Exp. 9	Yes	Within + Between	Within + Between	Within + Between	Within + Between	No

Note: Exp. = Experiment.
The RIF and facilitation reported here is collapsed across Category Practiced.
Details regarding the interactions appear in the relevant Results sections.

6.1 Colour is represented in episodic object recognition memory

The results from the familiar object experiments (Experiments 1-4, 6, and 8) revealed that for familiar objects there was significant RIF for Rp-Colour and Rp-Shape objects. Therefore, during the act of recalling an object from memory, other objects sharing shape only and objects sharing colour only, with the practiced object, can interfere with the correct recognition of the item in hand. Such interference led to the suppression of their memory, which was revealed in significant RIF.

The results from the novel object experiments (Experiments 5, 7, and 9) confirmed the pattern of results from the familiar objects experiments. The use of novel objects minimised the use of a verbal coding strategy thus allowing examination of the representation of colour in object memory as a perceptual feature (i.e., tapping on 'bottom-up' visual processing of shape and colour as opposed to 'top-down' knowledge). Admittedly, it is possible that the part shapes of the novel objects could be named at the basic level (e.g., square, triangle, star), and also the objects could be named based on their central component, their overall shape, or on similarity with a familiar object category. For instance, a group of novel objects could have been covertly named by participants as 'Tubes' or 'Ballerinas'. Nevertheless, it is unlikely that all participants would have universally used such verbal labels, unlike the basic category label 'Chair' or 'Table' would be used. Future related work using novel objects could ascertain whether verbal labels are used when viewing novel objects, by asking participants to name them and check for consistency in naming them.

Most critically for the current studies, the use of novel objects allowed greater experimental control over the stimuli. The use of novel objects allowed a much greater control over the design of Rp-Colour objects. For instance, in Experiments 1-3, where familiar objects were used, the Rp-Colour objects often shared not only colour (which was intended) but also overall configuration with the practiced objects (which was somewhat inevitable, in the service of maintaining the real-world nature of the familiar objects). The use of novel objects in Experiments 5, 7, and 9 made it possible to have Rp-Colour objects sharing the same colours as the Rp+ objects, but without having the same configuration of parts. The Rp-Shape objects in the familiar object experiments (Experiments 1-4, 6, and 8) necessarily shared both part shape and part configuration with the practiced (Rp+) objects. The use of novel objects in Experiments 5, 7, and 9 allowed examination of whether sharing part shape alone (and not both part shape and part configuration) can elicit RIF for the Rp-Shape objects. Indeed Experiments 5, 7, and 9 there was RIF for objects that shared part shape only but not part configuration.

6.2 Object shape and object colour produce significant RIF independently.

The current finding of RIF for objects sharing shape and those sharing colour alone with practiced objects, corroborates previous findings of shape and colour information independence, but it also extends it by showing that shape and colour information was encoded automatically (e.g., Brady et al., 2012; Hanna & Remington, 1996; Stefurak & Boynton, 1986). Previous demonstrations suggesting independent representations of shape and colour information (e.g., Hanna & Remington, 1996; Stefurak & Boynton, 1986) have been observed following an explicit instruction to attend to colour and shape information. In the current experiments object shape and colour information were encoded and subsequently led to interference effects despite the fact that no mention was made to the participants about having to remember shape and colour information.

In all of the experiments, sharing both shape and colour (Rp-Both) did not lead to greater RIF than sharing only one object property (Rp-Colour or Rp-Shape). One candidate explanation as to why there was a lack of greater RIF for Rp-Both objects, is that it may have been susceptible to some facilitation (greater resistance to forgetting) on the basis of being very similar to the Rp+ objects (also see Experiment 7 discussion). Previous studies (e.g., Anderson, 2003; Anderson et al., 2000) have shown that high levels of similarity between practiced and unpracticed objects can lead to a reduction of RIF, because of the concurrent influences of facilitation (as most features of unpracticed objects are practiced) and suppression caused by competition between practiced and unpracticed objects during recollection. This possibility is supported by the fact that in Experiments 4 and 6, although RIF was significant for Rp-Both objects, it was significantly *less* than RIF for the Rp-Shape condition. The better accuracy (thus less RIF) for Rp-Both objects is likely to have been due to the high level of similarity between those and the practiced (Rp+) objects, which was especially pronounced for familiar objects (Experiments 4 and 6).

The lack of greater RIF in the Rp-Both condition compared to the Rp-Colour and Rp-Shape conditions may be because shape and colour are represented in an integrated feature-based representation, where each feature is accessed independently of the other (e.g., see Hanna & Remington, 1996, for discussion). Based on the current experiment design it was not possible to determine whether shape and colour information were *represented independently* or represented in an integrated manner but *accessed independently* (see Hanna & Remington, 1996, for a similar suggestion regarding their results). Nevertheless, the current findings show that both object properties are explicitly represented and can contribute to the retrieval of objects from memory. This conclusion corroborates previous evidence for independent contributions of object shape and colour (e.g., Stefurak & Boynton, 1986; Hanna & Remington, 1996), and augments it by showing such effects for both familiar and novel objects (see also Brady et al., 2012).

6.3 Implications for understanding RIF

A significant contribution of the current work is the proof of concept for the modified retrieval (now recognition) practice paradigm. One strength of the original retrieval-practice paradigm is that it can eliminate issues of encoding specificity, because there is no change in the stimuli between study and test. Any differences during the test are solely the result of what happens to the stimuli in memory during the practice phase. This has the potential to get to the representations held in memory implicitly, by observing effects of interference in memory. The current work has modified this paradigm making it usable for a wider range of stimuli than previously used – i.e., complex objects, but most importantly using it as a tool to probe the nature and structure of memory representations – in this case object memory.

The current work revealed that RIF can be used to discover the micro-structure of object memory. As such, the current studies add to a limited set of studies showing RIF for episodic perceptual properties (e.g., Ciranni & Shimamura, 1999; Reppa et al., 2013; Sharman, 2011; Tempel & Frings, 2013). Ciranni and Shimamura (1999) were the first to show RIF for unpracticed items that were perceptually related to the practiced items. Two findings from the current experiments suggest that RIF was mediated by episodic representations. First, the finding of RIF using a recognition task with distractors that were semantically related to the target items suggests that RIF operated on the episodic representations of the studied objects. Second, the finding of RIF using novel objects with no previous associations or semantic meaning suggests that again RIF was operating on the episodic representations of the studied objects.

The current experiments demonstrate that the RIF paradigm can be used as a tool to elucidate feature-based representations in object memory. The findings have implications regarding the use of recognition memory tests to examine RIF and regarding the predictions of inhibitory and non-inhibitory accounts of RIF.

6.3.1. Implications regarding RIF in recognition memory tests

The current experiments examined RIF using a recognition task in the practice (Experiments 1-7) and test phase (Experiments 1-9). Previous work has successfully used Old/New recognition tasks during the *final test phase* of the retrieval practice task to show that retrieval practice effects (facilitation and RIF) can be observed in measures other than cued recall (e.g., Gómez-Ariza et al., 2005; Hicks & Starns, 2004).

Why RIF occurs at all using recognition tasks during the test phase is debated. According to some theorists, recognition judgements are based on conscious *recollection* of information about the spatiotemporal context of a studied episode (e.g., Verde, 2004). According to others, RIF in recognition memory tasks arises from the differences in the strength of familiarity between practiced and unpracticed objects (e.g., Spitzer & Bäuml, 2007), while still others suggest that both familiarity and recollection are affected by RIF (e.g., Gómez-Ariza et al., 2005; Hicks & Starns, 2004).

Although the current experiments were not specifically designed to examine whether RIF affects familiarity or recollection processes, recollection must have been involved. From the outset, steps were taken to ensure that the recognition task required recollection (as opposed to familiarity alone). First, the recognition task was not speeded, therefore reducing the need for participants to rely on familiarity cues alone (e.g., Hintzman & Caulton, 1997; Hintzman, Caulton, & Levitin, 1998; Jacoby, Jones, & Dolan, 1998; Gronlund, Edwards, & Ohrt, 1997). Second, the distractors were very similar to the targets, requiring access to item-specific details which familiarity alone would not provide access to. Third, participants received feedback during the recognition practice phase - a manipulation previously shown as necessary for interference to occur between practiced and unpracticed items (e.g., Raaijmakers & Jakab, 2012).

The most important indication that recollection processes were involved in the current studies, rather than only familiarity judgments was that *recognition practice* led to significant RIF in the current experiments. As the observation of RIF depends on competition (see Storm &

Levy, 2012 for review), it seems reasonable that recollection processes from the recognition task induced such competition (e.g., Clark, 1999). It is not clear how familiarity alone could be implicated in these experiments when much deeper processing was required of participants to recognise the objects as well as they did.

6.3.1.1 The use of a Yes/No recognition task without distractors

In Experiments 8 and 9 RIF was found despite the lack of distractors (recall that only target objects were shown during the test phase of the Yes/No recognition task in those two experiments). Participants should have responded 'Yes' to every object presented in the test phase as all the objects shown had been studied, and no distractor objects were shown. However, participants did not have such perfect recognition memory. Instead, they responded 'No' to objects sharing shape, colour, or both shape and colour with practiced objects which resulted in significant RIF. This finding demonstrates that memory for those objects was truly diminished due to competition at practice and not due to any strategic responding or distractor interference. Previous studies have observed memory impairment for target items at the test phase without using any distractors (e.g., Cox & Dobbins, 2011; Ley & Long, 1987, 1988; McKelvie, 1993; Wallace, 1978, 1982; Wallace et al., 1978), and not only have these distractor-free tasks been successful in measuring impairment for target items, but they also yield similar hit rates for targets items as the standard (target-distractor) recognition tests. Similarly, in the current thesis the pattern of hit rates in the no-distractor experiments resembled the pattern of accuracy in the experiments that included distractors. Finding RIF with no use of distractors at all is a particularly important finding, because it makes RIF an even more easy-to-use tool in order to examine the content of episodic representations.

6.3.2. Implications regarding RIF with re-presentation at practice

Previous evidence has shown that presentation alone of the studied stimuli is not sufficient to induce competition in memory to subsequently produce significant RIF (e.g., Anderson, 2003; Anderson & Bell, 2001; Anderson & Spellman, 1995; Anderson et al., 2000; Bäuml, 2002; Bäuml & Aslan, 2004, Ciranni & Shimamura, 1999; Dobler & Bäuml, 2013; Hanslmayr et al., 2010; Johansson et al., 2007; Saunders et al., 2009). According to the retrieval specificity assumption of the inhibitory account of RIF (e.g., Anderson, 2003; Anderson & Spellman, 1995; Storm & Levy, 2012), if a target item is re-presented during practice, the representation of related unpracticed items is not activated, therefore, it is unlikely to compete and thus be susceptible to RIF.

The task participants were required to do during the practice phase of Experiments 8 and 9 differed from that of all previous experiments. Their task during the practice phase in previous experiments was to decide whether they had seen the objects in the study phase or not by discriminating between targets and distractors. Their task during the practice phase of Experiments 8 and 9 was to judge the target objects on various attributes. Although this task may have been less engaging than the Old/New recognition task, the repeated exposure to the objects during the implicit judgement tasks still yielded significant facilitation of judged (practiced) objects and significant RIF for non-judged (unpracticed) objects. The current finding apparently contradicts Ciranni and Shimamura (1999) who did not find a RIF effect when they re-presented stimuli during the practice phase. However, in the Ciranni and Shimamura study, participants were not required to *do* anything at all with the Rp+ stimuli during practice (apart from attending to them). In contrast, participants in the current Experiments 8 and 9 were required to judge the Rp+ items in terms of different dimensions (e.g., attractiveness, or complexity). Indeed, previous studies have shown that when the practice task requires participants to engage or do something with the Rp+ items then RIF ensues. For instance, Raaijmakers and Jakab (2012) found significant RIF for unpracticed items following a practice phase that required participants to actively retrieve the category exemplar from which the target belonged to. Similarly, significant RIF was found by Verde (2013) when the practice phase involved making subjective judgements regarding the stimuli (not retrieval).

Verde (2013) found that simply showing participants the target items during practice (i.e., re-presentation) was not sufficient to induce RIF. However, significant RIF was observed when participants were required to make category judgements about the Rp+ items, or decide how much they liked the Rp+ items. Combined with the previous evidence, Experiments 8 and 9 of the current thesis have shown that RIF can be obtained without any active retrieval (either competitive or non-competitive). These findings are critical to the RIF literature as they provide new evidence regarding the conditions with which competition in memory may arise.

6.3.3. Implications regarding theoretical accounts of RIF

The current studies were not designed to examine the predictions of inhibitory versus non-inhibitory accounts of RIF. For example, the experiments did not manipulate item taxonomic frequency (e.g., Anderson et al., 1994; but see Levy, McVeigh, Marful, & Anderson, 2007) or manipulate independent cues at a final test (e.g., Anderson & Spellman, 1995; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006; Veling & van Knippenberg, 2004; see also Camp, Pecher, Schmidt, & Zeelenberg, 2009 and Huddleston & Anderson, 2012, for a recent discussion), both of which have been used to distinguish between the two accounts. However, three findings are pertinent in rejecting some proposed non-inhibitory explanations of RIF.

Firstly, according to the output interference theory (e.g., Roediger, 1973; Smith, 1971), RIF for certain items is caused because participants tend to recall the practiced (Rp+) items first, subsequently impairing the recall of unpracticed items. In the current experiments participants did not have the opportunity to consistently recall the practiced items first so output interference was controlled. The fact that RIF was nonetheless observed falsifies the output interference explanation of RIF – at least in the current experiments.

Second, two findings in the current studies pose a challenge to some non-inhibitory accounts of RIF, such as associative blocking (e.g., Butler et al., 2001; MacLeod et al., 2003), and encoding specificity accounts (e.g., Perfect et al., 2004). One is that RIF was observed despite a lack of significant facilitation effects for Rp+ items. This would suggest that RIF cannot solely be due to the fact that the strength of memory associated with the Rp+ items blocks or interferes with the memory of unpracticed items, as RIF could occur even when the items proposed to cause the memory blocking failed to be remembered. The second finding is that the magnitude of RIF differed between the Rp- objects within any given experiment and also differed for the same Rp- object between experiments. This would suggest that RIF was not solely dependent on the strengthening on Rp+ items as proposed by non-inhibitory accounts of RIF, which would predict a more uniform pattern of suppression of unpracticed items than observed here.

Another non-inhibitory account of RIF is the context-based account (Jonker et al., 2013). According to the context-based account it is the context that mediates the emergence of RIF. The account suggests that in order for RIF to occur the context between the study phase and the practice phase must change, and that the context of the practice phase must be activated during the test phase. The context-based account would predict RIF in Experiments 1-7, because there was a context change between study and practice, and the final test re-instated the practice context. However, it would not predict the significant RIF in Experiments 8 and 9, where RIF was found despite the fact that the context between the study and practice remained the same, and the test phase did not re-instate the practice phase.

Although the current findings do not support predictions of some non-inhibitory accounts, they do not fully support the inhibitory account of RIF either. For instance, the fact that RIF was found despite the lack of active retrieval during the practice phase in Experiments 8 and 9, is in direct contradiction to the retrieval specificity assumption of the inhibitory account of RIF (e.g., Anderson, 2003; Anderson & Spellman, 1995), which predicts that active retrieval of Rp+ objects is required for RIF to occur. Never-the-less the novel design of the current experiments has opened the doors for future research to further explore the mechanisms that underlie the RIF phenomenon.

6.4 The use of a recognition task *during practice* to induce RIF: Advantages and drawbacks

The current studies were the first to use a recognition task at practice to induce competition between practiced and related but unpracticed items. The finding that RIF was observed in recognition memory accuracy, suggests that the processes mediating recognition practice induced sufficient competition in memory to elicit RIF. The most likely process to have induced such competition is recollection (e.g., Clark, 1999; Mandler, 1980).

The use of the recognition task during practice comes with advantages and disadvantages. One advantage is that it allows the RIF paradigm to be used with complex visual materials that do not easily lend themselves to a cued-recall practice task. On the other hand the main drawback of recognition practice concerns the necessary use of distractor objects. Using distractor objects can increases cognitive workload and may interfere with the purpose of the experiment. In all experiments the distractor objects were designed to be similar to the targets objects to ensure that the recognition memory task was sufficiently difficult and to engage a competitive search-like recollection process (e.g., Clark, 1999; Humphreys, 1978; Mandler, 1980). Having a difficult recognition task, which relied more on recollection of details than on simple familiarity judgments, was deemed important to induce the necessary competition for RIF to occur.

In Experiments 1-5 distractors shared the same colour as the targets, and were discriminated from the targets on the basis of shape (overall configuration). This may have induced a bias against the Rp-Colour objects. That is, during the practice phase participants may have unintentionally learnt to say 'No' to any object that had the same colour as the Rp+ objects (to which they had to say 'Yes'). This 'learning' may have carried over to the test phase, where participants may have had the tendency to say 'No' to Rp-Colour objects (which shared the same colour as the Rp+ objects). This was particularly prominent in Experiments 2 and 4 where there was only RIF for Rp-Colour objects in the Lamps and Pots and category. The pattern of the Pots in particular stood out in design (i.e., cheetah and giraffe print; See Figures 2a and 4a) compared to the other objects (e.g., Chairs and Tables), therefore, competition during practice for these objects coupled with stronger interference for these objects from the distractors may have led to an increase in interference.

To counteract possible response strategies and ensure RIF was arising from perceptual processing, Experiment 6 (familiar objects) and Experiment 7 (novel objects) used distractor objects that were identical to the target objects in terms of shape (both parts and configuration), but different in terms of colour. If the significant RIF for Rp-Colour objects was solely due to an artificial lowering of accuracy due to a learnt response strategy (e.g., say 'No' to objects that share the same colour as the target objects), then encouraging a different response strategy, which would no longer disadvantage the Rp-Colour objects, would lead to the elimination of RIF.

Encouragingly, RIF remained significant in Experiments 6 and 7 (between-participant RIF) despite the change in the design of the distractors. However, the change in the distractors did influence two aspects of performance, albeit only for familiar objects. In Experiment 4 there was a more conservative response bias for Rp-Colour objects compared to Experiment 6 (with the re-designed distractors). This suggests that the nature of distractors, influenced response bias to some extent. Furthermore, the change in distractors increased the magnitude of RIF for Rp-Shape objects. Critically, however, it did not affect the presence of RIF for the Rp-Colour or the Rp-Shape conditions. Therefore, findings from the current experiments suggest that the sensitivity of recognition tests to RIF may be masked by the inhibition of perceptually related episodic distractors (as also suggested by Anderson, 2003). This issue is addressed in section 6.7 '*Directions for Future Research*' below.

6.5 Outstanding issues

The current studies have raised some issues for consideration in future related work.

6.5.1. Length of study time

The amount of time spent rating each object during the study phase was not standardised in the current experiments. The current findings cannot be easily accounted for in terms of differences in amount of time spent rating different objects, as there is no reason to suspect that participants may have systematically spent more time studying some targets (e.g., the Rp-Colour objects) but not others (e.g., the Rp-Neither ones). Even if one suggests that the RIF for the Rp-Shape and

Rp-Colour objects was due to less time spent viewing the objects during the attractiveness rating phase (e.g., because they may have first rated the Rp+ object, to which both object types were similar), this would still not explain the lack of RIF-like pattern of results in the control groups.

The amount of time available for viewing objects has been previously shown to determine whether colour information influences object recognition (e.g., Biederman & Ju, 1988). Future experiments using the current paradigm might consider systematically manipulating or enforcing exposure time for rating the objects during the study phase. Perhaps different magnitudes of RIF to shape versus colour would emerge with such manipulations. If the reason for no differences in RIF magnitude in the current work is due to encoding performance being at ceiling in the attractiveness rating phase, then perhaps limiting this exposure could lead to detectable differences in the encoded and represented features. While the current work demonstrates colour is always represented – perhaps limiting stimulus exposure would give new means to probe the memory and the object recognition process with this task.

6.5.2 Limitations in design and data.

Throughout all of the experiments in the current thesis the same objects were consistently used as the same Rp+ and Rp- objects. It might be possible that the pattern of findings reflect something specific about these particular objects, either in their appearance or because they were used as certain Rp stimuli (e.g., a particular Rp+ object may not have been remembered better due to the manipulation of task but because it stood out in some way from the other objects in the stimuli set). This possibility can be ruled out given that the objects were not always remembered or forgotten to the same level throughout the different experiments. However, rotating the Rp status of the objects should be considered in future research, along with using different objects from more diverse categories, or a different task (as opposed to Old/New recognition).

Counterbalancing the stimuli through rotating the Rp status of the objects could potentially deal with the recurring Item Type and Category Practiced interactions. That is, if the manipulation of practicing certain objects during the experiment was truly influencing responses, then interactions depending on which category was practiced may have continued to emerge even if the status of the Rp objects changed. However, if no category interaction emerged when the Rp status of the objects was rotated then it would suggest that the pattern of results reflects an issue with the design of the objects themselves as opposed to the experimental manipulation.

It could also be argued that the data from the current experiments was rather limited. That is, in all of the experiments there were only 4 trials per target condition per participant. Although this is not unlike previous studies which have also had a low number of trials per condition (e.g., Ciranni & Shimamura, 1999 – 12 uniquely coloured shapes, 4 circles, 4 crosses, 4 triangles; Nicholson & Humphrey, 2003 – 48 images presented in one of four colours, brown, green, blue, red), given that a primary focus of the current thesis was on accuracy it may have been more suitable to have included many more trials per condition. This potential problem with power may have been the cause of many effects not being reliable across both within and between comparisons. Increasing the number of trials may have resulted in more consistent results across experiments.

6.6 Directions for Future Research

6.6.1. The role of distractor objects

Although Experiments 8 and 9 of the current thesis attempted to deal with any issues with regards to distractor objects by removing them completely, future experiments using the current paradigm could manipulate distractor similarity. Completely dissimilar distractors (in terms of category as well as in terms of visual features) might rely on familiarity and not on recollection, therefore, RIF may not be observed at all in such conditions. If this were the case then a between-participants manipulation of distractor similarity might provide a means to test familiarity versus recollection accounts of RIF, as well as providing greater insight into the role this factor plays in the current work. Nevertheless, the finding of significant RIF in the absence of distractors, and the striking similarity in the pattern of RIF with experiments that used distractors, potentially makes the current modified paradigm a highly usable tool for examining the content of episodic representations of complex stimuli (where finding appropriate distractors might be difficult).

6.6.2. Effects of category sharing on RIF

One question that arose from the current thesis was whether the RIF effects found for the Rp-Shape and Rp-Colour objects was driven purely by perceptual features or by the combination of perceptual features and of category sharing. Notably, sharing semantic category is the single most important condition for the majority of studies examining RIF (see Anderson, 2003). To examine whether RIF can arise based on sharing only perceptual features and not category, future studies could use Rp-Shape and Rp-Colour objects that only shared visual features (i.e., shape or colour) with the practiced objects but not category (e.g., for the familiar objects - Rp+: yellow banana; Rp-Colour yellow chair; Rp-Shape: red boomerang; Rp-Neither green apple; and for novel objects the colours and part shapes of the objects could remain the same as in the current experiments but the central component within each category would differ).

6.6.3. Using RIF to probe independent representations of shape and colour for colour diagnostic objects.

The current experiments showed that in memory for familiar *non-colour diagnostic* and for novel objects, shape and colour information independently contribute to interference effects in memory. In contrast to the current findings, previous studies on naming and classification that have examined the issue of shape-colour information independence, have done so using *colour diagnostic objects*, and have found colour to be bound or integrated to shape information (e.g., Naor-Raz, Tarr, & Kersten, 2003; Price & Humphreys, 1989). It is possible that the use of non-colour diagnostic objects encouraged the independent processing of shape and colour, especially for the current novel object experiments; while the use of colour diagnostic objects in naming studies encouraged the integration of the object shape and colour information, leading to failures to find evidence for independent processing.

One way to examine whether shape and colour information make independent contributions to memory for colour diagnostic objects is to use the RIF paradigm in the same way that has been used in the current experiments. Consider an experiment where participants study a set of colour diagnostic objects, such as bananas, lemons, red post-boxes and red London buses, and so forth. In the practice phase, participants would perform a Yes/No recognition task on, say a yellow banana ('Yes' response) and a bunch of grapes ('No' response). The unpracticed (but studied) objects would share shape but not colour (e.g., a green banana), and colour but not shape (e.g., a yellow lemon). If colour is not an independently represented feature in memory for colour-diagnostic familiar objects, then there would be no significant RIF for any object that only shares the same colour as the yellow banana.

Admittedly, using familiar colour-diagnostic objects is ridden with issues that can potentially confound any interpretations regarding the representation of shape or colour information (which was the reason such objects were not used in the current studies). One of the most important considerations is category membership. For example, RIF for a green banana may come not only via sharing shape but also via sharing category. One way to exert maximal experimental control over object design in future work is to train participants to name and categorise novel objects. This would allow more precise examination of feature-based (shape, colour, texture, and so forth) representations while controlling for category membership and colour diagnosticity.

6.6.4 Can RIF for colour information be found in an implicit task?

It has been proposed that implicit and explicit memory tasks are mediated by different representations (e.g., Biederman & Cooper, 1992; Biederman & Gerhardstein, 1993; Zimmer & Steiner, 2003; Zimmer & Ecker, 2010). That proposal suggests that explicit memory tasks may be mediated by episodic (or *token*) representations that encode all available item and context information, including colour, and mediate *episodic recognition*. In contrast, implicit memory tasks may be mediated by object (or *type*) representations, typically assumed to be structural description representations encoding an object shape, and those representations facilitate *object recognition* and *classification*. Therefore, it has been proposed that object recognition may be mediated by type representations, which are structural description representations and do not include information that is not necessary for object identification, such as colour.

This distinction between the two different representations has been undermined by findings showing that both implicit and explicit memory tests can show a similar pattern of performance - i.e., they can both be similarly affected by study to test changes in object properties, such as rotation in depth (e.g., Lawson, 2004; Lawson & Humphreys, 1998; Srinivas, 1995). Instead, it is possible that differences between explicit and implicit memory tasks, such as different processing strategies employed by the two tasks (e.g., Whittlesea & Price, 2001) may be responsible for the discrepancies observed between the two tasks, as opposed to differences in the representations used by each task. For instance, in explicit memory tests participants are asked to try and memorise items for a later test, and during the test phase they are asked to recall whether the items during the test phase appeared in the study phase or not. In contrast, in implicit memory tests participants are not required to make such a connection between study and test. Therefore, in implicit memory tests the lack of difference in priming between same versus changed coloured objects may reflect the fact that such information is not used, as opposed to that it is not represented (e.g., Lawson, 2004 for a similar argument regarding viewpoint effects; Lawson & Humphreys, 1998; Srinivas, 1995). Indeed, when colour information becomes task-relevant at test, then a change in colour between study and test impairs priming (e.g., Vernon & Lloyd-Jones, 2003; Lloyd-Jones & Nakabayashi, 2009), even if it was not relevant for encoding (e.g. Vernon & Lloyd-Jones, 2003; Exp. 2b).

Nevertheless, it would be interesting to examine whether object colour information drives competition effects using an implicit memory task at the test phase that presumably employs object representations, such as a preference judgment task. For instance, using the modified RIF paradigm presented in the current thesis, in a study phase participants could perform incidental learning on objects like those used in the current experiments. Following practice of a subset of objects, a preference judgments test would be administered on all studied objects. If colour information is represented as part of *object* representations, then the pattern of results would resemble the pattern of results in the current studies: preference judgments to the Rp-Colour objects would be lower than those of the Nrp objects due to competition of colour information with the Rp+ objects during practice.

6.7 Concluding statement

Evidence from a modified version of the RIF paradigm revealed that both shape and colour information are automatically encoded in object memory and that both, independently drive competition effects in memory. These findings provide converging support to the limited existing evidence that colour is a represented object feature regardless of task demands or type of object being recognised.

The current research contributes to the memory literature by modifying an established memory paradigm so that it can be used as a tool for other kinds of empirical work to examine the perceptual properties of objects, their impact on episodic object recognition memory, and on furthering the understanding of RIF. The current thesis has modified the paradigm in such a way that it can be used as a tool to probe feature-based representations in memory, and extends its application to include complex stimuli that do not easily lend themselves to the typically used retrieval practice task. The use of a recognition task in the retrieval-practice paradigm demonstrates the paradigm to be useful in new ways, and the indirect probing of memory provides a method to examine memory representations that bypasses concerns relating to encoding specificity.

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APPENDIX A

Analysis of the Experimental Group Hit rates, False Alarms, B''_D bias and the Control Group data

Data Analysis

Test Phase Analyses: The data analysis procedure for the Experimental and Control Group analyses reported here is the same as for the analysis of *A'* scores reported in the thesis.

Speed-accuracy trade-off analysis. To ensure that there was no speed-accuracy trade-off during the test phase, a correlation was performed between the response times and the *A'* scores for each object type. Lack of significant correlation would confirm that the pattern of accuracy (i.e., lower accuracy to Rp- objects resulting in significant RIF) was not simply because participants were responding too fast.

Confidence ratings analysis. Cell means and analyses of the Experimental Group participants' confidence scores are reported. If participants were not guessing and were aware of their memories, they would be expected to show the highest confidence on Rp+ objects, and the lowest on the Rp- objects.

Recognition Practice Phase Analyses: Although the data of interest were the Test Phase data, the Recognition Practice Phase data were analysed to ensure that recognition practice was successful – i.e., that the Rp+ objects were successfully discriminated from their distractors. Ensuring the successful discrimination of Rp+ objects during recognition practice was important, to be certain that any lack of RIF in the Test Phase, was not simply due to lack of sufficient need for competition during the recognition practice phase.

Four separate 3 (Recognition Practice Phase: 1, 2, and 3) X 2 (Category Practiced: Tables and Chairs vs. Lamps and Pots) mixed model ANOVAs, on the hits, false alarms, *A'* and B''_D, were carried out. Category Practiced was manipulated between-participants. The factor of Key Response was not included in the analysis of the recognition practice data.

Experiment 1 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hit rates revealed only a significant main effect of Item Type, while the false alarms revealed a significant main effect of Item Type, and a significant main effect of Category Practiced, with significantly higher false alarm rates for those practiced Tables and Chairs compared to those who practiced Lamps and Pots. The main effect of Key Response was not significant and neither were any of the interactions. B''_D, showed a significant main effect of Item Type, and Category Practiced. Lamps and Pots were responded to overall more conservatively (participants were more likely to say 'No') than the Tables and Chairs category – that is participants were likely to report remembering the former compared to the latter. (Table 1a).

Table 1b shows the mean hit, false alarm scores, and B''_D for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

RIF: Significant between-participants RIF was present for each of the three unpracticed conditions (Rp-Colour, Rp-Shape and Rp-Neither), though corresponding within-participants RIF effects were absent. There were no significant differences in hits between Experimental Group objects (Rp- Colour, Rp- Shape and Rp- Neither).

Using false alarms as the dependant measure, Nrp objects yielded significantly more false alarms than Rp-Colour objects. However, there were no significant differences in false alarms between the Nrp and the Rp-Shape and Rp-Neither objects. Comparisons among the Experimental and Control groups revealed significantly higher false alarms for Rp-Neither objects in the Experimental group compared to the Control group. There were no significant differences in false alarms for Rp-Colour and Rp-Shape objects between the two groups. Comparison amongst the three Rp- conditions revealed no significant differences.

Using B''_D as the dependent measure, all three Rp- conditions were responded to more conservatively (participants more likely to say 'No') relative to the Nrp condition, while the three Rp- conditions did not differ in terms of B''_D. Comparisons between the Experimental and Control Groups on each Rp- condition, showed a conservative bias (Experimental participants more likely to respond 'No') towards Rp-Shape and Rp-Neither objects, while there was no such bias against the Rp-Colour objects.

Facilitation. In terms of hits, Rp+ objects were remembered significantly better than Nrp objects, but there was no significant difference between experimental and control group Rp+ objects.

With respect to false alarms, there was no significant difference between Rp+ objects and Nrp objects. However, there were significantly higher false alarms for Experimental group Rp+ objects compared to Control group Rp+ objects.

In terms of B''_D, Experimental Group participants showed more liberal responses (more likely to say 'Yes') to practiced (Rp+) objects compared to Nrp objects, and compared to Control Group Rp+ objects.

Speed-accuracy trade-off analysis. There was no significant correlation between A' scores and response times to objects in Experiment 1, r (140) = 0.09, $p > 0.05$.

Table 1a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 1.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Category Practiced X Key Response	
Dependent measure	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*
Hits (%)	10.18**	342	3.15	1319	1.79	1319	1.18	342	0.57	342	0.01	1319	0.75	342
False alarms (%)	2.92*	292	4.69*	706	0.66	706	0.19	292	0.38	292	0.00	706	0.39	292
B''_D	13.16**	0.18	8.03**	0.43	0.23	0.43	0.95	0.18	1.01	0.18	0.14	0.43	0.35	0.18

*$p<0.05$, **$p<0.001$

Table 1b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 1 Test Phase. Hits, false alarms, and B''_D are presented by Item Type collapsed across Category Practiced and Key Response. Confidence ratings are reported for the Experimental Group and are presented by Item Type only.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
				Hits					
Experimental Group	*M*	73.21	90.18	63.39	65.18	65.18			
	SD	*(21.57)*	*(18.43)*	*(24.98)*	*(24.85)*	*(26.65)*			
Control Group	*M*		85.27	80.80	85.71	84.82			
	SD		*(17.37)*	*(21.38)*	*(19.16)*	*(20.79)*			
Within comparisons	$t(27)=$		-4.48	1.94	1.59	1.74	-.33	-.40	.00
	$p=$		.0001**[f]	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comparisons	$t(54)=$	-2.08	1.03	-2.80	-3.46	-3.08			
	$p=$	.04*[Δ]	*ns*[f]	.007*	.001*	.003			
				False alarms					
Experimental Group	*M*	29.24	31.25	18.75	20.54	22.32			
	SD	*(15.60)*	*(19.98)*	*(19.98)*	*(20.47)*	*(19.65)*			
Control Group	*M*		16.07	15.62	19.64	13.39			
	SD		*(10.13)*	*(17.55)*	*(19.37)*	*(14.41)*			
Within Comparisons	$t(27)=$		-0.47	2.99	1.86	1.55	-.44	-.72	.44
	$p=$		*ns*	.01*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comparisons	$t(54)=$	3.45	3.59	0.62	0.17	1.94			
	$p=$	.001*[Δ]	.001*	*ns*	*ns*	*ns*			
				B''_D scores					
Experimental Group	*M*	-0.15	-0.40	0.26	0.21	0.23			
	SD	*(0.59)*	*(0.44)*	*(0.51)*	*(0.50)*	*(0.41)*			
Control Group	*M*		-0.04	0.05	-0.11	0.01			
	SD		*(0.35)*	*(0.36)*	*(0.37)*	*(0.28)*			
Within comparisons	$t(27)=$		2.23	-3.21	-2.48	-3.60	0.44	0.32	-0.17
	$p=$		.03*[f]	.003*	.02*	.001**	*ns*	*ns*	*ns*

Between comparisons	$t(54)=$ $p=$	-0.62 *ns*[Δ]	-3.39 .001**[f]	1.77 *ns*	2.67 .01*	2.27 .03*			
				Confidence Ratings					
Confidence Ratings	*M* *SD*	3.64 *(1.61)*	4.13 *(1.75)*	3.90 *(1.80)*	3.67 *(1.68)*	3.69 *(1.67)*			
Confidence Ratings comparisons	$t(27)=$ $p=$		-4.27 .0001**[f]	2.27 .03*	0.31 *ns*	0.51 *ns*	2.55 .02*	1.83 *ns*	0.23 *ns*

*$p<0.05$, **$p<0.001$, [f] = facilitation. [Δ] = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the Control and Experimental group hits, false alarms, and B''_D. Rp+ = Practiced objects from the practiced category. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Confidence Ratings. Table 1b shows the Confidence ratings per Item Type for the Experimental Group participants. Participants were significantly more confident in their responses to the Rp+ and Rp-Colour objects compared to the Nrp baseline. Responses to Rp-Colour objects were more confident than responses to Rp-Shape objects.

Recognition practice analysis.

Recognition practice in Experiment 1 was successful, with target objects being successfully discriminated from distractor objects (*Hit*=93.45, *SD*=8.12; *A'* = .93, *SD* = .09). Cell means appear in Table 1c.

Table 1c: Mean Hits, False alarms, *A'* and B''_D scores (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 1.

Category	Practiced	Hits (%)	False Alarms (%)	*A'*	B''_D
Phase 1	Tables and Chairs	92.86 *(10.26)*	11.31 *(15.19)*	0.93 *(0.06)*	-0.12 *(0.53)*
	Lamps and Pots	89.29 *(16.80)*	23.81 *(21.15)*	0.86 *(0.14)*	-0.37 *(0.44)*
	Total	91.07 *(13.78)*	17.56 *(19.16)*	0.89 *(0.11)*	-0.25 *(0.49)*
Phase 2	Tables and Chairs	92.86 *(8.56)*	8.33 *(17.90)*	0.93 *(0.08)*	0.07 *(0.29)*
	Lamps and Pots	88.69 *(12.06)*	17.26 *(28.02)*	0.86 *(0.19)*	-0.04 *(0.44)*
	Total	90.77 *(10.48)*	12.80 *(23.51)*	0.90 *(0.15)*	0.02 *(0.44)*
Phase 3	Tables and Chairs	93.45 *(8.12)*	8.33 *(12.23)*	0.93 *(0.07)*	-0.05 *(0.34)*
	Lamps and Pots	92.26 *(9.51)*	11.31 *(17.79)*	0.92 *(0.10)*	-0.07 *(0.42)*
	Total	92.86 *(8.70)*	9.82 *(15.05)*	0.92 *(0.09)*	-0.06 *(0.38)*
Total	Tables and Chairs	93.06 *6.69)*	9.33 *(13.89)*	0.95 *(0.06)*	-0.03 *(0.53)*
	Lamps and Pots	90.08 *(11.52)*	17.46 *(20.10)*	0.92 *(0.12)*	-0.11 *(0.56)*
	Total	91.57 *(9.37)*	13.39 *(17.45)*	0.93 *(0.09)*	-0.07 *(0.54)*

The ANOVA results are reported in Table 1d. For the hits the ANOVA revealed no significant effects. For false alarms, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 3 [t (27)= 2.45, p= .02], and no other significant differences. For *A'* scores the ANOVA revealed no significant effects. For B''_D scores, only Recognition Practice Phase had a significant main effect, with responses becoming more conservative from Phase 1 to Phase 2 [t (27)= 2.79, p= .01], and no other significant differences.

Table 1d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 1.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	0.62	57.62	0.70	266	0.30	57.62
False alarms (%)	3.73*	114	1.55	896	1.42	114
A'	2.26	0.00	1.83	0.03	1.59	0.00
B''_D	3.58*	0.14	1.18	0.29	0.65	0.14

*p<0.05, **p<0.001

Control Group analyses

Control Group mean Vs. Experimental Group Nrp. Control group hits were significantly higher compared to the Experimental Group Nrp hits, suggesting potential cross-category RIF for the Nrp objects in the Experimental Group. False alarms were significantly higher in the Experimental Group Nrp condition compared to the Control Group baselines. There was no significant difference between the Experimental Group Nrp B''_D and the overall Control Group mean B''_D (See Table 1b).

Repeated-measures ANOVAs. The repeated-measures ANOVA on the Control group hits revealed no significant main effects or interactions, demonstrating that the observed differences were due to the recognition practice manipulation (See Table 1e).

The Control Group false alarm repeated-measures ANOVA revealed no significant main effects or interactions (See Table 1e). This suggests that when there was no recognition practice, there was no difference in false alarms between different objects.

The Control Group B''_D repeated-measures ANOVA (Table 1e) showed only a significant Item Type by Category interaction. While there was no difference in response bias between any of the Rp conditions for the Tables and Chairs category, in the Lamps and Pots category Rp-Colour objects were responded to more conservatively than Rp+ and Rp-Shape objects, and Rp-Neither more conservatively than Rp-Shape objects (Table 1f).

Table 1e: Item Type X Category ANOVA statistics for the Control Group in Experiment 1.

	Item Type		Category		Item Type X Category	
Dependent measure	*F* (3, 81)	*MSE*	*F* (1, 27)	*MSE*	*F* (3, 81)	*MSE*
Hits (%)	1.30	220	0.98	558	0.89	306
False alarms (%)	1.54	244	3.07	481	1.70	264
A'	0.57	0.01	0.03	0.01	0.04	0.01
B''_D	1.90	0.14	1.36	0.48	2.79*	0.17

*p<0.05, **p<0.001

Table 1f: Control Group paired samples t-test statistics for B''_D by Item Type and Category for Experiment 1.

Statistic	Rp+ vs. Rp-Colour	Rp+ vs. Rp-Shape	Rp+ vs. Rp-Neither	Rp-Colour vs. Rp-Shape	Rp-Colour vs. Rp-Neither	Rp-Shape vs. Rp-Neither
			Tables and Chairs B''_D			
t(27) =	1.21	1.01	0.70	-0.13	-0.36	0.21
p=	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
			Lamps and Pots B''_D			
t(27) =	-2.76	0.26	-1.69	3.37	1.08	-2.67
p=	.01*	*ns*	*ns*	.001*	*ns*	.01

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks. **p*<0.01, ***p*<0.001

Experiment 2 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed a significant main effect of Item Type, a significant main effect of Key Response, with hit rates being significantly higher for participants who responded 'yes' with their left hand compared to those who responded 'yes' with their right hand, and a significant main effect of Category Practiced, with hits of participants in the Lamps and Pots group being significantly higher than participants in the Tables and Chairs group. There was a significant interaction between Item Type and Category Practiced, and a significant interaction between Category Practiced and Key Response. There were no significant interactions between Item Type and Key Response, or between Item Type, Category Practiced and Key Response (see Table 2a). As there was an Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means separately across categories practiced. Key Response was collapsed across Category Practiced as it was not of current theoretical interest.

The mixed model ANOVA on the False alarms revealed a significant main effect of Item Type. There was no significant main effect of Key Response, and no significant main effect of Category Practiced. There was a significant interaction between Item Type and Key Response. There were no other significant interactions (Table 2a). As there was no Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means collapsed across categories practiced.

The mixed model ANOVA on B''_D (Table 2a) showed a significant main effect of Item Type and a significant Item Type by Category Practiced interaction, with Rp-Neither Tables and Chairs responded to more conservatively than Rp-Neither Lamps and Pots. There was also a significant interaction between Category Practiced and Key Response, with participants responding 'Yes' with their right hand in the Tables and Chairs category showing a marginally significant conservative bias than participants responding 'Yes' with their right hand in the Lamps and Pots category.

Table 2b shows the mean Hit, False alarm, and B''_D scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

RIF. With regards to the hits, for the Tables and Chairs group there was significant within-participant RIF for Rp-Colour, Rp-Shape, and Rp-Neither objects. Comparison amongst the three Rp- conditions revealed that Rp-Colour objects yielded significantly larger RIF compared to Rp-Shape objects. There were no other significant differences in hit rates between Rp- objects. There was also significant between-participant RIF for Rp-Colour objects. However, there was no between-participant RIF for Rp-Shape and Rp-Neither objects.

For the Lamps and Pots group there was significant within-participant RIF for Rp-Colour objects, but not for Rp-Shape objects. There was significant within-facilitation for Rp-Neither objects. Comparison amongst the three Rp- conditions revealed that Rp-Colour objects yielded significantly larger RIF compared to Rp-Shape objects. There was also significantly larger RIF for Rp-Colour and Rp-Shape objects compared to Rp-Neither objects. There was significant between-participant RIF for Rp-Colour and Rp-Shape objects. There was no significant difference between the Experimental and Control group Rp-Neither objects.

With regards to the false alarms, Nrp items yielded significantly higher false alarm rates compared to all three Rp- conditions. Comparisons between the three Rp- conditions, revealed no significant differences. There were significantly higher false alarms for Rp-Colour and Rp-Shape objects in the Control group compared to the Experimental group. There was no significant difference in false alarms for Rp-Neither objects between the Experimental and Control groups.

In terms of B''_D, for the Tables and Chairs category, all three Rp- objects were responded to more conservatively relative to the Nrp objects. Rp-Colour objects were responded to more conservatively than Rp-Shape objects. Experimental Rp-Colour was responded to more conservatively than control Rp-Colour, while there were no other differences in bias between the Experimental and Control Groups.

For the Lamps and Pots category, only Rp-Colour objects were responded to more conservatively relative to the Nrp objects. Further within-participant comparisons showed that Rp-Colour and Rp-Shape objects were responded to more conservatively than Rp-Neither objects, with no other differences between the Rp- conditions. Experimental Rp-Colour and Rp-Shape objects were responded to more conservatively than Control Group Rp-Colour and Rp-Shape objects.

Facilitation: With respect to hits, Rp+ objects were remembered significantly better than Nrp objects, but there was no significant difference between experimental and control group Rp+ objects.

In terms of false alarms, there was no significant difference between Rp+ objects and Nrp objects. However, there were significantly higher false alarms for Control group Rp+ objects compared to Experimental group Rp+ objects.

In terms of B''_D, responses to Rp+ objects were significantly more liberal (more likely to say 'Yes') than responses to Nrp objects. Experimental and Control Groups did not differ in terms of B''_D for Rp+ objects.

Speed-accuracy trade-off analysis. There was no significant correlation between *A'* scores and response times to objects in Experiment 2, $r\ (140) = 0.10, p > 0.05$.

Confidence Ratings. Table 2b shows the Confidence Ratings per Item Type for the Experimental Group participants. Experimental Group participants yielded significantly higher confidence for their responses to the Rp+ objects compared to Nrp, Rp-Colour, Rp-Shape, and Rp-Neither objects. There were also significantly increased confidence ratings towards Rp-Neither objects compared to Rp-Colour objects.

Table 2a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 2.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Category Practiced X Key Response	
Dependent measure	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*
Hits (%)	25.04**	443	4.57*	1081	4.30*	1081	6.25**	443	0.88	443	4.85*	1081	1.66	443
False alarms (%)	7.59**	218	0.54	376	2.94	376	0.57	218	2.59*	218	3.74	376	0.54	218
B''_D	22.69**	0.17	0.34	0.47	0.13	0.47	3.95*	0.17	0.93	0.17	4.54*	0.47	0.66	0.17

$^*p<0.05$, $^{**}p<0.001$

Table 2b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 2 Test Phase. Hits and B''_D are presented by Item Type separately across Category Practiced and collapsed across Key Response. False alarms are presented by Item Type collapsed across Category Practiced and Key Response. Confidence ratings are reported for the Experimental Group and are presented by Item Type only.

				Hits					
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
				Tables and Chairs					
Experimental Group	*M*	73.66	82.14	33.93	57.14	42.86			
	SD	*(16.84)*	*(30.11)*	*(21.05)*	*(33.15)*	*(37.25)*			
Control Group	*M*		86.61	67.86	72.32	60.00			
	SD		*(15.93)*	*(27.10)*	*(19.65)*	*(29.99)*			
Within comparisons	*t(13)=*		-5.09	7.32	2.65	3.31	-3.242	-0.960	-1.421
	p=		.0001**[f]	.0001**	.02*	.006*	.006*	*ns*	*ns*
Between comparisons	*t(40)=*	-0.92	-0.63	-4.10	-1.87	-1.68			
	p=	*ns* [Δ]	*ns*[f]	.0001**	*ns*	*ns*			
				Lamps and Pots					
Experimental Group	*M*	68.75	98.21	37.50	57.14	87.50			
	SD	*(14.08)*	*(6.68)*	*(23.51)*	*(26.73)*	*(27.30)*			
Control Group	*M*		79.46	60.71	79.46	89.29			
	SD		*(18.07)*	*(24.93)*	*(25.51)*	*15.85)*			
Within comparisons	*t(13)=*		-5.09	4.34	1.62	2.34	-2.24	-4.63	2.52
	p=		.0001**[f]	.001*	*ns*	.036*[f]	.04*	.0001**	.03*
Between comparisons	*t(40)=*	-0.92	3.74	2.90	-2.63	-0.27			
	p=	*ns* [Δ]	.001*	.006*	.01*	*ns*			
				False alarms					
Experimental Group	*M*	25.22	25.00	8.93	16.07	10.71			
	SD	*(13.45)*	*(21.52)*	*(13.97)*	*(18.28)*	*(12.60)*			
Control Group	*M*		37.05	22.32	28.13	13.84			
	SD		*(15.40)*	*(16.44)*	*(14.28)*	*(14.17)*			
Within Comparisons	*t(27)=*		0.05	4.49	2.19	5.51	-1.69	-0.57	-1.44
	p=		*ns*	.0001**	.04*	.0001**	*ns*	*ns*	*ns*

Between comparisons	*t(54)=*	-.03	-2.41	-3.29	-2.75	-0.87			
	p=	*ns* $^{\Delta}$	.02*	.002*	.008*	*ns*			
			B''_D scores for Tables and Chairs						
Experimental Group	*M*	-0.05	-0.21	0.74	0.29	0.49			
	SD	*(0.46)*	*(0.61)*	*(0.28)*	*(0.60)*	*(0.64)*			
Control Group	*M*		-0.45	0.15	-0.05	0.38			
	SD		*(0.42)*	*(0.59)*	*(0.52)*	*(0.54)*			
Within comparisons	*t(13)=*		3.67	6.51	2.17	3.43	3.24	1.42	0.99
	p=		.001*^{f}	.0001**	.05*	.004*	.007*	*ns*	*ns*
Between comparisons	*t(40)=*	0.74	1.46	3.52	1.91	0.56			
	p=	*ns* $^{\Delta}$	*ns* ^{f}	.001*	*ns*	*ns*			
			B''_D scores for Lamps and Pots						
Experimental Group	*M*	0.21	-0.35	0.70	0.43	-0.06			
	SD	*(0.46)*	*(0.38)*	*(0.26)*	*(0.42)*	*(0.56)*			
Control Group	*M*		-0.16	0.23	-0.11	-0.07			
	SD		*(0.48)*	*(0.49)*	*(0.47)*	*(0.49)*			
Within comparisons	*t(13)=*		3.67	3.34	1.51	1.50	1.88	4.77	3.20
	p=		.001*^{f}	.005*	*ns*	*ns*	*ns*	.0001**	.007*
Between comparisons	*t(40)=*	0.74	1.35	3.40	3.56	0.09			
	p=	*ns* $^{\Delta}$	*ns* ^{f}	.002*	.001*	*ns*			
			Confidence Ratings						
Confidence Ratings	*M*	3.83	4.58	3.72	3.92	4.11			
	SD	*(1.66)*	*(1.62)*	*(1.70)*	*(1.66)*	*(1.73)*			
Confidence Ratings Comparisons	*t(27)=*		5.44	1.17	0.87	1.74	1.74	2.53	1.34
	p=		.0001**	*ns*	*ns*	*ns*	*ns*	.02*	*ns*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.
Note: Within comparisons = Within-participant comparisons (paired-samples t-tests) between Nrp baseline and each Rp condition, as well as comparisons among Rp- conditions. Between comparisons = Between-participant comparisons (independent-samples t-tests) between the control and experimental group hits, false alarms, and B''_D. Rp+ = Practiced objects from practiced category. Rp-Shape [Rp-S] = objects share same shape as Rp+ object. Rp-Colour [Rp-C] = objects share same colour as Rp+ object. Rp-Neither [Rp-N] = objects share category but not shape or colour with Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Recognition practice analysis

Recognition practice in Experiment 2 was successful, with target objects being successfully discriminated from distractor objects (*Hit*=97.62, *SD*=5.09; *A'*=.93, *SD* =.09). Cell means appear in Table 2c.

Table 2c: Mean Hits, False alarms, *A'* and B''_D scores (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 2.

	Category Practiced	Hits (%)	False Alarms (%)	*A'*	B''_D
Phase 1	Tables and Chairs	91.67 *(14.25)*	14.88 *(14.68)*	0.91 *(0.09)*	-0.20 *(0.46)*
	Lamps and Pots	92.86 *(8.56)*	11.31 *(10.65)*	0.93 *(0.04)*	-0.15 *(0.49)*
	Total	92.26 *(11.55)*	13.10 *(12.72)*	0.92 *(0.07)*	-0.17 *(0.47)*
Phase 2	Tables and Chairs	89.88 *(16.72)*	10.12 *(14.68)*	0.91 *(0.12)*	-0.03 *(0.38)*
	Lamps and Pots	97.02 *(5.28)*	7.74 *(11.99)*	0.95 *(0.05)*	-0.18 *(0.33)*
	Total	93.45 *(12.70)*	8.93 *(13.21)*	0.93 *(0.10)*	-0.11 *(0.36)*
Phase 3	Tables and Chairs	92.26 *(15.14)*	11.90 *(21.36)*	0.90 *(0.19)*	-0.13 *(0.44)*
	Lamps and Pots	97.62 *(5.09)*	1.79 *(3.55)*	0.97 *(0.02)*	0.02 *(0.22)*
	Total	94.94 *(11.42)*	6.85 *(15.89)*	0.93 *(0.13)*	-0.06 *(0.35)*
Total	Tables and Chairs	91.27 *(14.69)*	12.30 *(14.24)*	0.90 *(0.13)*	-0.12 *(0.42)*
	Lamps and Pots	95.83 *(6.31)*	6.94 *(8.73)*	0.95 *(0.04)*	-0.10 *(0.35)*
	Total	93.55 *(10.90)*	9.62 *(11.63)*	0.93 *(0.09)*	-0.11 *(0.39)*

The ANOVA results are reported in Table 2d. For the Hits the ANOVA revealed no significant effects. For False alarms, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 3 [t (27)= 2.16, p= .04], and no other significant differences. The ANOVAs on *A'* and B''_D showed no significant main effects or interactions.

Table 2d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 2.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	1.53	32.94	1.24	354	1.98	22.94
False alarms (%)	3.14*	90.37	1.52	398	1.35	90.37
A'	0.44	0.00	1.71	0.03	1.24	0.00
B''_D	0.82	0.12	0.02	0.23	1.43	0.12

*$p<0.05$, **$p<0.001$

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. There was no significant difference in hits, false alarms, or B''_D between the Experimental Group Nrp items and the Control Group scores (See Table 2b).

Repeated-measures ANOVAs. The repeated-measures ANOVA on the Control group Hits revealed a significant interaction between Item Type and Category (See Table 2e). For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher accuracy for Rp+ objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects. There was also significantly higher accuracy for Rp-Shape objects compared to Rp-Neither objects. There were no other significant differences between the Rp- objects. For the Lamps and Pots category there was significantly higher accuracy for Rp+ objects compared to Rp-Colour objects. There was also significantly higher accuracy for Rp-Neither objects compared to Rp+, Rp-Colour, and Rp-Shape objects. There was also significantly higher accuracy for Rp-Shape objects compared to Rp-Colour objects. There was no significant difference between Rp+ and Rp-Shape objects (see Table 2f).

The repeated-measures ANOVA on the control group False alarms revealed a significant main effect of Item Type. There was no significant main effect of Category and no significant interaction between Item Type and Category (see Table 2e). Planned comparisons revealed higher false alarm rates for the Rp+ objects compared to the Rp- objects. There were also significantly higher false alarms for Rp-Colour and Rp-Shape objects compared to Rp-Neither objects. There was no significant difference between Rp-Colour and Rp-Shape objects (see Table 2f).

The Control Group B''_D repeated-measures ANOVA showed a significant Item Type by Category Practiced interaction (See Table 2e). For Tables and Chairs, responses to Rp+ objects were more liberal (participants more likely to say 'Yes') compared to the other three Rp object types, while for Lamps and Pots, responses to Rp-Colour objects were more conservative (participants more likely to say 'No') than the other three Rp conditions (Table 2f).

Table 2e: Item Type X Category ANOVA statistics for the Control Group in Experiment 2.

	Item Type		Category		Item Type X Category	
Dependent measure	*F* (3, 81)	*MSE*	*F* (1, 27)	*MSE*	*F* (3, 81)	*MSE*
Hits (%)	8.32**	403	3.62	444	8.60**	464
False alarms (%)	20.55**	260	2.64	382	2.18	445
A'	5.05*	0.01	4.60*	0.02	3.00*	0.02
B''_D	14.35**	0.21	0.35	0.20	6.19*	0.22

*p<0.05, **p<0.001

Table 2f: Control Group paired samples t-test statistics for Hits, *A'*, and B''_D by Item Type and Category, and for False alarms by Item Type collapsed across Category for Experiment 2.

Statistic	Measure	Rp+ vs. Rp-Colour	Rp+ vs. Rp-Shape	Rp+ vs. Rp-Neither	Rp-Colour vs. Rp-Shape	Rp-Colour vs. Rp-Neither	Rp-Shape vs. Rp-Neither
				Tables and Chairs			
t(27) =	*Hits (%)*	3.29	3.62	4.68	-0.72	1.03	2.05
p=		.003*	.0001**	.0001**	*ns*	*ns*	.05
	A'	-0.43	-0.47	-0.78	0.16	-0.18	-0.38
		ns	*ns*	*ns*	*ns*	*ns*	*ns*
	B''_D	-3.90	-3.30	-6.50	1.50	-2.03	3.68
		.001*	.003*	.0001**	*ns*	.05	.001*
				Lamps and Pots			
t(27) =	*Hits (%)*	3.21	0.00	-2.17	-3.07	-5.44	-2.09
p=		.003*	*ns*	.04	.005*	.0001**	.05
	A'	2.08	-0.15	-5.13	1.78	4.71	-3.27
		ns	*ns*	.0001**	*ns*	.0001**	.003*
	B''_D	-2.94	-0.39	-0.74	3.14	2.65	-0.32
		.007*	*ns*	*ns*	.004*	.01	*ns*
				Total			
t(27) =	*False alarms (%)*	4.11	2.97	7.58	-1.95	3.29	-4.77
p=		.0001**	.006*	.0001**	*ns*	.003*	.0001**
	A'	1.09	-0.39	-3.83	-1.56	-3.20	-2.13
		ns	*ns*	.001*	*ns*	.004*	.04

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks. *$p<0.01$, **$p<0.001$

Experiment 3 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed a significant main effect of Item Type. There was no significant main effect of Category Practiced or Key Response. However, there was a significant interaction between Item Type and Category Practiced. There were no other significant interactions (see Table 3a). As there was a significant interaction between

Item Type and Category Practiced, planned comparisons to examine RIF and facilitation are reported for Item Type separately across Category Practiced.

The mixed model ANOVA on the false alarms revealed a significant main effect of Item Type only. As there was no Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means collapsed across categories practiced (Table 3a).

The mixed model ANOVA on B''_D revealed a significant main effect of Item Type and a significant Item Type by Category Practiced interaction, with a significantly greater conservative bias for Nrp and Rp-Colour objects in the Lamps and Pots category compared to the Tables and Chairs category (Table 3a).

Table 3b shows the mean hit, false alarm, and B''_D scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

RIF. In terms of hits, there was significant within-participant RIF for Rp-Colour and Rp-Shape objects, and significant within-facilitation for Rp-Neither objects. Comparison amongst the three Rp- conditions revealed significantly higher hits for Rp-Neither objects compared to Rp-Colour and Rp-Shape objects. There was no significant difference between the Rp-Colour and Rp-Shape objects. There was also significant between-participant RIF for Rp-Colour and Rp-Shape objects. There was no significant difference for Rp-Neither objects between the Experimental and Control Groups.

With regards to false alarms, there were higher false alarm rates for the Rp-Colour and Rp-Shape objects compared to the Nrp objects. There were higher false alarm rates for the Nrp objects compared to the Rp-Neither objects. Comparisons amongst the three Rp- conditions revealed no significant differences in false alarms. There were significantly higher false alarms for all three of the Rp- objects in the Control group compared to the Experimental group.

In terms of B''_D, for the Tables and Chairs category, both Rp-Colour and Rp-Shape objects were responded to more conservatively relative to the Nrp objects (Lamps and Pots). Rp-Colour and Rp-Shape objects were responded to more conservatively than Rp-Neither objects. Experimental and Control Group comparisons only showed significantly more conservative B''_D for Rp-Shape objects for the Experimental Group. For the Lamps and Pots category, only Rp-Colour objects were responded to more conservatively relative to the Nrp objects (Tables and Chairs). Further within-participant comparison showed that both the Rp-Colour and Rp-Shape objects were responded to more conservatively than Rp-Neither objects. Experimental Rp-Colour and Rp-Shape were responded to more conservatively than the equivalent conditions in the Control Group.

Facilitation. In terms of hits, Rp+ objects were remembered significantly better than Experimental Nrp objects, and Control group Rp+ objects.

In terms of false alarms, there was no significant difference in false alarms between Rp+ objects and Nrp objects. However, there were significantly higher false alarms for Control group Rp+ objects compared to Experimental group Rp+ objects.

In terms of the B''_D dependant measure, responses to Rp+ objects were significantly more liberal (participants more likely to say 'Yes') than responses to experimental Nrp objects. There was no difference in B''_D for Rp+ objects between the Experimental and Control Groups.

Speed-accuracy trade-off analysis. There was no significant correlation between *A'* scores and response times to objects in Experiment 3, $r\ (140) = 0.03, p > 0.05$.

Table 3a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 3.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Category Practiced X Key Response	
Dependent measure	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*	*F* (4,96)	*MSE*	*F* (1,24)	*MSE*	*F* (4,96)	*MSE*
Hits (%)	31.87**	424	2.80	290	0.10	290	3.60*	424	0.65	424	0.31	290	4.13*	424
False alarms (%)	6.56**	258	1.04	386	2.60	386	0.57	258	0.82	258	3.96	386	1.17	258
B''_D	28.18**	0.15	2.61	0.25	0.50	0.25	2.73*	0.15	2.57*	0.15	0.08	0.25	1.68	0.15

*p<0.05, **p<0.001

Table 3b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 3 Test Phase. Hits and B''_D are presented by Item Type separately across Category Practiced and collapsed across Key Response, False alarms are presented by Item Type collapsed across Category Practiced and Key Response. Confidence ratings are reported for the Experimental Group and are presented by Item Type only.

				Hits					
	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-N	Rp-S vs. Rp-N
				Tables and Chairs					
Experimental Group	*M*	78.57	94.64	62.50	42.86	94.64			
	SD	*(12.91)*	*(14.47)*	*(21.37)*	*(33.15)*	*(10.65)*			
Control Group	*M*		87.50	75.89	74.11	81.25			
	SD		*(17.35)*	*(22.03)*	*(22.03)*	*(26.90)*			
Within comparisons	*t(13)=*		-5.98	2.11	4.19	-3.71	1.56	-5.26	5.20
	p=		.0001**[f]	.05*	.001*	.003*[f]	*ns*	.0001**	.0001**
Between comparisons	*t(40)=*	-1.68	1.33	1.88	-3.65	1.79			
	p=	*ns* $^{\Delta}$	*ns*	*ns*	.001*	*ns*			
				Lamps and Pots					
Experimental Group	*M*	68.75	98.21	37.50	57.14	87.50			
	SD	*(14.08)*	*(6.68)*	*(23.51)*	*(26.73)*	*(27.30)*			
Control Group	*M*		80.36	62.50	74.11	87.50			
	SD		*(19.67)*	*(22.05)*	*(24.04)*	*(14.43)*			
Within comparisons	*t(13)=*		-5.98	4.34	1.62	-2.34	-2.24	-4.63	2.52
	p=		.0001**[f]	0.001*	*ns*	0.04*[f]	0.04*	0.0001**	0.03*
Between comparisons	*t(40)=*	-1.68	3.29	-3.39	-2.08	0.00			
	p=	*ns* $^{\Delta}$	.002*[f]	.002*	.04*	*ns*			
				False alarms					
Experimental Group	*M*	27.68	24.11	12.50	14.29	9.82			
	SD	*(13.44)*	*(20.95)*	*(17.35)*	*(18.55)*	*(14.17)*			
Control Group	*M*		38.84	23.66	27.68	17.41			
	SD		*(17.46)*	*(16.08)*	*(13.33)*	*(14.17)*			
Within Comparisons	*t(27)=*		0.80	4.13	3.13	5.38	-0.37	0.77	-1.00
	p=		*ns*	.0001**	.0001**	.0001**	*ns*	*ns*	*ns*

Between comparisons	*t(54)*=	0.67	-2.86	-2.50	-3.10	-2.00			
	p=	*ns*$^{\Delta}$	.006*	.02*	.003*	.05*			
				B''_D scores for Tables and Chairs					
Experimental Group	*M*	-0.24	-0.40	0.36	0.57	-0.06			
	SD	*(0.40)*	*(0.40)*	*(0.46)*	*(0.51)*	*(0.31)*			
Control Group	*M*		-0.50	0.07	-0.11	0.04			
	SD		*(0.44)*	*(0.63)*	*(0.56)*	*(0.60)*			
Within comparisons	*t(13)*=		2.98	3.90	5.50	1.51	0.97	3.07	3.69
	p=		.006*^{f}	.002*	.0001**	*ns*	*ns*	.009*	.003*
Between comparisons	*t(40)*=	0.78	0.64	1.56	3.78	0.56			
	p=	*ns*$^{\Delta}$	*ns*^{f}	*ns*	.001*	*ns*			
				B''_D scores for Lamps and Pots					
Experimental Group	*M*	0.21	-0.35	0.70	0.43	-0.06			
	SD	*(0.46)*	*(0.38)*	*(0.26)*	*(0.42)*	*(0.56)*			
Control Group	*M*		-0.19	0.17	-0.01	-0.14			
	SD		*(0.50)*	*(0.43)*	*(0.50)*	*(0.44)*			
Within comparisons	*t(13)*=		2.98	3.34	1.51	1.50	1.88	4.77	3.20
	p=		.006*^{f}	.005*	*ns*	*ns*	*ns*	.0001**	.007*
Between comparisons	*t(40)*=	0.78	1.09	4.19	2.77	0.52			
	p=	*ns*$^{\Delta}$	*ns*^{f}	.0001**	.008*	*ns*			
				Confidence Ratings					
Confidence Ratings	*M*	4.05	4.72	4.09	4.14	4.92			
	SD	*(0.97)*	*(0.77)*	*(1.19)*	*(1.04)*	*(1.06)*			
Confidence Ratings Comp	*t(27)*=		5.36	0.45	0.96	6.82	0.40	5.13	5.06
	p=		.0001**	*ns*	*ns*	.0001**	*ns*	.0001**	.0001**

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the control and experimental group hits, false alarms, and B''_D (see text for details). Rp+ = Practiced objects from practiced category. Rp-Shape [Rp-S] = objects share same shape as Rp+ object. Rp-Colour [Rp-C] = objects share same colour as Rp+ object. Rp-Neither [Rp-N] = objects share category but not shape or colour with Rp+ object.

Confidence Ratings. Experimental participants showed higher confidence in their responses to Rp+ objects compared to Nrp, Rp-Colour, and Rp-Neither objects. Confidence was significantly higher for responses to Rp-Neither objects compared to the Rp-Colour and Rp-Shape objects.

Recognition practice analysis

Recognition practice in Experiment 3 was successful, with target objects being successfully discriminated from distractor objects (*Hit* = 97.62, *SD* = 5.09; *A'* = .95, *SD* = 0.05). Cell means appear in Table 3c.

Table 3c: Mean Hits, False alarms, *A'*, and B''_D (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 3.

	Category Practiced	Hits (%)	False Alarms (%)	*A'*	B''_D
Phase 1	Tables and Chairs	95.24 *(6.30)*	10.71 *(10.04)*	0.93 *(0.05)*	-0.24 *(0.40)*
	Lamps and Pots	92.86 *(8.56)*	11.31 *(10.65)*	0.93 *(0.04)*	-0.15 *(0.49)*
	Total	94.05 *(7.43)*	11.01 *(10.34)*	0.93 *(0.04)*	-0.20 *(0.45)*
Phase 2	Tables and Chairs	94.05 *(8.91)*	5.36 *(7.74)*	0.95 *(0.03)*	0.05 *(0.47)*
	Lamps and Pots	97.02 *(5.28)*	7.74 *(11.99)*	0.95 *(0.05)*	-0.18 *(0.33)*
	Total	95.45 *(7.09)*	6.55 *(9.87)*	0.95 *(0.04)*	-0.07 *(0.40)*
Phase 3	Tables and Chairs	97.02 *(4.14)*	0.60 *(2.23)*	0.97 *(0.01)*	0.15 *(0.25)*
	Lamps and Pots	97.62 *(5.09)*	1.79 *(3.55)*	0.97 *(0.02)*	0.02 *(0.22)*
	Total	97.32 *(4.62)*	1.19 *(2.89)*	0.97 *(0.02)*	0.09 *(0.23)*
Total	Tables and Chairs	95.44 *(6.45)*	5.56 *(6.67)*	0.95 *(0.03)*	-0.01 *(0.37)*
	Lamps and Pots	95.83 *(6.31)*	6.94 *(8.73)*	0.95 *(0.04)*	-0.10 *(0.35)*
	Total	95.63 *(6.38)*	6.25 *(7.70)*	0.95 *(0.04)*	-0.06 *(0.36)*

The ANOVA results are reported in Table 3d. For the Hits the ANOVA revealed no significant main effects and no significant interaction. For False alarms scores, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 2 [t (27)= 2.84, p= .009], from Phase 1 to Phase 3 [t (27)= 5.25, p= .0001], and from Phase 2 to Phase 3 [t (27)= 3.20, p= .003]. The ANOVA on the recognition practice phase A' scores showed a significant main effect of Recognition Practice Phase, with accuracy increasing with each phase (Phase 1 - Phase 2, t (27) = -2.02, p = .05; Phase 1 – Phase 3, t (27) = -4.64, p = .0001; Phase 2 – Phase 3, t (27) = -2.94, p = .007. The same ANOVA on B''_D showed a significant main effect of Recognition Practice Phase, with responses becoming more conservative from Phase 1 to Phase 3, t (27) = -2.99, p = .006.

Table 3d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 3.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	1.85	40.57	0.07	50.49	1.24	40.57
False alarms (%)	16.01**	42.29	0.30	133	0.14	42.29
A'	11.18**	0.01	0.09	0.00	0.10	0.01
B''_D	4.55*	0.12	0.96	0.18	1.64	0.12

*p<0.05, **p<0.001

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Control Group hits, false alarms and B''_D revealed no significant difference between the experimental group Nrp items and the control group scores (See Table 3b).

Repeated-measures ANOVAs. The repeated-measures ANOVA (Table 3e) on the Control Group hits revealed a significant interaction between Item Type and Category. For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher accuracy for Rp+ objects compared to Rp-Colour and Rp-Shape objects. There were no other significant differences between Rp objects. For the Lamps and Pots category there was significantly higher accuracy for Rp+ objects compared to Rp-Colour objects, and significantly higher accuracy for Rp-Neither objects compared to Rp-Colour and Rp-Shape objects. There were no other significant differences between Rp objects (Table 3f).

The repeated-measures ANOVA on the Control Group false alarms revealed a significant interaction between Item Type and Category (See Table 3e). For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher false alarms for Rp+ objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects. There were also significantly higher false alarms for Rp-Shape objects compared to Rp-Colour and Rp-Neither objects. There was no significant difference in false alarms between Rp-Colour and Rp-Neither objects. For the Lamps and Pots category there were significantly higher false alarms for Rp+ objects compared to Rp-Neither objects. There were no other significant differences in false alarms between the Rp objects (Table 3f).

The repeated-measures ANOVA on Control Group B''_D (Table 3e) showed only a significant main effect of Item Type, with Rp+ objects responded to more liberally than all the other Rp objects (Table 3f).

Table 3e: Item Type X Category ANOVA statistics for the Control Group in Experiment 3.

	Item Type		Category		Item Type X Category	
Dependent measure	$F(3, 81)$	*MSE*	$F(1, 27)$	*MSE*	$F(3, 81)$	*MSE*
Hits (%)	6.77**	464	1.50	477	2.68*	381
False alarms (%)	14.28**	319	0.99	477	5.47*	302
A'	7.83**	0.01	0.77	0.02	6.34*	0.01
B''_D	7.10**	0.29	1.99	0.19	2.43	0.23

*$p<0.05$, **$p<0.001$

Table 3f: Control Group paired samples t-test statistics for Hits, False alarms, and *A'* by Item Type and Category, and for B''_D by Item Type collapsed across Category for Experiment 3.

Statistic	Measure	Rp+ vs. Rp-Colour	Rp+ vs. Rp-Shape	Rp+ vs. Rp-Neither	Rp-Colour vs. Rp-Shape	Rp-Colour vs. Rp-Neither	Rp-Shape vs. Rp-Neither
				Tables and Chairs			
t(27) = *p=*	*Hits (%)*	2.16 .04	3.07 .005*	1.07 *ns*	0.34 *ns*	-0.97 *ns*	-1.11 *ns*
	False alarms (%)	4.25 .0001**	2.74 .01	5.61 .0001**	-2.29 .03	1.76 *ns*	3.49 .002*
	A'	-2.30 .03	0.03 *ns*	-3.61 .001*	2.38 .003*	-1.44 *ns*	-3.02 .006*
				Lamps and Pots			
t(27) = *p=*	*Hits (%)*	3.12 .004*	0.93 *ns*	-1.61 *ns*	-1.95 *ns*	-6.15 .0001**	-2.36 .03
	False alarms (%)	0.93 *ns*	1.97 *ns*	3.06 .005*	0.85 *ns*	1.49 *ns*	0.65 *ns*
	A'	2.05 *ns*	-0.03 *ns*	-3.14 .004*	-2.21 .04	-4.72 .0001**	-2.54 .02
				Total			
t(27) = *p=*	*A'*	0.26 *ns*	0.02 *ns*	-4.27 .0001**	-0.27 *ns*	-2.92 .007*	3.12 .004*
	B''_D	-4.31 .0001**	-3.13 .004*	-3.65 .001*	1.46 *ns*	1.96 *ns*	-0.06 *ns*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks. *$p<0.01$, **$p<0.001$

Experiment 4 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed significant a significant main effect of Item Type. There was no significant main effect of Category Practiced and no significant main effect of Key Response. However, there was a significant interaction between Item Type and Category Practiced. There were no other significant interactions (Table 4a). As there was a significant interaction between Item Type and Category Practiced, planned comparisons to examine RIF and facilitation are reported for Item Type separately across Category Practiced.

The mixed model ANOVA (Table 4a) on the experimental group False alarms revealed a significant main effect of Item Type. There was no significant main effect of Category Practiced and no significant main effect of Key Response. There were no significant interactions. As there was no Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means collapsed across categories practiced.

The mixed model ANOVA on B''_D (Table 4a) showed a significant main effect of Item Type and a significant Item Type by Category Practiced interaction, with a more conservative bias towards Rp+ objects in the Lamps and Pots category, and a more conservative bias towards Rp-Both objects in the Tables and Chairs category.

Table 4a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 4.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
Dependent measure	*F* (5,120)	*MSE*	*F* (1,24)	*MSE*	*F* (1,24)	*MSE*	*F* (5,120)	*MSE*	*F* (5,120)	*MSE*	*F* (1,24)	*MSE*	*F* (5, 120)	*MSE*
Hits (%)	38.48**	402	3.77	568	0.11	568	4.51*	402	0.84	402	0.34	568	0.95	402
False alarms (%)	6.06**	201	0.13	605	0.06	605	1.24	201	0.30	201	0.92	605	1.11	201
B''_D	32.29**	0.13	0.16	0.31	0.11	0.31	2.77*	0.13	0.21	0.13	1.19	0.31	0.31	0.13

*$p<0.05$, **$p<0.001$

Table 4b shows the mean Hit, False alarm, and B''_D scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

RIF. For the Tables and Chairs group there was significant within- and between-participant RIF for Rp-Colour, Rp-Shape, and Rp-Both objects. There was significant within-participant facilitation for Rp-Neither objects, but no difference in Rp-Neither objects between the Experimental and Control groups. Comparison amongst the four Rp- items revealed significantly better recognition for Rp-Neither items compared to Rp-Colour, Rp-Shape, and Rp-Both objects. There were no other significant differences between the Rp- objects.

For the Lamps and Pots group there was significant within-participant RIF for Rp-Colour and Rp-Shape objects. There was no significant within-participant RIF for Rp-Both and Rp-Neither objects. Comparison amongst the four Rp- items revealed significantly better recognition for Rp-Neither objects compared to Rp-Colour and Rp-Shape objects. There was also significantly better recognition for Rp-Both and Rp-Shape objects compared to Rp-Colour objects. There were no significant differences between Rp-objects. There was significant between-participant RIF for Rp-Colour objects, and no between-participant RIF for the Rp-Shape, Rp-Both, and Rp-Neither objects.

Using false alarms as the dependant measure, Nrp false alarm rates were significantly higher than all four of the Rp- conditions. Comparisons amongst the four Rp- conditions revealed no significant differences. Independent samples t-tests revealed significantly higher false alarms for Rp-Colour, Rp-Shape, and Rp-Both objects in the Control group compared to the

Experimental group. There was no significant difference in false alarms for Rp-Neither objects between the two groups.

In terms of B''_D, for the Tables and Chairs category, the pattern of bias was as would be expected: Rp-Colour, Rp-Shape, and Rp-Both objects were responded to more conservatively relative to the Nrp objects and to the Rp-Neither objects. There was no difference in response bias between the Nrp and the Rp-Neither items. Experimental and Control Group comparisons showed that participants in the Experimental Group responded to Rp-Colour, Rp-Shape and Rp-Both objects more conservatively (more likely to say 'No') than Control Group participants. There was no difference in bias between Experimental and Control Rp-Neither objects.

For the Lamps and Pots category, a slightly difference pattern of bias emerged, where Rp-Colour and Rp-Shape objects, but not Rp-Both, were responded to more conservatively relative to Nrp objects. As with the Tables and Chairs, there was no difference in B''_D between the Nrp and the Rp-Neither objects. Mirroring the pattern of bias for the Tables and Chairs, Rp-Colour, Rp-Shape and Rp-Both objects were responded to more conservatively in the Experimental Group compared to the Control Group. There was no difference in bias between experimental and control Rp-Neither objects (Table 4b).

Facilitation. For the hits, Rp+ objects were remembered significantly better than Experimental Nrp objects, and Control group Rp+ objects.

There was no significant difference in false alarms between Rp+ objects and Nrp objects. However, there were significantly higher false alarms for Control group Rp+ objects compared to Experimental group Rp+ objects.

Table 4b: Experimental and Control Group mean, standard deviation, and t-test statistics for Hits, False alarms, and B''_D from the Experiment 4 Test Phase. Hits and B''_D are presented by Item Type separately across Category Practiced and collapsed across Key Response. False alarms are presented by Item Type collapsed across Category Practiced and Key Response. Confidence ratings are reported for the Experimental Group and are presented by Item Type only.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Hits Tables and Chairs													
Exp. Group	*M*	73.21	100	42.86	30.36	50.00	85.71						
	SD	*(11.54)*	*(0.00)*	*(26.73)*	*(31.28)*	*(21.93)*	*(18.90)*						
Control Group	*M*		90.18	77.68	65.18	82.14	88.39						
	SD		*(19.65)*	*(19.65)*	*(24.85)*	*(17.82)*	*(22.03)*						
Within comp	*t(13)=*		-9.50[f]	3.88	5.35	3.26	-2.56	1.07	0.84	-6.00	2.07	6.05	-4.91
	p=		.0001*	.002*	.0001**	.006*	.02*[f]	*ns*	*ns*	.0001**	.05*	.0001**	.0001**
Between comp	*t(40)=*	-0.78	1.86	-4.79	-3.92	-5.10	0.39						
	p=	*ns* [Δ]	*ns*	.0001**	.0001**	.0001**	*ns*						
Hits Lamps and Pots													
Exp. Group	*M*	78.57	96.43	32.14	58.93	75.00	83.93						
	SD	*(11.34)*	*(9.08)*	*(28.47)*	*(21.05)*	*(25.94)*	*(15.83)*						
Control Group	*M*		87.50	58.93	66.96	85.71	79.46						
	SD		*(14.43)*	*(25.65)*	*(30.47)*	*(18.55)*	*(23.62)*						
Within comp	*t(13)=*		-9.50[f]	6.54	2.52	0.58	-1.13	-2.90	4.16	-5.84	1.61	3.18	-1.33
	p=		.0001**	.0001**	.03*	*ns*	*ns*	.01*	.001*	.0001**	*ns*	.007*	*ns*
Between comp	*t(40)=*	-0.78	2.11	-3.08	-0.88	1.54	0.64						
	p=	*ns* [Δ]	.04*[f]	.004*	*ns*	*ns*	*ns*						
False alarms													
Exp. Group	*M*	23.57	16.96	10.71	8.04	5.36	11.61						
	SD	*(15.45*	*(19.31)*	*(14.32)*	*(13.70)*	*(12.47)*	*(19.82)*						
Control Group	*M*		34.38	23.21	19.20	16.07	15.18						
	SD		*(17.55)*	*(20.33)*	*(13.39)*	*(14.38)*	*(12.89)*						

Within comp	*t(27)=*		1.41	3.65	5.46	5.29	3.54	1.00	-1.80	-0.24	-0.83	1.00	-1.49
	p=		*ns*	.001*	.0001**	.0001**	.001*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comp	*t(54)=*	0.54	-3.53	-2.66	-3.08	-2.98	-0.80						
	p=	ns^{Δ}	.001*	.01*	.003*	.004*	*ns*						
						B''_D scores for Tables and Chairs							
Exp. Group	*M*	0.09	-0.46	0.63	0.74	0.64	0.11						
	SD	*(0.40)*	*(0.32)*	*(0.45)*	*(0.34)*	*(0.32)*	*(0.45)*						
Control Group	*M*		-0.45	0.10	0.28	0.06	-0.14						
	SD		*(0.46)*	*(0.53)*	*(0.52)*	*(0.47)*	*(0.39)*						
Within comp	*t(13)=*		3.55	3.97	5.09	4.14	0.20	0.97	0.19	4.09	0.84	5.76	4.03
	p=		.004*	.002*	.001**	.001**	*ns*	*ns*	*ns*	.001**	*ns*	.001**	.001**
Between comp	*t(40)=*	0.32	0.07	3.16	3.02	4.17	1.84						
	p=	ns^{Δ}	*ns*	.003*	.004*	.001**	*ns*						
						B''_D scores for Lamps and Pots							
Exp Group	*M*	-0.01	-0.14	0.73	0.54	0.32	0.10						
	SD	*(0.43)*	*(0.43)*	*(0.27)*	*(0.34)*	*(0.46)*	*(0.43)*						
Control Group	*M*		-0.32	0.20	0.13	-0.06	0.11						
	SD		*(0.42)*	*(0.53)*	*(0.59)*	*(0.47)*	*(0.48)*						
Within comp	*t(13)=*		0.91	5.98	3.49	1.79	0.83	1.72	2.67	5.03	1.53	4.45	1.43
	p=		*ns*	.001**	.004*	*ns*	*ns*	*ns*	.02*	.001**	*ns*	.001**	*ns*
Between comp	*t(40)=*	0.32	1.27	3.55	2.44	2.52	0.02						
	p=	ns^{Δ}	*ns*	.001**	.02*	.02*	*ns*						
						Confidence Ratings							
Conf Ratings	*M*	4.02	4.58	3.91	4.00	4.28	4.83						
	SD	*(1.57)*	*(1.56)*	*(1.58)*	*(1.65)*	*(1.51)*	*(1.46)*						
Conf Ratings comp	*t(27)=*		6.14	1.18	0.37	2.64	6.18	0.78	2.39	5.47	3.14	5.71	3.46
	p=		.001**	*ns*	*ns*	.01*	.001**	*ns*	.02*	.001**	.004*	.001**	.002*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the control and experimental group hits, false alarms, and B''_D (see text for details). Rp+ =

Practiced objects from the practiced category. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Both [Rp-B] = objects that share the same shape and colour with the Rp+ objects. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Facilitation. In terms of B''_D, for the Tables and Chairs, responses to Rp+ objects were significantly more liberal than responses to Nrp objects. However, there was no significant difference in bias between Experimental Group Rp+ objects and Control Group Rp+ objects. For the Lamps and Pots category, there was no significant difference in bias between Rp+ and Nrp objects, or between the Rp+ experimental and Control Groups.

Speed-accuracy trade-off analysis. There was no significant correlation between A' scores and response times to objects in Experiment 4, r (168) = 0.08, $p > 0.05$.

Confidence Ratings. Table 4b shows the Confidence ratings per Item Type for the Experimental Group participants. Participants had increased confidence to Rp+ objects compared to Nrp, Rp-Colour, Rp-Shape, and Rp-Both objects. Of all the unpracticed conditions, responses to Rp-Neither objects attracted the highest confidence ratings. Responses to Rp-Neither and Rp-Both objects were significantly more confident compared to the remaining unpracticed objects.

Recognition practice analysis

Recognition practice in Experiment 4 was successful, with target objects being successfully discriminated from distractor objects (*Hit*=98.21, *SD*=3.55). Cell means appear in Table 4c.

Table 4c: Mean Hits, False alarms, A' and B''_D (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 4.

	Category Practiced	Hits (%)	False Alarms (%)	A'	B''_D
Phase 1	Tables and Chairs	87.50 *(13.38)*	22.62 *(22.75)*	0.86 *(0.12)*	-0.20 *(0.45)*
	Lamps and Pots	98.21 *(3.55)*	10.12 *(12.31)*	0.95 *(0.04)*	-0.29 *(0.41)*
	Total	92.86 *(8.46)*	16.37 *(17.53)*	0.90 *(0.08)*	-0.24 *(0.43)*
Phase 2	Tables and Chairs	84.52 *(10.77)*	17.26 *(23.68)*	0.86 *(0.14)*	0.10 *(0.47)*

	Lamps and Pots	91.67 *(10.34)*	4.17 *(8.49)*	0.94 *(0.05)*	0.17 *(0.35)*
	Total	88.10 *(10.55)*	10.71 *(16.08)*	0.90 *(0.09)*	0.13 *(0.41)*
Phase 3	Tables and Chairs	91.07 *(10.57)*	12.50 *(18.99)*	0.91 *(0.09)*	-0.03 *(0.47)*
	Lamps and Pots	96.43 *(5.39)*	2.38 *(5.09)*	0.96 *(0.02)*	0.07 *(0.32)*
	Total	93.75 *(7.98)*	7.44 *(12.04)*	0.94 *(0.06)*	-0.06 *(0.38)*
Total	Tables and Chairs	87.70 *(11.57)*	17.50 *(21.80)*	0.88 *(0.12)*	-0.04 *(0.46)*
	Lamps and Pots	95.44 *(6.42)*	5.56 *(8.63)*	0.95 *(0.04)*	-0.02 *(0.36)*
	Total	91.57 *(9.00)*	11.50 *(15.20)*	0.91 *(0.08)*	-0.03 *(0.41)*

The ANOVA results are reported in Table 4d. For the Hits the ANOVA revealed a significant main effect of Recognition Practice Phase with a reduction in hits from Phase 1 to Phase 2 [$t\,(27)= 2.08, p= .05$], and then an increase in hits from Phase 2 to Phase 3 [$t\,(27)= -2.54, p= .02$]. There was no difference in hits between Phase 1 and Phase 3. There was also a significant main effect of Category Practiced for the hits, with participants in the Lamps and Pots group performing significantly better than the Tables and Chairs group [$t\,(27)= -2.90, p= .008$]. There was no significant interaction. For False alarms scores, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 2 [$t\,(27)= 2.33, p= .03$], and from Phase 1 to Phase 3 [$t\,(27)= 3.48, p= .002$]. There were no other significant differences. For *A'* scores, the main effect of Recognition Practice Phase was significant, with increased *A'* from Phase 1 to Phase 3, $t\,(27) = -2.64, p = .01$, and from Phase 2 to Phase 3, $t\,(27) = -2.08, p = .05$. There was also a significant main effect of Category Practiced, with better recognition in the Lamps and Pots category compared to the Tables and Chairs category, $t\,(26) = -2.65, p = 0.01$. For B''_D scores, only Recognition Practice Phase had a significant effect, with responses becoming more conservative from Phase 1 to Phase 2, t (27) = -4.03, p = .0001, and from Phase 1 to Phase 3, t (27) = -2.52, p = .02.

Table 4d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 4.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	3.80*	68.17	8.90*	141	0.76	68.17
False alarms (%)	6.20*	92.21	4.51	660	0.19	92.21
A'	3.77*	0.00	7.01*	0.02	0.92	0.00
B''_D	7.10*	0.15	0.07	0.23	0.49	0.15

*p<0.05, **p<0.001

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Control Group hits, false alarms, and B''_D revealed no significant difference between the Experimental Group Nrp items and the Control Group scores.

Repeated-measures ANOVAs. The repeated-measures ANOVA (Table 4e) on the Control Group hits revealed a significant interaction between Item Type and Category. For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher accuracy for Rp+ objects compared to Rp-Colour and Rp-Shape objects. There was significantly higher accuracy for Rp-Colour and Rp-Both objects compared to Rp-Shape objects. There was also significantly higher accuracy for Rp-Neither objects compared to the Rp-Colour and Rp-Shape objects. There were no other significant differences. For the Lamps and Pots category there was significantly higher accuracy for Rp+ objects compared to Rp-Colour and Rp-Shape objects. There was also significantly higher accuracy for Rp-Both objects compared to Rp-Colour and Rp-Shape objects.

There was also significantly higher accuracy for Rp-Neither objects compared to Rp-Colour objects. There were no other significant differences (Table 4f).

The repeated-measures ANOVA on the Control Group False alarms revealed a significant interaction between Item Type and Category (See Table 4e). For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher false alarms for Rp+ objects compared to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects. There were no other significant differences. For the Lamps and Pots category there were significantly higher false alarms for Rp+ objects compared to Rp-Shape, Rp-Both, and Rp-Neither objects. There were also significantly higher false alarms for Rp-Colour objects compared to Rp-Both and Rp-Neither objects. There were no other significant differences (Table 4f).

For the B''_D dependent measure, the Control Group repeated-measures ANOVA (Table 4e) showed only a significant main effect of Item Type, with Rp+ objects attracting a more liberal bias than all other Rp objects (Table 4f).

Table 4e: Item Type X Category ANOVA statistics for the Control Group in Experiment 4.

	Item Type		Category		Item Type X Category	
Dependent measure	$F(4, 108)$	*MSE*	$F(1, 27)$	*MSE*	$F(4, 108)$	*MSE*
Hits (%)	14.00**	424	4.25*	412	2.81*	411
False alarms (%)	10.83**	315	0.27	522	3.03*	240
A'	8.52**	0.01	4.49*	0.02	5.71**	0.01
B''_D	14.83**	0.20	0.38	0.28	2.12	0.19

*p<0.05, **p<0.001

Table 4f: Control Group paired samples t-test statistics for Hits, False alarms, and *A'* by Item Type and Category, and for B''_D by Item Type collapsed across Category for Experiment 4.

Statistic	Measure	Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
					Tables and Chairs						
t(27) =	*Hits (%)*	2.39	5.02	1.73	0.33	2.10	-1.00	-2.12	-4.16	-3.95	-1.37
p=		.02	.0001**	*ns*	*ns*	.05	*ns*	.04	.0001**	.001*	*ns*
	False alarms (%)	6.01	4.18	4.94	4.60	-0.19	0.49	0.000	0.68	0.18	-0.40
		.0001**	.0001**	.0001**	.0001**	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
	A'	-0.92	1.10	-2.12	-1.45	1.82	-0.95	-0.56	-3.43	-2.42	0.11
		ns	*ns*	.04	*ns*	*ns*	*ns*	*ns*	.002*	.02	*ns*
					Lamps and Pots						
t(27) =	*Hits (%)*	4.66	3.48	0.49	1.80	-1.18	-4.55	-3.26	-2.88	-1.63	1.76
p=		.0001**	.002*	*ns*	*ns*	*ns*	.0001**	.003*	.008*	*ns*	*ns*
	False alarms (%)	0.40	2.27	3.44	4.03	1.47	2.75	3.20	0.85	1.87	0.89
		ns	.03	.002*	.0001**	*ns*	.01	.003*	*ns*	*ns*	*ns*
	A'	3.57	1.22	-1.85	-1.35	-2.42	-4.47	-4.43	-2.89	-2.43	0.43
		.001*	*ns*	*ns*	*ns*	.02	.0001**	.0001**	.007*	.02	*ns*
					Total						
t(27) =	*A'*	2.16	1.72	-3.10	-1.96	-0.81	-4.13	-3.59	-5.28	-3.59	0.36
p=		*0.04*	*ns*	.006*	*ns*	*ns*	.0001**	.001*	.0001**	.001*	*ns*
	B''_D	-6.92	-7.10	-5.40	-4.92	-0.56	1.81	1.75	2.54	2.18	0.17
		.0001**	.0001**	.0001**	.0001**	*ns*	*ns*	*ns*	.02	.04	*ns*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks.

*p<0.01, **p<0.001

Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

Experiment 5 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed a significant main effect of Item Type only. There were no significant interactions (Table 5a). As there was no significant interaction between Item Type and Category Practiced, planned comparisons to examine RIF and facilitation are reported for Item Type collapsed across Category Practiced.

The mixed model ANOVA (Table 5a) on the Experimental group False alarms revealed a significant main effect of Item Type only. There were no significant interactions. As there was no Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means collapsed across categories practiced.

The mixed model ANOVA (Table 5a) on Experimental Group B''_D showed a significant Item Type by Category Practiced interaction, with a greater conservative bias towards Rp-Colour objects in the Probes and Tubes category. Planned comparisons were carried out to specifically examine facilitation and RIF, separately across Categories Practiced.

Table 5b shows the mean hits, false alarms, and B''_D for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Table 5a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 5.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
Dependent measure	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*
Hits (%)	9.70**	547	0.36	1118	0.81	1118	2.09	547	0.10	547	0.001	1118	0.67	547
False alarms (%)	4.04*	292	0.48	629	0.01	629	1.30	292	1.02	292	1.33	629	0.82	292
B''_D	10.98**	0.22	0.37	0.24	1.31	0.24	2.52*	0.22	1.05	0.22	0.13	0.24	1.60	0.22

*$p<0.05$, **$p<0.001$

RIF. There was no significant within-participant RIF for Rp-Both or for Rp-Neither objects. However there was significant within-participant RIF for Rp-Colour and Rp-Shape objects. Comparison amongst the four Rp- conditions revealed no significant differences between any of the Rp- conditions. There was significant between-participant RIF for Rp-Shape and Rp-Both objects, but not for Rp-Colour and Rp-Neither objects.

There were higher false alarm rates for the Rp-Shape objects compared to the Nrp objects. There were no significant differences between the Nrp and any other Rp- condition. Comparisons amongst the four Rp- conditions revealed no significant differences. There were significantly higher false alarms for Rp-Shape, and Rp-Both items in the Control group compared to the Experimental group. There were no other significant differences in false alarms between the two groups.

In terms of B''_D, for the Ballerinas and Mowers category, there were no significant differences in response bias within the Experimental Group, or between the experimental and Control Group.

For the Probes and Tubes category, only Rp-Colour and Rp-Shape objects were responded to more conservatively relative to the Nrp objects. Experimental and Control Group comparisons, showed that Rp-Colour, Rp-Shape and Rp-Both objects were responded to more conservatively in the Experimental Group compared to the Control Group. There was no difference in B''_D for Rp-Neither objects between Experimental and Control Groups.

Facilitation. With respect to hits, Rp+ objects were remembered significantly better than Experimental Nrp objects, and Control group Rp+ objects.

There was no significant difference in false alarms between the Experimental group Rp+ objects compared to the Experimental group Nrp objects, or the Control group Rp+ objects.

In terms of B''_D, responses to Rp+ objects were significantly more liberal than to Nrp objects. However, there was no significant difference in B''_D between Experimental Group Rp+ objects and Control Group Rp+ objects.

Speed-accuracy trade-off analysis. There was a weak but significant correlation between *A'* scores and response times to objects in Experiment 5, r (168) = 0.19, $p = 0.01$, with slightly faster responses to incorrectly recognised Rp- objects.

Confidence Ratings. Experimental participants showed significant increased confidence ratings in their responses to the Rp+ objects compared to Nrp, Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects. There was significantly lower confidence ratings for Rp-Both objects compared to Nrp, Rp-Colour and Rp-Neither objects. Confidence ratings for responses to Rp-Shape objects were lower compared to confidence in responses to Nrp, Rp-Colour, and Rp-Neither objects. Finally, confidence ratings for Rp-Colour responses were higher compared to confidence ratings for Nrp objects. There were no other significant differences in confidence ratings (Table 5b).

Table 5b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 5 Test Phase. Hits and False alarms are presented by Item Type collapsed across Category Practiced and collapsed across Key Response. B''_D is presented by Item Type and by Category Practiced and collapsed across Key Response. Confidence ratings are reported for the Experimental Group and are presented by Item Type only.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Hits							
Exp.	*M*	68.21	92.86	57.14	53.57	66.07	67.86						
Group	*SD*	*(18.97)*	*(13.36)*	*(29.55)*	*(30.97)*	*(26.54)*	*(26.23)*						
Control	*M*		79.91	66.07	68.30	81.70	72.77						
Group	*SD*		*(17.46)*	*(19.50)*	*(20.83)*	*(16.83)*	*(18.65)*						
Within	*t(27)=*		-5.36[f]	2.46	2.29	0.39	0.12	0.55	1.10	-1.84	1.53	1.89	-0.27
comp	*p=*		.0001**	.02*	.03*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between	*t(54)=*	-1.25	3.12	-1.34	2.09	-2.63	-0.81						
comp	*p=*	*ns*[Δ]	.003*[f]	*ns*	.04*	.01*	*ns*						
						False alarms							
Exp.	*M*	18.21	27.68	13.39	9.82	12.50	12.50						
Group	*SD*	*(12.71*	*(26.65)*	*(20.95)*	*(14.17)*	*(14.43)*	*(18.63)*						
Control	*M*		33.93	18.75	18.30	23.21	17.86						
Group	*SD*		*(21.48)*	*(20.83)*	*(16.13)*	*(16.91)*	*(17.82)*						
Within	*t(27)=*		-1.64	1.22	3.25	1.59	1.47	1.07	-0.21	0.21	0.72	0.83	0.00
comp	*p=*		*ns*[f]	*ns*	.003*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between	*t(54)=*	-1.24	-0.97	-0.96	-2.09	-2.55	-1.10						
comp	*p=*	*ns*[Δ]	*ns*	*ns*	.04*	.01*	*ns*						
						B''_D scores for Ballerinas and Mowers							
Exp	*M*	0.22	-0.40	0.15	0.41	0.45	0.46						
Group	*SD*	*(0.47)*	*(0.41)*	*(0.48)*	*(0.58)*	*(0.50)*	*(0.37)*						
Control	*M*		-0.30	0.07	0.18	0.13	0.16						
Group	*SD*		*(0.45)*	*(0.61)*	*(0.61)*	*(0.51)*	*(0.55)*						

Within comp	*t(13)=*		4.27	0.52	1.08	1.13	1.92	1.29	1.80	2.06	0.15	0.26	0.08
	p=		.001**	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comp	*t(40)=*	1.40	0.74	0.42	1.19	1.89	1.83						
	p	*ns*$^{\Delta}$	*ns*	*ns*	*ns*	*ns*	*ns*						
B''_D scores for Probes and Tubes													
Exp Group	*M*	0.25	-0.26	0.63	0.55	0.23	0.16						
	SD	*(0.51)*	*(0.41)*	*(0.37)*	*(0.58)*	*(0.56)*	*(0.56)*						
Control Group	*M*		-0.14	0.35	0.21	-0.30	0.13						
	SD		*(0.60)*	*(0.47)*	*(0.54)*	*(0.43)*	*(0.55)*						
Within comp	*t(13)=*		4.27	3.20	3.03	0.06	0.43	1.06	1.78	3.00	1.45	2.30	0.30
	p=		.001**	.007*	.01*	*ns*	*ns*	*ns*	*ns*	.01*	*ns*	.04*	*ns*
Between comp	*t(40)=*	1.40	0.72	1.99	2.12	3.42	0.18						
	p=	*ns*$^{\Delta}$	*ns*	.05*	.04*	.001**	*ns*						
Confidence Ratings													
Conf Ratings	*M*	3.97	4.52	4.15	3.74	3.79	4.14						
	SD	*(1.56)*	*(1.63)*	*(1.61)*	*(1.54)*	*(1.52)*	*(1.47)*						
Conf Ratings comp	*t(27)=*		3.43	2.03	2.41	2.53	1.38	3.16	3.12	0.07	0.48	3.06	2.74
	p=		.002*	.05*	.02*	.02*	*ns*	.004*	.004*	*ns*	*ns*	.005*	.01*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the control and experimental group Hits, false alarms, and B''_D (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Both [Rp-B] = objects that share shape and colour with the Rp+ objects. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Recognition practice analysis

Recognition practice in Experiment 5 was successful, with target objects being successfully discriminated from distractor objects (*Hit* = 93.45, *SD* = 8.76; *A'* = .88, *SD* = .10). Cell means appear in Table 5c.

Table 5c: Mean Hits, False alarms, *A'*, and B''_D (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 5.

	Category Practiced	Hits (%)	False Alarms (%)	*A'*	B''_D
Phase 1	Ballerinas and Mowers	89.88 *(10.93)*	22.02 *(12.91)*	0.88 *(0.06)*	-0.31 *(0.37)*
	Probes and Tubes	86.90 *(10.19)*	28.57 *(14.88)*	0.85 *(0.07)*	-0.36 *(0.40)*
	Total	88.39 *(10.56)*	25.30 *(13.89)*	0.87 *(0.06)*	-0.34 *(0.38)*
Phase 2	Ballerinas and Mowers	85.71 *(16.80)*	13.10 *(18.11)*	0.84 *(0.23)*	0.04 *(0.47)*
	Probes and Tubes	85.12 *(13.55)*	19.05 *(13.25)*	0.88 *(0.06)*	-0.15 *(0.49)*
	Total	85.42 *(15.18)*	16.07 *(15.68)*	0.86 *(0.15)*	-0.05 *(0.48)*
Phase 3	Ballerinas and Mowers	91.67 *(16.01)*	11.31 *(14.47)*	0.91 *(0.11)*	-0.12 *(0.36)*
	Probes and Tubes	93.45 *(8.76)*	15.48 *(15.63)*	0.91 *(0.07)*	-0.28 *(0.35)*
	Total	92.56 *(12.39)*	13.39 *(15.05)*	0.91 *(0.09)*	-0.20 *(0.35)*
Total	Ballerinas and Mowers	89.09 *(14.58)*	15.48 *(15.17)*	0.88 *(0.13)*	-0.13 *(0.40)*
	Probes and Tubes	88.49 *(10.83)*	21.03 *(14.58)*	0.88 *(0.07)*	-0.27 *(0.41)*
	Total	88.79 *(12.71)*	18.25 *(14.88)*	0.88 *(0.10)*	-0.20 *(0.40)*

The ANOVA results are reported in Table 5d. For the hits the ANOVA revealed no significant main effects and no significant interaction. For False alarms scores, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 2 [t (27)= 3.16, p= .004], and from Phase 1 to Phase 3 [t (27)= 3.70, p= .001]. There were no other significant differences. For *A'* scores the ANOVA showed no significant main effects and no significant interaction. For B''_D scores, only Recognition Practice Phase had a significant main effect, with responses becoming more conservative from Phase 1 to Phases 2, t (27) = -2.76, p = .01.

Table 5d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 5.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	3.98*	90.56	0.02	330	0.44	90.56
False alarms (%)	9.34**	117	1.48	439	0.09	117
A'	2.73	0.01	0.00	0.02	1.05	0.01
B''_D	4.29*	0.13	1.64	0.24	0.27	0.13

*p<0.05, **p<0.001

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Control Group hits, false alarms, and B''_D revealed no significant difference between the experimental group Nrp items and the control group scores (See Table 5e).

Repeated-measures ANOVAs. The repeated-measures ANOVA (Table 5e) on the Control Group hits revealed a significant main effect of Item Type only. Planned comparisons revealed significantly higher hit rates for Rp+ objects compared to Rp-Colour and Rp-Shape objects. There were significantly higher hits for Rp-Both objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects. There were also significantly higher hit rates for Rp-Neither items compared to Rp-Colour items. There were no other significant differences between the Rp objects (Table 5f).

The repeated-measures ANOVA on the Control Group False alarms revealed a significant interaction between Item Type and Category (See Table 5e). For the Ballerinas and Mowers category paired samples t-tests for Rp conditions revealed significantly higher false alarms for Rp+

objects compared to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects. There were no other significant differences between the Rp- objects. For the Probes and Tubes category there were significantly higher false alarms for Rp+ objects compared to Rp-Shape objects. There were significantly higher false alarms for Rp-Both objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects. There were no other significant differences (Table 5f).

The same ANOVA on B''_D revealed a significant Item Type by Category interaction (Table 5e), with a more conservative bias towards Rp-Colour objects in the Probes and Tubes category compared to the same objects in the Ballerinas and Mowers category, and a more conservative bias towards Rp-Both objects in the Ballerinas and Mowers category compared to the same objects in the Probes and Tubes category. Within the Ballerinas and Mowers category paired samples t-tests revealed a significantly liberal bias towards Rp+ objects compared to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects. Within the Probes and Tubes category there was a significantly liberal bias towards Rp+ objects compared to Rp-Colour and Rp-Shape objects, a significantly liberal bias towards Rp-Both objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects, and a significantly liberal bias towards Rp-Neither objects compared to Rp-Colour objects (Table 5f).

Table 5e: Item Type X Category ANOVA statistics for the Control Group in Experiment 5.

	Item Type		Category		Item Type X Category	
Dependent measure	$F(4, 108)$	*MSE*	$F(1, 27)$	*MSE*	$F(4, 108)$	*MSE*
Hits (%)	6.56**	407	1.42	308	2.06	554
False alarms (%)	5.32*	485	3.03	389	6.37**	294
A'	1.49	0.02	3.13	0.01	1.73	0.02
B''_D	8.19**	0.25	0.00	0.19	4.43*	0.23

*$p<0.05$, **$p<0.001$

Table 5f: Control Group paired samples t-test statistics for False alarms and B''_D by Item Type and Category and for Hits by Item Type collapsed across Category for Experiment 5.

Statistic	Measure	Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
					Ballerinas and Mowers						
$t(27) =$	*False alarms (%)*	4.20	3.66	6.03	4.29	0.000	1.30	0.14	1.24	0.14	-0.69
$p=$		.0001**	.001*	.0001**	.0001**	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
	B''_D	-2.76	-3.56	-4.18	-4.40	-0.80	-0.52	-0.53	0.36	0.13	0.21
		.01	.001*	.0001**	.0001**	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
					Probes and Tubes						
$t(27) =$	*False alarms (%)*	1.44	2.50	-0.92	1.83	0.17	-2.46	0.18	-3.12	0.000	3.23
$p=$		*ns*	.02	*ns*	*ns*	*ns*	.02	*ns*	.004*	*ns*	.003*
	B''_D	-3.28	-2.54	1.17	-1.79	1.06	6.05	2.48	4.54	0.52	-4.02
		.003*	.02	*ns*	*ns*	*ns*	.0001**	.02	.0001**	*ns*	.0001**
					Total						
$t(27) =$	*Hit*	3.43	2.72	-0.56	1.84	-0.48	4.02	-2.15	3.58	1.14	2.84
$p=$		.002*	.01	*ns*	*ns*	*ns*	.0001**	.04	.001*	*ns*	.008*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks.

*$p<0.01$, **$p<0.001$

Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

Experiment 6 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed a significant main effect of Item Type only. There were no significant interactions (Table 6a). As there was no significant interaction between Item Type and Category Practiced, planned comparisons to examine RIF and facilitation are reported for Item Type collapsed across Category Practiced.

For the false alarms there was a significant main effect of Item Type. There was no significant main effect of Category Practiced, and no significant main effect of Key Response. There was a significant interaction between Item Type and Category Practiced, and a significant interaction between Category Practiced and Key Response (Table 6a). There were no other significant interactions. As there was an Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means separately across categories practiced. Key Response was not of current theoretical interest therefore planned comparisons were carried out collapsed across response key.

The mixed model ANOVA on B''_D scores (Table 6a) showed a significant main effect of Item Type only. Planned comparisons were carried out to specifically examine facilitation and RIF, collapsed across Categories Practiced

Table 6b shows the mean hit, false alarm, and B''_D scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Table 6a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 6.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
Dependent measure	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*
Hits (%)	33.44**	485	0.06	1204	0.00	1204	0.91	485	0.40	485	0.96	1204	1.71	485
False alarms (%)	4.01*	245	0.15	429	0.01	429	3.04*	245	0.42	245	5.77*	429	0.81	245
B''_D	18.23**	0.14	0.30	0.33	0.02	0.33	2.34	0.14	0.30	0.14	0.79	0.33	1.31	0.14

*$p<0.05$, **$p<0.001$

RIF. There was significant within- and between- participant RIF for all four of the Rp- conditions. Comparison amongst the four Rp- conditions revealed significantly better recognition for Rp-Both objects compared to Rp-Shape objects, and significantly better recognition for Rp-Colour objects compared to Rp-Neither and Rp-Shape objects. There were no other significant differences between the Rp- objects.

In terms of false alarms, for the Tables and Chairs group planned comparisons showed that there were significantly higher false alarms for the Nrp objects compared to Rp-Both and Rp-Neither objects. There were no significant differences in false alarms between the Nrp and the Rp-Colour and Rp-Shape objects. Comparison amongst the four Rp- items revealed significantly higher false alarms for the Rp-Shape objects compared to the Rp-Both objects. There were no other significant differences in false alarms. Finally, there were no significant differences in false alarms between the Experimental and Control Groups.

For the Lamps and Pots group planned comparisons showed that there was significantly lower false alarms for Rp-Shape objects compared to Nrp, Rp-Both, Rp-Colour, and Rp-Neither objects. There were no other significant differences in false alarms. There were significantly higher false alarms for Rp-Shape, and Rp-Both objects in the Control group compared to the Experimental group. There were no other significant differences in false alarms between the Experimental and Control Groups.

In terms of B''_D, participants responded more conservatively (more likely to say 'No') to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects relative to Nrp objects, and relative to all Control Group Rp- objects.

Table 6b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 6 Test Phase. Hits and B''_D are presented by Item Type collapsed across Category Practiced and collapsed across Key Response. False alarms are presented by Item Type separately across Category Practiced and collapsed across Key Response. Confidence ratings are reported for the Experimental Group only.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
Total Hits													
Exp.	*M*	70.89	91.96	55.36	24.11	50.89	37.50						
Group	*SD*	*(12.99)*	*(13.70)*	*(32.17)*	*(25.89)*	*(25.89)*	*(28.46)*						
Control	*M*		88.84	76.79	57.59	82.59	60.27						
Group	*SD*		*(11.46)*	*(19.16)*	*(19.94)*	*(14.17)*	*(18.34)*						
Within	*t(27)=*		-5.88[f]	2.76	9.25	4.00	6.15	4.54	-0.61	3.38	6.03	1.86	1.92
comp	*p=*		.0001**	.01*	.0001**	.0001**	.0001**	.0001**	*ns*	.002*	.0001**	*ns*	*ns*
Between	*t(54)=*	-0.72	0.93	-3.03	-5.42	-5.68	-3.56						
comp	*p=*	*ns*[Δ]	*ns*	.004*	.0001**	.0001**	.001*						
Tables and Chairs False alarms													
Exp.	*M*	24.64	10.71	14.29	19.64	5.36	10.71						
Group	*SD*	*(11.17*	*(18.90)*	*(18.90)*	*(20.05)*	*(14.47)*	*(23.44)*						
Control	*M*		9.82	18.75	28.57	16.96	12.50						
Group	*SD*		*(19.65)*	*(19.98)*	*(17.63)*	*(22.62)*	*(17.35)*						
Within	*t(13)=*		5.13	2.06	1.02	3.97	2.39	-0.76	-1.24	0.43	-2.51	-1.33	-0.90
comp	*p=*		.0001**	*ns*	*ns*	.002*	0.03*	*ns*	*ns*	*ns*	.03*	*ns*	*ns*
Between	*t(40)=*	1.44	0.14	-0.70	-1.48	-1.74	-0.28						
comp	*p=*	*ns*[Δ]	*ns*	*ns*	*ns*	*ns*	*ns*						
Lamps and Pots False alarms													
Exp.	*M*	24.29	3.57	16.07	1.79	17.86	14.29						
Group	*SD*	*(14.26*	*(9.08)*	*(15.83)*	*(6.68)*	*(22.85)*	*(16.16)*						
Control	*M*		19.64	25.00	14.29	44.64	10.71						
Group	*SD*		*(21.90)*	*(23.57)*	*(19.75)*	*(27.52)*	*(17.25)*						
Within	*t(13)=*		5.13	1.48	5.18	1.63	1.78	3.31	0.22	0.32	2.59	2.46	0.49
comp	*p=*		.0001**	*ns*	.0001**	*ns*	*ns*	.006*	*ns*	*ns*	.02*	.03*	*ns*

Between comp	*t(40)=*	1.44	-2.62	1.28	-2.29	-3.14	0.65						
	p=	*ns*$^{\Delta}$	.01*	*ns*	.03*	.003*	*ns*						
						B''_D scores							
Exp Group	*M*	0.10	0.03	0.40	0.77	0.53	0.65						
	SD	*(0.42)*	*(0.39)*	*(0.50)*	*(0.32)*	*(0.46)*	*(0.34)*						
Control Group	*M*		-0.04	-0.00	0.31	-0.20	0.44						
	SD		*(0.33)*	*(0.46)*	*(0.36)*	*(0.36)*	*(0.34)*						
Within comp	*t(27)=*		0.74	2.87	6.94	4.54	5.67	3.47	1.04	2.71	2.54	1.44	1.16
	p=		*ns*	.008*	.001**	.001*	.001**	.002*	*ns*	.01*	.02*	*ns*	*ns*
Between comp	*t(54)=*	0.59	0.70	3.10	4.98	6.64	2.26						
	p=	*ns*$^{\Delta}$	*ns*	.003*	.001**	.001*	.03*						
						Confidence Ratings							
Conf Ratings	*M*	3.82	4.64	4.06	3.92	4.01	4.07						
	SD	*(1.53)*	*(1.40)*	*(1.52)*	*(1.54)*	*(1.59)*	*(1.57)*						
Conf Ratings comp	*t(27)=*		5.98	2.05	0.67	1.45	2.07	0.76	0.30	0.07	0.53	1.11	0.33
	p=		.001**	.05*	*ns*	*ns*	.05*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the control and experimental group hits, false alarms, and B''_D (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Both [Rp-B] = objects that share shape and colour with the Rp+ objects. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Facilitation. In terms of hits, Rp+ objects were remembered significantly better than Experimental Nrp objects, but not any better than Control group Rp+ objects. While for false alarms, there were significantly higher false alarms for Nrp objects compared to Rp+ objects. However, there was no significant difference in false alarms between the Control group Rp+ objects and the Experimental group Rp+ objects. There was no difference in B''_D between experimental Rp+ objects compared to Nrp objects, or compared to Control Group Rp+ objects.

Speed-accuracy trade-off analysis. There was no significant correlation between A' scores and response times to objects in Experiment 6, $r\ (168) = 0.04, p > 0.05$.

Confidence ratings. Experimental participants gave higher confidence ratings to Rp+ objects compared to Nrp, Rp-Colour, Rp-Shape, and Rp-Both objects. Confidence ratings for Nrp objects were significantly lower compared to Rp-Colour and Rp-Neither objects (Table 6b).

Recognition practice analysis

Recognition practice in Experiment 6 was successful (Table 6c), with target objects being successfully discriminated from distractor objects (*Hit*=89.88, *SD*=11.41; A' = .85, *SD* = .10).

Table 6c: Mean Hits, False alarms, A', and B''_D (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 6.

	Category Practiced	Hits (%)	False Alarms (%)	A'	B''_D
Phase 1	Tables and Chairs	85.71 *(9.49)*	28.57 *(14.88)*	0.84 *(0.07)*	-0.32 *(0.42)*
	Lamps and Pots	89.88 *(11.41)*	32.14 *(15.63)*	0.84 *(0.09)*	-0.53 *(0.27)*
	Total	87.80 *(10.45)*	30.36 *(15.52)*	0.84 *(0.08)*	-0.42 *(0.35)*
Phase 2	Tables and Chairs	83.93 *(12.43)*	22.02 *(18.95)*	0.86 *(0.08)*	-0.13 *(0.52)*
	Lamps and Pots	83.93 *(15.83)*	28.57 *(11.19)*	0.83 *(0.12)*	-0.36 *(0.36)*
	Total	83.93	25.30	0.84	-0.25

		(14.13)	*(15.07)*	*(0.10)*	*(0.44)*
Phase 3	Tables and Chairs	85.12	19.64	0.87	-0.13
		(10.93)	*(14.84)*	*(0.08)*	*(0.27)*
	Lamps and Pots	83.93	16.07	0.87	0.04
		(12.43)	*(17.74)*	*(0.13)*	*(0.53)*
	Total	84.52	17.86	0.87	-0.04
		(11.68)	*(16.29)*	*(0.11)*	*(0.40)*
Total	Tables and Chairs	84.92	23.41	0.86	-0.19
		(10.95)	*(16.22)*	*(0.08)*	*(0.40)*
	Lamps and Pots	85.91	25.60	0.85	-0.28
		(13.22)	*(14.85)*	*(0.12)*	*(0.39)*
	Total	85.42	24.50	0.85	-0.24
		(12.09)	*(15.54)*	*(0.10)*	*(0.40)*

The ANOVA results are reported in Table 6d. For the Hits the ANOVA revealed no significant main effects and no significant interaction. For False alarms scores, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 3 [t (27)= 5.20, p= .0001], and from Phase 2 to Phase 3 [t (27)= 2.25, p= .03]. There were no other significant differences. For *A'* scores the ANOVA revealed no significant effects. For B''_D scores, only Recognition Practice Phase had a significant main effect, with responses becoming more conservative from Phase 1 to Phases 2, t (27) = -2.02, p = .05, and from Phase 1 to Phase 3, t (27) = -3.94, p = .001.

Table 6d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 6.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	1.51	80.45	0.07	289	0.69	80.45
False alarms (%)	8.95**	124	0.20	495	1.53	124
A'	1.25	0.01	0.11	0.02	0.58	0.01
B''_D	7.80**	0.13	0.76	0.24	2.69	0.13

*p<0.05, **p<0.001

Control Group analyses

Control Group mean Vs. Experimental Group Nrp. Control Group hits, false alarms, and B''_D revealed no significant difference between the Experimental group Nrp items and the Control Group scores (See Table 6b).

Repeated-measures ANOVAs. The repeated-measures ANOVA (Table 6e) on the Control Group hits revealed a significant main effect of Item Type only. Planned comparisons revealed significantly higher hit rates for Rp+ objects compared to Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither objects. There were significantly higher hits for Rp-Both objects compared to Rp-Shape and Rp-Neither objects. There were also significantly higher hits for Rp-Colour objects compared to Rp-Shape and Rp-Neither objects. There were no other significant differences (Table 6f).

The repeated-measures ANOVA on the Control Group false alarms revealed a significant main effect of Item Type, a significant main effect of Category, and a significant interaction between Item Type and Category (See Table 6e). For the Tables and Chairs category paired samples t-tests for Rp conditions revealed significantly higher false alarms for Rp-Shape objects compared to Rp+, Rp-Colour, Rp-Both, and Rp-Neither objects. There were also significantly higher false alarms for Rp-Colour objects compared to Rp+ objects. There were no other significant differences. For the Probes and Tubes category there was significantly higher false alarms for Rp-Both objects compared to Rp+, Rp-Colour, Rp-Shape, and Rp-Neither objects. There were significantly higher false alarms for Rp-Colour objects compared to Rp-Shape and Rp-Neither objects. There were also significantly higher false alarms for Rp+ objects compared to Rp-Neither objects. There were no other significant differences (Table 6f).

The Control Group repeated-measures ANOVA on B''_D revealed a significant Item Type by Category interaction (Table 6e), with a more conservative response bias towards Rp+ and Rp-Both objects in the Tables and Chairs category compared to the Lamps and Pots category. Within the Tables and Chairs category paired samples t-tests revealed a significantly liberal bias towards Rp-Colour and Rp-Both objects compared to Rp-Shape and Rp-Neither objects. For the Lamps and Pots category there was a significantly liberal bias towards Rp+ and Rp-Colour objects compared to Rp-Shape and Rp-Neither objects, and a significantly liberal bias towards Rp-Both objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects (Table 6f).

Table 6e: Item Type X Category ANOVA statistics for the Control Group in Experiment 6.

	Item Type		Category		Item Type X Category	
Dependent measure	$F(4, 108)$	*MSE*	$F(1, 27)$	*MSE*	$F(4, 108)$	*MSE*
Hits (%)	25.34**	418	0.08	438	1.43	462
False alarms (%)	7.59**	407	4.05*	529	10.75**	311
A'	11.84**	0.02	3.94	0.02	8.18*	0.02
B''_D	23.35**	0.17	1.44	0.26	4.19*	0.20

*p<0.05, **p<0.001

Table 6f: Control Group paired samples t-test statistics for False alarms, *A'*, and B''_D by Item Type and Category and for Hits by Item Type collapsed across Category for Experiment 6.

Statistic	Measure	Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Tables and Chairs					
t(27) =	*False alarms (%)*	-2.07	-4.97	-1.69	-0.50	-2.27	0.36	1.37	2.66	3.20	-1.23
p=		.05	.0001**	*ns*	*ns*	.03	*ns*	*ns*	.01	.003*	*ns*
	A'	2.33	7.06	0.86	4.22	5.29	-0.73	2.05	-5.71	-4.70	2.37
		.03	.0001**	*ns*	.0001**	.0001**	*ns*	*ns*	.0001**	.0001**	.03
	B''_D	1.32	-1.04	1.58	-1.59	-2.32	0.19	-3.54	2.57	-1.08	-2.84
		ns	*ns*	*ns*	*ns*	.03	*ns*	.001*	.02	*ns*	.008*
						Lamps and Pots					
t(27) =	*False alarms (%)*	-0.95	1.24	-4.24	2.07	2.27	-2.92	2.59	-5.11	0.78	5.60
p=		*ns*	*ns*	.0001**	.05	.03	.007*	.02	.0001**	*ns*	.0001**
	A'	4.19	2.88	4.74	3.78	0.01	1.37	-0.43	1.37	-0.33	-1.76
		.0001**	.008*	.0001**	.001*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
	B''_D	-1.88	-7.72	1.58	-9.24	-2.64	2.68	-4.33	6.18	-1.31	-8.78
		ns	.0001**	*ns*	.0001**	.01	.01	.0001**	.0001**	*ns*	.0001**
						Total					
t(27) =	*Hit*	4.77	7.55	2.32	7.75	4.25	1.40	4.06	5.73	0.65	5.84
p=		.0001**	.0001**	.03	.0001**	.0001**	*ns*	.0001**	.0001**	*ns*	.0001**
	A'	4.95	6.45	4.66	4.73	3.39	0.74	0.74	-2.50	-2.48	-0.12
		.0001**	.0001**	.0001**	.0001**	.002*	*ns*	*ns*	.02	.02	*ns*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks.

*p<0.01, **p<0.001

Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

Comparison of Item Type between Experiments 3 and 6.

A comparison of Item Type between Experiments 3 and 6 was conducted in order to examine the cause of the better accuracy for Rp+ objects compared to all other Rp- objects in Experiment 6. It was suggested that the addition of the Rp-Both condition in Experiment 6 boosted the encoding and subsequently the memory of the Rp+ objects, since they shared the same features (shape and colour) with the Rp-Both objects. The comparisons appear in the table below (Rp-Both was not included in the comparisons, as this condition was not present in Experiment 3).

Table 6g: Comparison of Control Group Rp objects between Experiments 3 and 6.

Statistic	Measure	Rp+	Rp-Colour	Rp-Shape	Rp-Neither
t (54) =	*A'*	-5.08	-1.53	2.03	2.80
p =		.0001**	*ns*	.04*	.007*

**p<.05, **p<.01*

Comparison between Experiments 4 and 6

Test Phase Analyses

A mixed model ANOVA on the Experimental Group hits RIF magnitude with Experiment (4 vs. 6) as the between-participants factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both and Rp-Neither) as the within-participants factor revealed a significant main effect of Experiment, F (1, 54) = 16.57, p = .0001, a significant main effect of Rp- condition, F (3, 162) = 13.03, p = .0001, and a significant interaction, F (3, 162) = 5.27, p = .03. There was significantly more RIF for Rp-Shape in Experiment 6 compared to Experiment 4, t (54) = -1.99, p = 0.05, while there was significant more RIF for Rp-Colour objects in Experiment 4 compared to Experiment 6, t (54) = 2.92, p = 0.005. For Rp-Neither objects, RIF magnitude was larger in Experiment 6 compared to Experiment 4, t (54) = -

6.60, p = 0.0001, while there was no difference in RIF magnitude between experiments for Rp-Both objects, t (54) = -0.93, p > 0.05.

Finally, to ensure that any differences in RIF between the two experiments were not due to a change in task difficulty, a comparison of Nrp hits between the experiments was carried out, which showed no significant difference, t (54) = 1.52, p > .05.

A mixed model ANOVA on the Experimental Group false alarms with Experiment (4 vs. 6) as the between-participant factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both, Rp-Neither) as the within-participant factor revealed no significant main effect of Experiment, F (1, 54) = 1.73, P > 0.05, no significant main effect of Rp- condition, F (3, 162) = 1.02, P > 0.05, and no significant interaction between Experiment and Rp- condition, F (3, 162) = 0.30, P > 0.05.

A mixed model ANOVA on B''_D scores with Experiment (4 vs. 6) as the between-participant factor, and Rp-Condition (Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither) as the within-participants factor. There was no significant main effect of Experiment, F (1, 54) = 2.51, p>.05, but there was a significant main effect of Rp-Condition, F (3, 162) = 7.78, p<.001, and a significant interaction, F (3, 162) = 12.32, p<.001. Independent-samples t-tests showed that B''_D for Rp-Colour was *less conservative* in Experiment 6 compared to Experiment 4, t (54) = 2.42, p=.02. The only other difference was in Rp-Neither B''_D scores, which were more conservative in Experiment 6 than in Experiment 4, t (54) = 5.20, p<.001.

Recognition Phase analyses

Independent samples t-tests revealed significantly higher hits in Experiment 4 compared to Experiment 6, t (52) = 2.64, p = .01; significantly more false alarms in Experiment 6 compared to Experiment 4, t (52) = -3.40, p = .001; significantly better recognition in terms of A' in Experiment

4 compared to Experiment 6, t (52) = 2.87, p = .006; and a significantly greater liberal bias in Experiment 6 compared to Experiment 4, t (52) = 2.82, p = .007.

Experiment 7 Results

Test Phase Analyses

Experimental Group analyses

Mixed model ANOVAs. The mixed model ANOVA on the hits revealed a significant main effect of Item Type only. There were no significant interactions (see Table 7a). As there was no significant interaction between Item Type and Category Practiced, planned comparisons to examine RIF and facilitation are reported for Item Type collapsed across Category Practiced.

The mixed model ANOVA (Table 7a) on the Experimental Group false alarms revealed no significant main effect of Item Type. However, there was a significant main effect of Category Practiced, with significantly higher false alarms in the Ballerinas and Mowers group compared to the Probes and Tubes group. There was no significant main effect of Key Response, and no significant interactions. As there was no Item Type by Category Practiced interaction, planned comparisons to examine RIF and facilitation were carried out on Item Type means collapsed across categories practiced.

The mixed model ANOVA (Table 7a) on B''_D showed a significant three-way interaction between Item Type, Category Practiced, and Key Response, with participants who responded 'Yes' with their left hand in the Probes and Tubes category showing a significantly more conservative than those who responded 'Yes' with their left hand in the Ballerinas and Mowers category for the Rp+ objects.

Table 7a: Item Type X Category Practiced X Key Response ANOVA statistics for the Experimental Group in Experiment 7.

	Item Type		Category Practiced		Key Response		Item Type X Category Practiced		Item Type X Key Response		Category Practiced X Key Response		Item Type X Key Response X Category Practiced	
Dependent measure	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*	*F* (5, 120)	*MSE*	*F* (1, 24)	*MSE*	*F* (5, 120)	*MSE*
Hits (%)	13.26**	448	0.86	1215	0.86	1215	0.24	448	0.27	448	2.20	1215	1.89	448
False alarms (%)	0.94	353	7.70*	861	2.05	861	0.78	353	0.15	353	1.13	861	1.27	353
B''_D	8.47**	0.17	1.69	0.38	3.08	0.38	0.67	0.17	0.27	0.17	0.07	0.38	2.31*	0.17

*$p<0.05$, **$p<0.001$

RIF. There was significant within-participant RIF for Rp-Shape and Rp-Neither objects, but not for Rp-Colour and Rp-Both objects. Comparison amongst the four Rp- conditions revealed significantly better recognition for Rp-Colour and Rp-Both objects compared to Rp-Shape objects. There were no other significant differences between Rp- objects. Finally, there was significant between-participant RIF for all four of the Rp- objects.

Using false alarms as the dependant measure, there was significantly higher false alarms for Nrp objects compared to Rp-Both and Rp-Neither objects. There were no other significant differences between the Nrp and the Rp- objects. Comparisons amongst the four Rp- conditions revealed no significant differences. Finally, there were no significant differences in false alarms for any of the Rp conditions between the Experimental and Control Groups.

Using B''_D as the dependent measure, Rp-Shape, Rp-Both, and Rp-Neither objects were responded to more conservatively relative to Nrp objects, and relative to Control Group Rp- objects. There was no significant difference in bias between Rp-Colour objects relative to Nrp objects or Control Group Rp-Colour objects. The latter result suggests that changing the distractors (to no longer disadvantage Rp-Colour objects) eliminated the response bias between Rp-Colour and the two baselines (Nrp and Control Group Rp-Colour).

Facilitation: In terms of hits, Rp+ objects were remembered significantly better than Experimental Nrp objects. However there was no significant difference between Experimental group Rp+ objects and Control group Rp+ objects.

For the false alarms, there was no significant difference between Rp+ objects and Nrp objects, or between Experimental group Rp+ objects and Control group Rp+ objects.

For B''_D, there was a more liberal bias (participants more likely to say 'Yes') towards Rp+ relative to Nrp objects. However, there was no significant difference in bias between Experimental and Control Group Rp+ objects.

Table 7b shows the mean hits, false alarm, and B''_D scores for the Experimental and Control Group participants, as well as within- and between- participant RIF and facilitation (rows titled 'Within' and 'Between' respectively).

Speed-accuracy trade-off analysis. There was no significant correlation between A' scores and response times to objects in Experiment 7, r (168) = 0.04, $p > 0.05$.

Confidence Ratings. Table 7b shows the Confidence ratings per Item Type for the Experimental Group participants. Experimental participants had more confidence in their responses to the Rp+ compared to Nrp, Rp-Colour, Rp-Shape, and Rp-Both objects. Confidence ratings were lower for Rp-Shape compared to Nrp, Rp-Both, and Rp-Neither objects.

Table 7b: Experimental and Control Group mean, standard deviation, and t-test statistics for hits, false alarms, and B''_D from the Experiment 7 Test Phase. Hits, False alarms, and B''_D are presented by Item Type collapsed across Category Practiced and collapsed across Key Response. Confidence ratings are reported for the Experimental Group only.

	Statistic	Nrp	Rp+	Rp-Colour	Rp-Shape	Rp-Both	Rp-Neither	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Hits							
Exp. Group	*M*	64.29	84.82	58.93	41.96	58.93	50.00						
	SD	*(16.20)*	*(20.79)*	*(20.04)*	*(24.58)*	*(22.79)*	*(28.05)*						
Control Group	*M*		79.91	73.66	58.93	77.68	70.98						
	SD		*(16.44)*	*(18.11)*	*(17.96)*	*(18.74)*	*(17.70)*						
Within comp	$t(27)=$		-4.84^f	1.21	4.93	1.09	3.12	2.95	0.00	1.54	2.49	1.25	1.36
	$p=$		.0001**	*ns*	.0001**	*ns*	.004*	.007*	*ns*	*ns*	.02*	*ns*	*ns*
Between comp	$t(54)=$	-2.05	0.98	-2.28	-2.95	-3.36	-3.35						
	$p=$	.05*$^{\Delta}$	*ns*	.03*	.005*	.001*	.001*						
						False alarms							
Exp. Group	*M*	26.61	22.32	21.43	18.75	16.96	18.75						
	SD	*(13.06)*	*(30.69)*	*(20.09)*	*(22.18)*	*(19.31)*	*(21.11)*						
Control Group	*M*		26.34	18.75	22.77	18.30	21.88						
	SD		*(16.44)*	*(16.14)*	*(25.01)*	*(19.69)*	*(18.52)*						
Within comp	$t(13)=$		0.84	1.40	1.70	2.56	2.53	0.46	-0.96	0.59	-0.36	0.00	-0.39
	$p=$		*ns*	*ns*	*ns*	0.02*	0.02*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Between comp	$t(40)=$	1.35	-0.61	0.55	-0.64	-0.26	-0.59						
	$p=$	*ns*$^{\Delta}$	*ns*	*ns*	*ns*	*ns*	*ns*						
						B''_D scores							
Exp Group	*M*	0.18	-0.09	0.30	0.54	0.42	0.45						
	SD	*(0.41)*	*(0.53)*	*(0.55)*	*(0.39)*	*(0.40)*	*(0.44)*						
Control Group	*M*		-0.14	0.10	0.26	0.05	0.12						
	SD		*(0.39)*	*(0.41)*	*(0.38)*	*(0.35)*	*(0.41)*						
Within comp	$t(27)=$		2.33	1.21	3.68	2.28	3.35	2.04	0.95	1.44	1.16	0.93	0.25
	$p=$		.03*	*ns*	.001**	.03*	.002*	.05*	*ns*	*ns*	*ns*	*ns*	*ns*

Between comp	$t(54)=$ $p=$	0.25 *ns* Δ	0.42 *ns*	1.49 *ns*	2.69 .009*	3.64 .001**	2.89 .006*						
						Confidence Ratings							
Conf Ratings	*M* *SD*	3.79 *(1.69)*	4.46 *(1.72)*	3.69 *(1.70)*	3.46 *(1.57)*	3.91 *(1.68)*	3.78 *(1.73)*						
Conf Ratings comp	$t(27)=$ $p=$		6.83 .001**	0.83 *ns*	3.39 .002*	1.12 *ns*	0.12 *ns*	1.74 *ns*	1.38 *ns*	0.80 *ns*	3.76 .001*	2.46 .02*	1.04 *ns*

*$p<0.05$, **$p<0.001$, ^{f} = facilitation. $^{\Delta}$ = Experimental Nrp compared to Total Control scores.

Note: Within comparisons = Within-participants comparisons (paired-samples t-tests) between the Nrp baseline and each of the Rp conditions, as well as comparisons among the Rp- conditions. Between comparisons = Between-participants comparisons (independent-samples t-tests) between the control and experimental group hits, false alarms, and B''_D (see text for details). Rp+ = Practiced objects from the practiced category. Rp-Shape [Rp-S] = objects that share the same shape with the Rp+ object. Rp-Colour [Rp-C] = objects that share the same colour with the Rp+ object. Rp-Both [Rp-B] = objects that share shape and colour with the Rp+ objects. Rp-Neither [Rp-N] = objects that share category but not shape or colour with the Rp+ object. Response bias values above zero indicate a conservative bias (less likely to say yes to an old object), and those below zero indicate a liberal bias (more likely to respond yes to an old object).

Recognition practice analysis

Recognition practice in Experiment 7 was successful, with target objects being successfully discriminated from distractor objects (*Hit*=83.93, *SD*=21.55; *A'* = .82, *SD* = .14). Cell means appear in Table 7c.

Table 7c: Mean Hits, False alarms, *A'*, and B''_D (and their associated *SD*) per Recognition Practice Phase and per Category Practiced, for the Experimental group in Experiment 7.

	Category Practiced	Hits (%)	False Alarms (%)	*A'*	B''_D
Phase 1	Ballerinas and Mowers	78.57 *(13.36)*	38.10 *(16.57)*	0.76 *(0.14)*	-0.34 *(0.35)*
	Probes and Tubes	81.55 *(19.93)*	26.79 *(22.69)*	0.80 *(0.19)*	-0.13 *(0.48)*
	Total	80.06 *(16.65)*	32.44 *(19.63)*	0.78 *(0.16)*	-0.23 *(0.41)*
Phase 2	Ballerinas and Mowers	74.41 *(14.05)*	26.19 *(16.30)*	0.80 *(0.11)*	0.02 *(0.46)*
	Probes and Tubes	83.93 *(21.55)*	18.45 *(16.72)*	0.85 *(0.16)*	-0.12 *(0.49)*
	Total	79.17 *(17.80)*	22.32 *(16.51)*	0.82 *(0.13)*	-0.05 *(0.48)*
Phase 3	Ballerinas and Mowers	82.14 *(14.57)*	25.60 *(18.90)*	0.82 *(0.15)*	-0.14 *(0.44)*
	Probes and Tubes	83.93 *(14.05)*	9.52 *(16.30)*	0.89 *(0.12)*	0.26 *(0.35)*
	Total	83.04 *(14.31)*	17.60 *(17.60)*	0.86 *(0.13)*	0.06 *(0.40)*
Total	Ballerinas and Mowers	78.37 *(13.99)*	29.96 *(17.26)*	0.79 *(0.13)*	-0.15 *(0.42)*
	Probes and Tubes	83.13 *(18.51)*	18.25 *(18.57)*	0.85 *(0.15)*	0.01 *(0.44)*
	Total	80.75 *(16.25)*	24.11 *(17.91)*	0.82 *(0.14)*	-0.07 *(0.43)*

The ANOVA results are reported in Table 7d. For the Hits the ANOVA revealed no significant main effects and no significant interaction. For False alarms scores, only Recognition Practice Phase had a significant main effect, with a reduction in false alarms from Phase 1 to Phase 2 [t (27)= 3.76, p= .001], from Phase 1 to Phase 3 [t (27)= 4.29, p= .0001], and from Phase 2 to

Phase 3 [t (27)= 2.40, p= .02]. For A' scores the ANOVA revealed a significant main effect of Recognition Practice Phase, with higher A' in Phases 2 and 3 compared to Phase 1 [t (27) = -2.05, p = .05; t (27) = -3.47, p = .002], and in Phase 3 compared to Phase 2, t (27) = -2.06, p = .05. For B''_D scores, there was a significant main effect of Recognition Practice Phase, with responses becoming more conservative from Phase 1 to 2 and 3. There was also a significant Phase X Category Practiced interaction, with responses to Probes and Tubes being more conservative compared to Ballerinas and Mowers in Phase 3 only, t (26) = -2.69, p = .01.

Table 7d: Recognition practice Phase X Category Practiced ANOVA statistics for the Experimental Group in Experiment 7.

	Recognition practice Phase		Category Practiced		Recognition practice Phase x Category Practiced	
Dependent measure	*F (2, 52)*	*MSE*	*F (1, 26)*	*MSE*	*F (2, 52)*	*MSE*
Hits (%)	1.03	111	0.79	601	1.09	111
False alarms (%)	15.03**	108	3.78	764	1.14	108
A'	7.19*	0.01	1.31	0.05	0.16	0.01
B''_D	5.64*	0.11	1.55	0.34	4.80*	0.11

*p<0.05, **p<0.001

Control Group Analyses

Control Group mean Vs. Experimental Group Nrp. Control Group hits were significantly higher than Experimental Group Nrp scores, suggesting potential cross-category RIF for the Nrp objects in the Experimental Group. There was no significant difference between the Experimental Group Nrp false alarms and B''_D and the overall Control Group mean false alarms and B''_D (Table 7b).

Repeated-measures ANOVAs. The repeated-measures ANOVA (Table 7e) on the Control Group hits revealed a significant main effect of Item Type. There was no significant main effect of Category. However, there was a significant interaction between Item Type and Category. For the Ballerinas and Mowers category paired samples t-tests for Rp conditions revealed significantly higher accuracy for Rp+ and Rp-Colour objects compared to Rp-Shape and Rp-Neither objects. There were no other significant differences. For the Probes and Tubes category there was significantly higher accuracy for Rp+ objects compared to Rp-Colour and Rp-Shape objects. There was significantly higher accuracy for Rp-Colour and Rp-Neither objects compared to Rp-Shape objects. There was significantly higher accuracy for Rp-Both objects compared to Rp-Colour, Rp-Shape, and Rp-Neither objects. There were no other significant differences (Table 7f).

The repeated-measures ANOVA on the control group False alarms revealed no significant main effect of Item Type. There was a significant main effect of Category, with higher false alarms for Rp-Colour items in the Ballerinas & Mowers category compared to the Probes & Tubes category. There was no significant interaction between Item Type and Category (Table 7e).

The Control Group B''_D repeated-measures ANOVA (Table 7e) showed a significant Item Type by Category interaction, with a more conservative bias towards Rp-Colour and Rp-Shape objects in the Probes and Tubes category compared to the Ballerinas and Mowers category. Within the Ballerinas and Mowers category paired samples t-tests revealed a significantly liberal bias towards Rp+ objects compared to Rp-Shape, Rp-Both, and Rp-Neither objects. For the Probes and Tubes category there was a significantly liberal bias towards Rp+ and Rp-Both objects compared to Rp-Colour and Rp-Shape objects, and a significantly liberal bias towards Rp-Neither objects compared to Rp-Shape objects (Table 7f).

Table 7e: Item Type X Category ANOVA statistics for the Control Group in Experiment 7.

	Item Type		Category		Item Type X Category	
Dependent measure	$F(4, 108)$	*MSE*	$F(1, 27)$	*MSE*	$F(4, 108)$	*MSE*
Hits (%)	9.46**	399	0.42	435	6.01**	310
False alarms (%)	1.47	408	6.32*	623	0.19	280
A'	2.76*	0.02	3.39	0.03	2.41*	0.02
B''_D	6.21**	0.19	1.99	0.25	3.72*	0.15

*$p<0.05$, **$p<0.001$

Table 7f: Control Group paired samples t-test statistics for Hits, *A'*, and B''_D by Item Type and Category for Experiment 7.

Statistic	Measure	Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Ballerinas and Mowers					
t(13) =	*Hits (%)*	0.19	2.59	1.78	2.27	2.30	1.78	2.17	-0.66	-0.66	0.17
p=		*ns*	.02	*ns*	.03	.03	*ns*	.04	*ns*	*ns*	*ns*
	A'	-1.00	1.22	0.92	0.58	1.71	1.66	1.18	-0.29	-0.53	-0.42
		ns	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
	B''_D	-0.95	-2.66	-2.82	-2.91	-1.71	-1.94	-1.34	-0.05	0.31	0.38
		ns	.01	.009*	.007*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
						Probes and Tubes					
t(13) =	*Hits (%)*	2.10	5.03	-1.14	1.55	3.10	-3.65	-1.15	-7.73	-4.60	3.55
p=		.05	.0001**	*ns*	*ns*	.004*	.001*	*ns*	.0001**	.0001**	.001*
	A'	-0.17	1.98	-2.11	0.02	2.06	-2.01	0.27	-3.65	-2.48	2.62
		ns	*ns*	.05	*ns*	.05	.05	*ns*	.001*	.02	.01
	B''_D	-3.39	-4.88	-0.56	-1.97	-1.20	2.62	1.24	4.13	2.75	-1.63
		.002*	.0001**	*ns*	*ns*	*ns*	0.01	*ns*	.0001**	.01	*ns*
						Total					
t(27) =	*A'*	-0.69	1.99	-0.42	.46	2.47	0.10	1.43	-2.15	-1.53	0.94
p =		*ns*	.05	*ns*	*ns*	.02	*ns*	*ns*	.04	*ns*	*ns*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks.

*$p<0.01$, **$p<0.001$

Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

Comparison between Experiments 5 and 7

Test Phase Analyses

A mixed model ANOVA carried out on the Experimental Group hits RIF magnitude with Experiment (5 vs. 7) as the between-participants factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both and Rp-Neither) as the within-participants factor, revealed no significant main effect of Experiment, $F(1, 54) = 1.71, p > .05$, and no significant interaction between Experiment and Rp-condition, $F(3, 162) = 1.51, p > .05$. There was a significant main effect of Rp- condition, $F(3, 162) = 3.55, p = 0.02$. The differences between the four Rp- conditions are reported in Tables 5b and 7b.

Independent samples t-tests to compare the Nrp hits between Experiments 5 and 7, showed no significant difference, $t(54) = 0.83, p > .05$.

A mixed model ANOVA on the Experimental Group false alarms with Experiment (5 vs. 7) as the between-participant factor and Rp- condition (Rp-Colour, Rp-Shape, Rp-Both, Rp-Neither) as the within-participant factor revealed a significant main effect of Experiment, $F(1, 54) = 4.09, P = 0.05$. There was no significant main effect of Rp- condition, $F(3, 162) = 0.40, P > 0.05$; and no significant interaction between Experiment and Rp- condition, $F(3, 162) = 0.21, P > 0.05$.

In terms of B''_D, in Experiment 5 there was significant conservative bias for Rp-Colour, Rp-Shape and Rp-Both objects (Probes and Tubes only), but in Experiment 7 only Rp-Shape and Rp-Both objects showed significant conservative bias. Therefore, the change of distractors influenced the pattern of response bias, disadvantaging objects that shared the same shape as the practiced objects – that is, Rp-Shape and Rp-Both objects. However, a mixed model ANOVA out on B''_D scores with Experiment (5 vs. 7) as the between-participant factor, and Rp-Condition (Rp-Colour, Rp-Shape, Rp-Both, and Rp-Neither) as the within-participants factor, revealed no significant effects (all $p > .05$), indicating that observed differences in response bias for the two novel objects experiments were not significant. In other words, the difference in distractors did not influence response bias for novel objects, despite its influence on familiar objects (see Experiment 4 and 6 comparison).

Recognition Phase analyses

Independent samples t-tests revealed significantly higher hits in Experiment 5 compared to Experiment 7, $t\ (52) = 2.44, p = .02$. There was no significant difference in false alarms between the two groups, $t\ (52) = -1.49, p > .05$. There was significantly better recognition in terms of A' in Experiment 5 compared to Experiment 7, $t\ (52) = 1.99, p = .05$, however there was no significant difference in bias between the two groups, $t\ (52) = -1.46, p > .05$.

Experiment 8 Results

Speed-accuracy trade-off analysis. There was no significant correlation between hits and response times to objects in Experiment 8, $r\ (168) = -0.01, p > 0.05$.

Control Group Hits - Test Phase Analysis

Table 8a: Item Type X Category ANOVA statistics for the Control Group in Experiment 8.

	Item Type		Category		Item Type X Category	
Dependent measure	*F*(4, 108)	*MSE*	*F*(1, 27)	*MSE*	*F*(4, 108)	*MSE*
Hits (%)	24.29**	320	0.33	336	2.79*	272

*p<0.05, **p<0.001

Table 8b: Control Group paired samples t-test statistics for Hits by Item Type and Category in Experiment 8.

Statistic		Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Total					
t(54) =	*Hits*	3.31	6.09	1.30	2.74	3.89	1.64	6.55	5.33	8.28	3.21
p =	*(%)*	.003*	.001*	*ns*	.01	.001*	*ns*	.001*	.001*	.001*	.003*
						Tables and Chairs					
t(27) =	*Hits*	0.81	4.62	2.08	2.08	3.87	0.87	3.30	2.78	6.09	3.10
p=	*(%)*	*ns*	.001*	.05	.05	.001*	*ns*	.003*	.01	.001*	.004*
						Lamps and Pots					
t(27) =	*Hits*	3.73	4.48	0.00	1.89	1.47	3.73	5.40	4.77	6.23	2.55
p=	*(%)*	.001*	.001*	*ns*	*ns*	*ns*	.001*	.001*	.001*	.001*	.02

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks. *p<0.01, **p<0.001
Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

Comparison of Item Type between Experiments 3 and 8.

A comparison of Item Type between Experiments 3 and 8 was conducted in order to examine the cause of the better accuracy for Rp+, Rp-Both, and Rp-Neither objects in Experiment 8. It was suggested that the addition of the Rp-Both condition in Experiment 8 boosted the encoding and subsequently the memory of the Rp+ objects, since they shared the same features (shape and colour) with the Rp-Both objects. Furthermore, Rp-Neither may have been better remembered in Experiment 8 compared to Experiment 3 not only because they were more distinct than all other objects (as was the case in Experiment 3), but also because there were no distractor objects, therefore, the Rp-Neither objects in Experiment 8 may have stood out even more compared to the stimuli set as a whole. The comparisons appear in the table below (Rp-Both was not included in the comparisons, as this condition was not present in Experiment 3).

Table 8c: Comparison of Control Group Rp objects between Experiments 3 and 8.

Statistic	Measure	Rp+	Rp-Colour	Rp-Shape	Rp-Neither
t (54) =	*A'*	-1.77	-2.62	1.52	-4.40
p =		.08	.01*	*ns*	.0001**

*p<.05, **p<.01

Experiment 9 Results

Speed-accuracy trade-off analysis. There was no significant correlation between hits and response times to objects in Experiment 9, r (168) = -0.03, $p > 0.05$.

Control Group Hits - Test Phase Analysis

Table 9a: Item Type X Category ANOVA statistics for the Control Group in Experiment 9.

	Item Type		Category		Item Type X Category	
Dependent measure	*F*(4, 108)	*MSE*	*F*(1, 27)	*MSE*	*F*(4, 108)	*MSE*
Hits (%)	7.96**	425	2.35	275	1.47	481

*p<0.05, **p<0.001

Table 9b: Control Group paired samples t-test statistics for Hits by Item Type and Category in Experiment 9.

Statistic		Rp+ vs. Rp-C	Rp+ vs. Rp-S	Rp+ vs. Rp-B	Rp+ vs. Rp-N	Rp-C vs. Rp-S	Rp-C vs. Rp-B	Rp-C vs. Rp-N	Rp-S vs. Rp-B	Rp-S vs. Rp-N	Rp-B vs. Rp-N
						Total					
t(27) =	*Hits*	3.07	3.95	0.33	3.38	2.14	2.41	0.39	4.26	1.62	3.40
p=	*(%)*	.005*	.001*	*ns*	.002*	.04	.02	*ns*	.001*	*ns*	.002*

Note: All comparisons are Bonferroni corrected. Significant differences are indicted by asterisks.
*p<0.01, **p<0.001
Rp-C = Rp-Colour, Rp-S = Rp-Shape, Rp-B = Rp-Both, Rp-N = Rp-Neither.

APPENDIX B

Information and Consent forms
Debriefing form
Ethical form

Information and Consent form (Experimental)

The aim of this study is to contribute to the understanding of representations in object memory.

The experiment will be comprised of 3 phases:-

- In the first phase, your task will be to look at a set of objects that will be displayed individually in the centre of the screen. You will then be asked to rate how attractive you find them on a scale of 1 (not at all attractive) to 5 (very attractive) by pressing the corresponding number on the keypad.

- In the second phase, you will have to practice a subset of the objects. You will be shown **some** of the studied objects from the first phase and new objects. Your task will be to decide whether or not you saw the object during the study phase. There will be 3 blocks of practice sessions, and in-between each session you will be required to complete a filler task.

- In the final phase, you will be shown **all** the studied objects from the first phase and new objects. Your task will be to decide whether or not you saw the object during the study phase. You will also be asked to rate how confident you are in your response from 1(Not all confident) to 6 (Very confident).

Further instructions and specific details regarding how to respond in each phase will be displayed on the computer screen before each phase begins. The experiment will last approximately 25-30 minutes.

Your rights as a participant, including the right to withdraw at any point without penalty are ensured. Your results will not contain your name and it will not be possible to identify individual data.

If you have any questions at all, please feel free to ask them now.

If you would like to participate and you are over the age of 18, please fill in your details and sign below.

Name (Print)……………………………………………………………….. Sex: Male/Female

Date of birth……………………………..

Signed……………………………………………………….. Date…………………..

Information and Consent form (Control)

The aim of this study is to contribute to the understanding of representations in object memory.

The experiment will be comprised of 3 phases:-

- In the first phase, your task will be to look at a set of objects that will be displayed individually in the centre of the screen. You will then be asked to rate how attractive you find them on a scale of 1 (not at all attractive) to 5 (very attractive) by pressing the corresponding number on the keypad.

- In the second phase, you will be required to complete a filler task.

- In the final phase, you will be shown **all** the studied objects from the first phase and new objects. Your task will be to decide whether or not you saw the object during the study phase.

Further instructions and specific details regarding how to respond in each phase will be displayed on the computer screen before each phase begins. The experiment will last approximately 25-30 minutes.

Your rights as a participant, including the right to withdraw at any point without penalty are ensured. Your results will not contain your name and it will not be possible to identify individual data.

If you have any questions at all, please feel free to ask them now.

If you would like to participate and you are over the age of 18, please fill in your details and sign below.

Name (Print).. Sex: Male/Female

Date of birth.................................

Signed... Date.....................

Debriefing form

The aim of the current experiment was to examine whether object colour is represented in long-term episodic memory for objects, and if so, whether that representation is bound with or independent to object shape.

A variant of the retrieval-practice paradigm (Anderson, Bjork, & Bjork, 1994) was used, whereby you rated objects for attractiveness in a study phase. Then, for the experimental group a subset of the studied objects was practiced using an Old/New recognition task. For the control group, this second phase consisted of a filler task and no practice. In a final test phase, memory for all studied objects was examined.

For each practiced object there were different types of Rp- object: sharing the same shape only (Rp-shape), the same colour only (Rp-colour), both shape and colour (Rp-Both, [depending on the experiment]), or neither shape nor colour (Rp-neither), with the practiced object.

Interference effects in memory between practiced and unpracticed items are typically revealed in the temporary forgetting of related unpracticed items – known as *retrieval-induced forgetting* (RIF).

The rationale was that any such interference effect would inform us about the relative contribution of shape and colour on the episodic memory representations of objects. If colour is represented in object memory independently of object shape, then objects sharing colour only and objects sharing shape only with the practiced objects would be susceptible to similar levels of retrieval-induced forgetting.

References

[1] Anderson, M. C., Bjork, E. L., & Bjork, R. A. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory & Cognition, 20,* 1063-1087.

[2] Ciranni, M. A., & Shimamura, A. P. (1999). Retrieval-induced forgetting in episodic memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 25,* 1403-1414.

[3] Nicholson, K. G., & Humphrey, G. K. (2003). The effect of colour congruency on shape discriminations of novel objects. *Perception, 32,* 339-353.

Thank you very much for taking part in the study.

If you have any questions please contact either Kate Williams (363469@swansea.ac.uk) or Irene Reppa (i.reppa@swansea.ac.uk)

Department of Psychology

ETHICS COMMITTEE

Memo

To:	**Kate Williams**
	Student Number(s): 363469
From:	**Dr. Jeremy Tree**
	for Departmental Ethics Committee
Copy:	**Dr. Irene Reppa**
Date:	**22nd October, 2012**
Re:	**Competition in memory between shape and surface object properties**

Your proposed study, "Competition in memory between shape and surface object properties", has been reviewed and is approved. Provided that the information obtained is kept absolutely confidential and that no personally identifiable information is entered on computer, you may proceed with your studies.

Please ensure that the signed copy of this Ethical Approval, together with any other paperwork associated with your research, is included in your final write up.

In order for your study to be displayed on the **Experiment Management System (Participant Pool):**

1. Forward this approval via email to Dr. Irene Reppa (i.reppa@swansea.ac.uk)
   AND
2. Send a request for your study to be made visible, via the link on the EMS website (see Researcher Documentation for details).

Application for Risk Assessment and Ethical Approval

PLEASE COMPLETE THE FORM USING TYPESCRIPT

(hand written applications will not be considered)

Name	Kate Williams — Student Number: 363469 (if applicable)
Address	[redacted]
University E-mail address	363469@swansea.ac.uk
Title of Proposed Research	**Competition in memory between shape and surface object properties.**
Type of Researcher (please tick)	☐ Undergraduate student ☐ MSc student - Abnormal and Clinical Psychology ☐ MSc student - Research Methods in Psychology ☐ MSc student - Cognitive Neuroscience ☒ PhD student ☐ Member of staff **For MSc students only**: This ethics application is for: (please tick) ☐ Empirical Project 1 ☐ Empirical Project 2 ☐ Empirical Project 3 ☐ 60 credit project
Name of supervisor	Dr Irene Reppa

1. Briefly describe the main aims of the research you wish to undertake. Please use non-technical language wherever possible.

The proposed study aims to contribute to the understanding of the representations used to represent objects in long-term memory. This line of enquiry will examine which visual properties of objects guide their retrieval and investigate whether these properties differ for semantic and episodic representations of 3D objects. In particular, the study will examine whether retrieval of an object's identity on the basis of one attribute (i.e. shape) interferes with retrieval of the same object on the basis of a different attribute (i.e. colour) using familiar and unfamiliar shapes. These shapes will be pictures of tables, chairs, lamps and pots, and novel objects grouped into labeled categories (labels will be mowers, ballerinas, birds, tubes, etc).

2. Briefly describe the overall design of the project

The experiment will be based on a mixed-subjects design manipulating two within- and one-between-subjects independent variables (IVs). The first IV will be Item type: Rp+ (practiced items), Rp- (non-practiced items from the practiced category), and NRP (non-practiced items from non-practiced categories). The second IV will be Property sharing with four levels: Rp- items will share shape, surface property, both or neither with the Rp+ items. The between-subjects IV will be the retrieval practice condition with two levels: experimental (retrieval practice), control (no retrieval practice).

The dependant variable will be accuracy of recognition in the test phase.

3. Briefly describe the methods of data collection and analysis. Please describe all measures to be employed (e.g., questionnaire responses, reaction times, accuracy, skin conductance

responses, etc.). If questionnaire or interviews are to be used, please provide the questionnaire / interview questions and schedule.

In the Study phase participants will learn a set of objects with certain shapes and colour/texture. For example, participants will learn square, round and rectangular tables made of wood, metal, plastic or glass (e.g. *Square Metal* table, *Square Wooden* table; *Round Metal* table, *Round Wooden* table; *Rectangle Metal* table, *Rectangle Wooden* table; and similarly with other objects that share the same object properties). In the retrieval practice phase, participants will practice retrieval of a subset of objects from half of the categories (e.g. *Round Glass table*). In the final phase Ps will retrieve all studied objects from all categories.

4. Location of the proposed research (i.e., Departmental labs, schools, etc)

Lab 931D in the Department of Psychology, 9th floor, Vivian Tower.

5. Describe the participants: give the age range, gender, inclusion and exclusion criteria, and any particular characteristics pertinent to the research project.

Adults (male and female) over the age of 18 will take part in this study.

6. How will the participants be selected and recruited?

☒ Subject pool.
☒ General public
☐ Other. Please give details:

7. Will the study be advertised outside the Department's Electronic Subject Pool system (e.g. via a poster or email notice)?		
	Yes	☐
	No	☒

If yes, please provide the wording of the advertisement here (or attach a copy of the intended advertisement to this Ethics Form):

[redacted]

8. What procedures (e.g., interviews, computer-based learning tasks, etc.) will be carried out on the participants?

Stimuli will be presented on the computer screen and responses will be made via keys on a standard QWERTY keyboard. Participants will be required to learn a set of objects and recognise them at a later stage among a set of similar but distracter objects.

9. What potential risks to the participants do you foresee and how do you propose to ameliorate/deal with potential risks? For instance, provide contact details of Student Counseling services and relevant community support organizations, etc.

None foreseen.

10. What potential risks to the interests of the researchers do you foresee and how will you ameliorate/deal with potential risks?

None foreseen.

11.	How will you brief and debrief participants? *(Please attach copy of debrief information to be given to participants)*
	Written and verbal briefing and debriefing forms will be provided.

12. Will informed consent be sought from participants?	Yes *(Please attach a copy of the consent form)*	☒
	No	☐
If no, please explain below:		

13.	If there are doubts about participants' abilities to give informed consent, what steps have you taken to ensure that they are willing to participate?
No participants under the age of 18 will take part, minimizing the risk of the participants not being able to give informed consent.	

14.	If participants are under 18 years of age, please describe how you will seek informed consent. If the proposed research is to be conducted in a school, please describe how you will seek general consent from the relevant authorities and attach a copy of any written consent.
No participants under the age of 18 will take part.	

15.	How will consent be recorded?
Written consent will be obtained through a consent form which participants must sign.	

16. Will participants be informed of the right to withdraw without penalty?	Yes	☒
	No	☐
If no, please detail the reasons for this:		

17.	How do you propose to ensure participants' confidentiality and anonymity?
Electronic data files will be anonymous and kept in a password-protected computer in the Department of Psychology. Consent forms will be kept as hard copies in department of Psychology.	

18. Please describe which of the following will be involved in your arrangements for storing data:

- ☐ Manual files (e.g. paper documents or X-rays)
- ☒ Home or other personal computer
- ☒ University computer
- ☐ Private company or work-based computer
- ☐ Laptop computer
- ☐ Other (please define)

Please explain, for each of the above, the arrangements you will make for the security of the data (please note that any data stored on computer must have password protection as a minimum requirement): Participants names will not be stored with electronic files. The computer in which files are stored will be password protected.

19. Will payments or subject pool credits be made to participants?	Yes	☒
	No	☐
If yes, please specify quantities involved (e.g., £5 or 1 hour credits): 2 credits will be given for 30 minutes of participation time.		

Applicant's signature: __K. E. Williams K. E. Williams Date: __16/10/2012__________

Supervisor's signature: ____________________ Date: 16.10.2012.

PLEASE SUBMIT ALL APPLICATIONS FOR ETHICAL APPROVAL VIA JACKIE SCHOLZ, ROOM 801

****RESEARCH MAY ONLY COMMENCE ONCE ETHICAL APPROVAL HAS BEEN OBTAINED****

CHECKLIST OF ATTACHMENTS:
PLEASE REMEMBER TO ATTACH COPIES OF EACH OF THE FOLLOWING (WHERE RELEVANT)

INCOMPLETE APPLICATIONS WILL NOT BE CONSIDERED

☒ Copy of Participant Information Sheet
☒ Copy of Consent Form
☒ Copy of Participant debrief

☐ Copy of any questionnaires and/or interview schedules to be employed

☐ Copy of written consent from local authorities (e.g., schools)

☐ If your proposed research is with 'vulnerable' groups (e.g., children, people with developmental disorder), please attach a copy of your clearance letter from the Criminal Records Bureau (if UK) or equivalent non-UK clearance.

Departmental Ethics Committee Use Only

Members of the Departmental Ethics Committee have considered the ethical issues raised by this project, and have the following comments:

Straightforward cognitive based project - no foreseeable problems

Please ensure that you take account of these comments and prepare a revised submission that should be either shown to your supervisor (if you are an undergraduate or postgraduate student) or resubmitted (if you are a member of staff) to the Departmental Ethics Committee.

Signed on behalf of Departmental Ethics Committee:

[signature]

Date: 22/10/2012

Were there any significant safety issues that needed resolving?

Yes	☐
No	☒

If YES:

School Safety Officer Approval (Tony Aldridge):

____

Date: ______________________

NOTE TO LEVEL 3 PROJECT & POSTGRADUATE STUDENTS:
PLEASE INCLUDE A SIGNED COPY OF YOUR ETHICS FORM & CONFIRMATION LETTER OF APPROVAL AS AN APPENDIX IN YOUR FINAL YEAR PROJECT OR THESIS.