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Long term negative priming and inhibition of return : episodic retrieval of inhibitory states

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Long-Term Negative Priming and Inhibition of Return: Episodic Retrieval of Inhibitory States

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Summary

Negative priming (NP) reveals impaired response to a target that was previously an irrelevant distractor, suggesting that transient inhibition aids correct short-term behaviour. However, controversial research that shows NP effects over long periods of time indicates that memory can contribute to performance in this task. In the current research, four experiments used new implicit memory paradigms to explore the proposal that long-term NP results from episodic retrieval of inhibition associated with previously irrelevant information. Indeed, long-term NP was found with novel faces and objects over delays of either six minutes and 96 displays or three minutes and 56 displays. These outcomes confirmed the existence of long-term NP and suggested that episodic retrieval of inhibition mediates the effect. Interestingly, long-term effects with objects also indicated that episodic retrieval of excitation associated with prior targets affected performance. Episodic retrieval of inhibition was further examined in Inhibition of Return (IOR), where slowed response to a previously cued target suggests that transient inhibition aids short-term search. Five experiments used new implicit memory tasks to explore short- and long-term IOR over delays of between 1800 ms and zero displays and 18 minutes and 96 displays. Robust short-term IOR was found when cueing objects in faces or locations in scenes. Importantly, the first evidence for long-term IOR was also obtained, however only when cueing objects appearing in the left visual field. By contrast, long-term facilitation was found when cueing objects in the right visual field. There was no long-term IOR when cueing locations. These outcomes further support the idea that episodic retrieval of inhibition and excitation underlie performance in long-term IOR, however only when associated with stable object representations, which may be differentially processed across the cerebral hemispheres. Together, the results suggest that episodic retrieval of attentional states may generally mediate correct behaviour over time.

Chapter One

Memory for Inhibitory States

in Long-Term Behaviour

1.1. Objectives

- Describe NP paradigm and converging evidence that transient inhibition of irrelevant information aids correct behaviour in this task;
- Review controversial findings of long-term NP effects, which can be explained by memory mechanisms, not transient inhibition;
- Propose that long-term NP may be explained by episodic retrieval of prior inhibitory states associated with irrelevant information;
- Consider the generalisability of this proposal to another paradigm, IOR, that reveals inhibitory processes similar to those in NP;
- Explain how this thesis investigates episodic retrieval of inhibition by searching for long-term NP and IOR effects in new implicit memory tasks.

1.2. Abstract

Chapter 1 explores the transient attentional processes that aid successful behaviour in *Negative Priming (NP)* and *Inhibition of Return (IOR)* tasks to determine whether these mechanisms can mediate performance over time. Evidence is provided that inhibition underlies behaviour in NP tasks, where responses are slow to a target that was previously an irrelevant distractor. Converging evidence that transient neural suppression aids behaviour in NP tasks is described, as well as a neural network model that explains this process. Interestingly, recent research has found NP when up to 30 days intervene between ignoring a distractor and responding to it as a target. Because neural inhibition decays quickly and over processing of intervening items, memory processes must be engaged when performance is measured over time. It is proposed that irrelevant distractors are encoded into episodic memory along with associated inhibition, and when they are later presented as targets, episodic retrieval reinstates inhibition to slow response.

A second paradigm, IOR, can determine whether episodic retrieval of inhibition generally aids long-term behaviour. IOR effects also reveal inhibitory processes, as response is slow to a target location cued with an irrelevant flash in the proceeding display. These inhibitory processes are the same as in NP, because they are explained by transient neural suppression, they elicit similar behavioural effects, and they are explained by the same neural network model. Although no research has investigated long-term effects, recent studies have found IOR when cueing six consecutive objects over nearly four seconds. If inhibition associated with objects is maintained in working memory, then object-based inhibition may be stored in and retrieved from episodic memory to reveal long-term IOR. Accordingly, the current research investigates the existence of long-term NP and IOR effects in new implicit memory tasks designed to encourage observation of inhibition over time. Prior research suggests the experimental procedures must encourage encoding and retrieval of information from episodic memory by presenting novel stimuli, processing object-based representations, using an intervening task, and reinstating encoding context. In sum, finding long-term NP and IOR effects may shed light on the nature of the processes that aid goal-directed behaviour over time.

1.3. Inhibitory Processes Mediate Negative Priming (NP) Effects

Humans have evolved to live, work, and play in a highly complex visual world and are constantly faced with stimuli that evoke competing responses. Without the ability to prevent response to the most dominant perceptual input, action in the environment would be haphazard and unrelated to behavioural goals (Diamond, 1990). At the most basic level, survival depends on coherent behavioural responses to relevant information. Early hominids would not have survived if they had not been able to forage for edible foods and leave inedible ones on the bush, or if they could not hunt for weak prey instead of strong prey. Modern men and women are faced with similar survival situations, for example, when they need to react correctly to the brake pedal and the accelerator to avoid potentially lethal automobile accidents. This remarkably adaptive ability to respond appropriately to relevant items in the face of competing responses is the foundation of one of the most enduring areas of inquiry in cognitive psychology.

Early research on this topic often used a repetition priming (RP) paradigm to demonstrate that attending and responding to an object results in faster subsequent response to the same item (e.g., Jacoby & Dallas, 1981; Scarborough, Cortese, & Scarborough, 1977). This effect has often been interpreted as evidence for a facilitatory mechanism of selective attention that has been described in terms of a filter (e.g., Broadbent, 1958; Treisman, 1969), spotlight (Posner, 1980; Eriksen & Eriksen, 1974), zoom lens (Eriksen & Murphy, 1987; Eriksen & St. James, 1986), or gradient (Downing & Pinker, 1985). According to these models, relevant items that fall in the focus of attention receive excitatory processing that aids correct selection and response even when competing information is present. This irrelevant information, which is outside the focus of attention, is assumed to be blocked from access to perceptual or response systems (e.g., Broadbent, 1958; Treisman, 1969; Deutsch & Deutsch, 1963) or to passively decay (Van Der Heijden, 1981). However, in contrast with these views, research suggests that irrelevant information is not merely ‘ignored’, but that it is actively processed.

In an early example of such a finding, Stroop (1935) observed that participants had difficulty naming the ink colour in which a colour word was written. For example, they were slower to say the ink colour 'red' when presented with GREEN versus when presented with RED. One interpretation of this effect is that the distractor colour word GREEN is not ignored, but that it is automatically processed in parallel with the red ink colour, causing interference from simultaneous activation of two competing responses (e.g., Keele, 1972). A variety of other research has also found that irrelevant information is not ignored, but is actively processed (e.g., Bridgeman, Lewis, Heit, & Nagle, 1979; Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Duncan-Johnson & Kopell, 1981; Eriksen & Eriksen, 1974; Goldberg & Segraves, 1987; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988; Greenwald, 1972; Lhermitte, 1983; Miller & Hackley, 1992; Navon, 1977; Norman, 1981; Simon, 1969; Weiskrantz, 1986). Together, this research suggests that active processing of irrelevant information actually assists correct response to relevant items, thereby providing a cognitive solution to the problem of "how to avoid the behavioural chaos that would result from an attempt to simultaneously perform all possible actions for which sufficient causes exist" (Neumann, 1987, pp. 374).

1.3.1. NP Paradigm

The NP paradigm in particular was developed to allow an indirect view of how processing of irrelevant stimuli contributes to correct behavioural response (for reviews see Fox, 1995; May, Kane, & Hasher, 1995; Neill, Valdes, & Terry, 1995). In an example of a traditional NP task, Tipper (1985, Experiment 1; see also Dalrymple-Alford & Budayr, 1966, Neill, 1977; Rock & Gutman, 1981;

Tipper & Cranston, 1985) presented trials in successive pairs of displays, where the first display was the *prime* and the second display was the *probe*. As shown in Figure 1:1, on each display, two spatially superimposed line drawings were presented. On prime displays, the participant was required to remember the stimulus shown in a red outline, the *target*, and ignore another item shown in a green outline, the *distractor*. In the immediately following probe display, they had to name the target while ignoring the distractor. In the critical *ignored repetition (IR)* condition, the prime distractor became the target in the probe display, and a new item was shown as the probe distractor. Relative to a control condition where two new line drawings were shown, participants were slower to respond to the IR target, thus defining the NP effect. Importantly, Tipper suggested NP indicates that irrelevant information is not 'ignored', but that it is actively processed to aid correct response to the prime target. However, this processing has the consequence of slowing subsequent response to a previously irrelevant item.

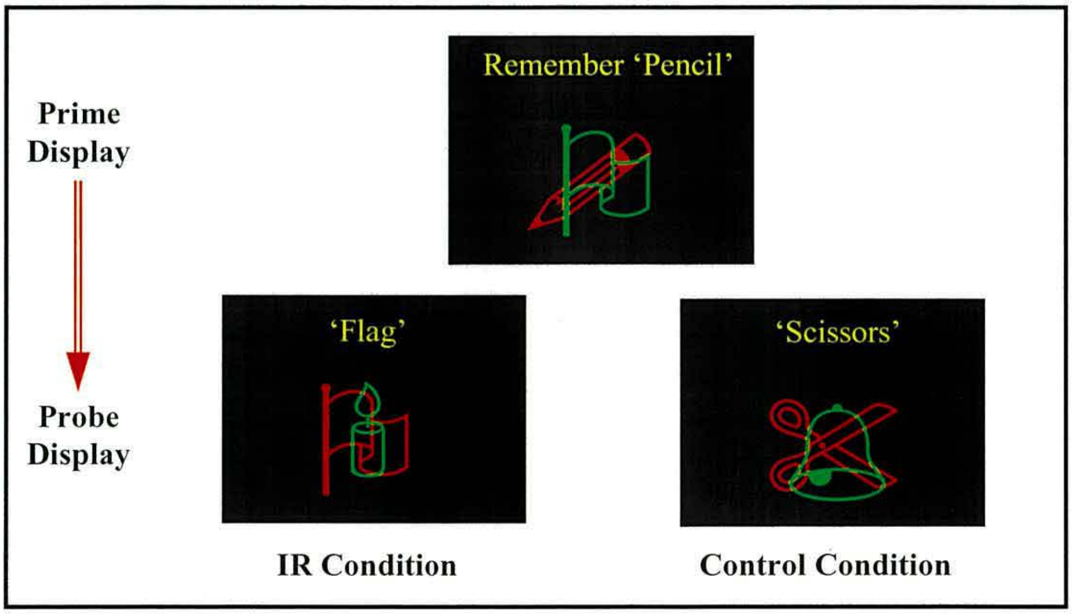

Figure 1:1. Sample prime and probe displays in a NP task (adapted from Tipper, 1985).

Over the years, the NP effect has been found in a wide variety of experimental contexts and is thought to be quite robust. For example, NP has been elicited using different stimuli, such as letters (e.g., Allport, Tipper, & Chmiel, 1985; Neill, Valdes, Terry, & Gorfein, 1992), words (e.g., Grison & Strayer, 2001; Malley & Strayer, 1995), line drawings (e.g., Tipper, 1985), faces (e.g., Khurana, 2000), spoken words (e.g, Banks, Roberts, & Cirrani, 1995), and nonsense shapes (e.g., DeSchepper & Treisman, 1996; Strayer & Grison, 1999). The effect has also been found in various tasks, including same-different matching (e.g., DeSchepper & Treisman, 1996), naming (e.g., Strayer & Grison, 1999; Tipper & Cranston, 1985), reaching (e.g., Tipper, Lortie, & Baylis, 1992), localisation (e.g., Milliken, Tipper, & Weaver, 1994), referent size (e.g., MacDonald, Joordens, & Seergobin, 1999), Stroop-like tasks (e.g., Dalrymple-Alford & Budayr, 1966; Neill, 1977; Stroop, 1935), flanker-like tasks (e.g., Neill, Lissner, & Beck, 1990), and categorisation (e.g., Tipper & Driver, 1988). Furthermore, NP has been obtained with manual (e.g., Neill et al., 1992; Neill & Valdes, 1992; Tipper et al., 1992) and verbal responses (e.g., Allport et al., 1985; Tipper, 1985). Clearly, NP is a general phenomenon that suggests a second attentional process aids behaviour in addition to facilitation of relevant items. [1]

1.3.2. NP Reveals Inhibitory Processes

One of the dominant explanations for the NP effect is that inhibition of irrelevant distractor information during the prime display aids facilitated response to the

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[1] Although not the focus of the current research, other models attempt to explain NP effects based on: response blocking (e.g., Tipper & Cranston, 1985); episodic retrieval (e.g., Neill et al., 1992), code-coordination (e.g., Lowe, 1979), feature mismatch (e.g., MacDonald et al., 1999), perceptual mismatch (e.g., Park & Kanwisher, 1994), transfer-inappropriate processes (e.g., Neill & Mathis, 1998), dual inhibition and memory mechanisms (e.g., Kane, May, Hasher, Rahhal, & Stoltzfus, 1997), perceptual load (e.g., Lavie & Fox, 2000), and temporal discriminability (e.g., Milliken, Merikle, Joordens, & Seiffert, 1998).

target. However, because this inhibitory processing lingers into the subsequent probe display, if the distractor becomes a target item, then it takes time to overcome prior inhibition, which hampers probe response.

There is a variety of independent support for the presence of inhibitory mechanisms in NP tasks based on neuropsychological research with clinical populations. In particular, populations revealing deficits in inhibitory processing might fail to show NP effects because without inhibition of the prime distractor participants would not be slow to respond to previously irrelevant items. Indeed, just this result has been obtained with schizophrenics (e.g., Beech, Powell, McWilliam, & Claridge, 1989; Laplante, Everett, & Thomas, 1992), schizotypes (e.g., Beech & Claridge, 1987; Watson & Tipper, 1997), the elderly (e.g., Connelly & Hasher, 1993; Hasher, Stoltzfus, Zacks, & Rympa, 1991; Kane et al., 1997; Simone & McCormick, 1999; but see Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; Kramer, Humphrey, Larish, & Logan, 1994; Kramer & Strayer, 2001; Schooler, Neumann, Caplan, & Roberts, 1997), youths (e.g., Simone & McCormick, 1999; Tipper, Bourque, Anderson, & Brehaut, 1989), people with depression (e.g., Benoit, Fortin, Lemelin, Laplante, & Everett, 1992), high cognitive failure (e.g., Tipper & Baylis, 1987), anxiety (e.g., Fox, 1994), obsessive-compulsive disorder (e.g., Enright & Beech, 1990; Enright & Beech, 1993; but see MacDonald, Antony, MacLeod, & Swinson, 1999), Tourette's syndrome (e.g., Ozonoff, Strayer, McMahon, & Fillioux, 1998), frontal lobe lesions (e.g., Metzler & Parkin, 2000), Huntington's disease (e.g., Stout, Wylie, Simone, & Siemers, 2001), and Parkinson's disease (e.g., Downes, Sharp, & Sagar, 1991; Filoteo, Rilling, & Strayer, 2002; but see Stout et al., 2001).

Evidence of inhibitory processing in NP tasks has also been found in neuroimaging and electrophysiological research, which provides additional insight into how inhibition may be implemented neurally. For example, Dakins, Cincotta, Peterson, Merritt, and DeLosh (2000), used functional Magnetic Resonance Imaging (fMRI) to find evidence of reduced activation in supplementary, premotor, and primary motor cortices contralateral to the responding hand in the probe display of the IR condition. One interpretation of this result is that it indicates reduced activity in neural regions related to response preparation and execution processes in displays where NP is obtained. Additionally, event-related brain potential (ERP) research by DeLosh et al. (2000) has shown reduced positivity in the P300 component in the IR displays. This result can also be interpreted as providing evidence for neural suppression of perceptual representations associated with stimuli that are selectively ignored (but see Grison & Strayer, 1998; Strayer & Grison, 2002). Because of this converging evidence, there is wide support for the idea that inhibitory processes underlie NP effects.

1.3.3. Neural Network Model of Reactive Inhibition in NP

The most highly specified model to account for NP is Houghton and Tipper's (1994; Houghton, Tipper, Weaver, & Shore, 1996) neural network model of *reactive inhibition* (see Figure 1:2 below), where internal representations of irrelevant stimuli are inhibited to the degree that they are activated (see also Malley & Strayer, 1995; Strayer & Grison, 1999). Although the model, along with relevant computer simulations, is described in detail elsewhere (Houghton & Tipper, 1994; Houghton et al., 1996), it is briefly summarised here.

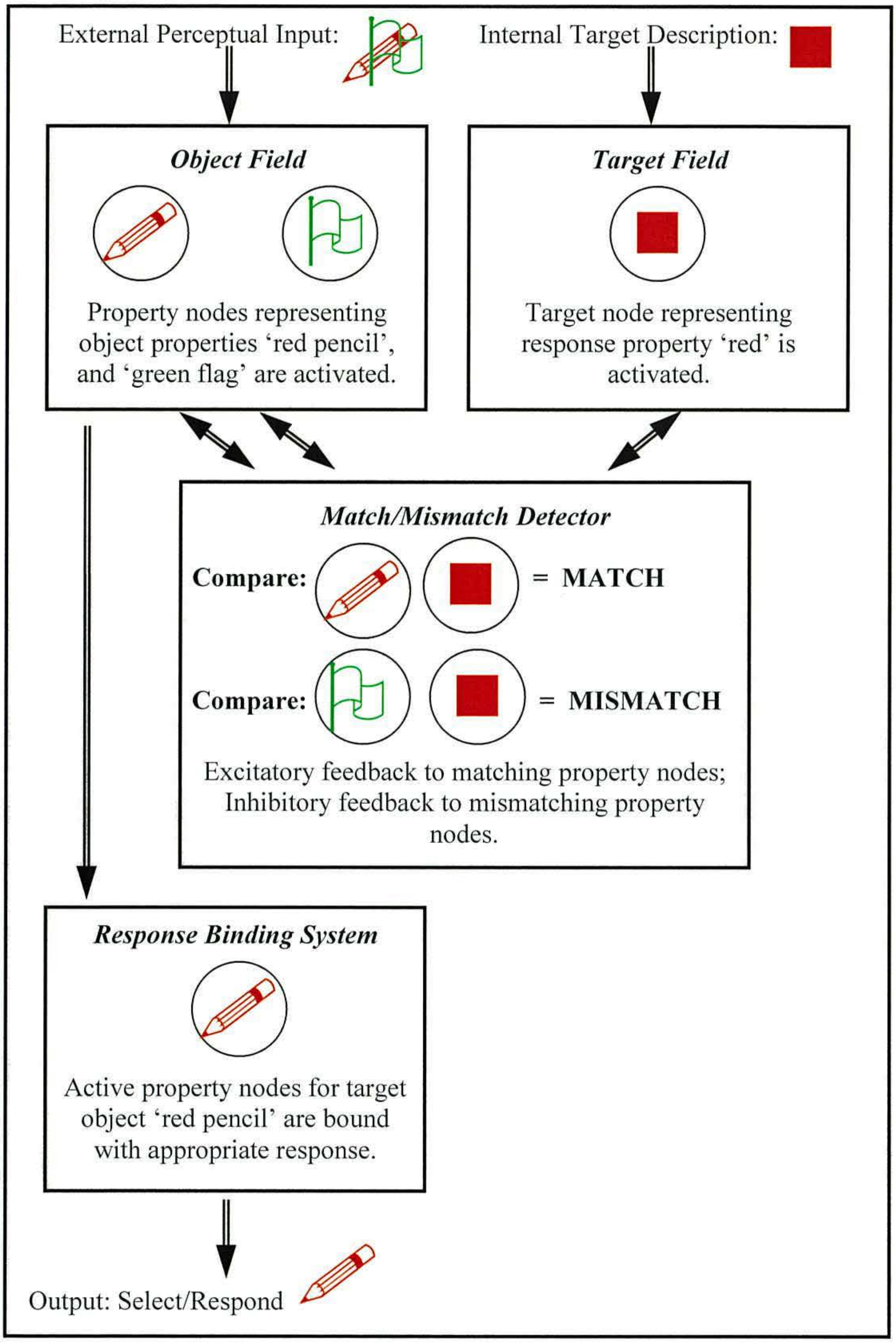

Figure 1:2. Schematic of processing in a neural network model during a NP task (adapted from Houghton & Tipper, 1994). See text for details.

According to the model, stimuli presented during a prime display of a NP task (e.g., Tipper, 1985, Experiment 1) might be processed in the following way (see Figure 1:2 above). First, perceptual inputs of target and distractor items, for example a red pencil and a green flag respectively, activate property nodes in the *Object Field* representing those objects. At the same time, knowledge about the task requirements, for example 'select the red item', activates a node representing the target property 'red' in the *Target Field.* The 'red' target node is then iteratively compared with property nodes for 'red pencil' and 'green flag' in the *Match/Mismatch Field.* Because the property nodes for 'red pencil' match the target node 'red', excitatory feedback increases their activation levels in the Object Field. By contrast, because the property nodes for 'green flag' mismatch the target node 'red', inhibitory feedback decreases their activation levels in the Object Field. In this way, the Match/Mismatch Field acts as a self-adjusting gain control mechanism where the degree of inhibitory feedback to mismatching property nodes depends on the degree that these nodes were initially activated. Over time, the dual mechanism of excitatory and inhibitory feedback allows the activation of property nodes representing the 'red pencil' and 'green flag' to become differentiated such that activation is relatively greater for the former nodes than for the latter (see Figure 1.3 below). These patterns of activation are then fed forward to a *Response Binding System*, which consequently allows binding of the most activated property nodes, those pertaining to the 'red pencil', to response schemata for correct behaviour. In the case of the prime display, the appropriate response is to remember the red item.

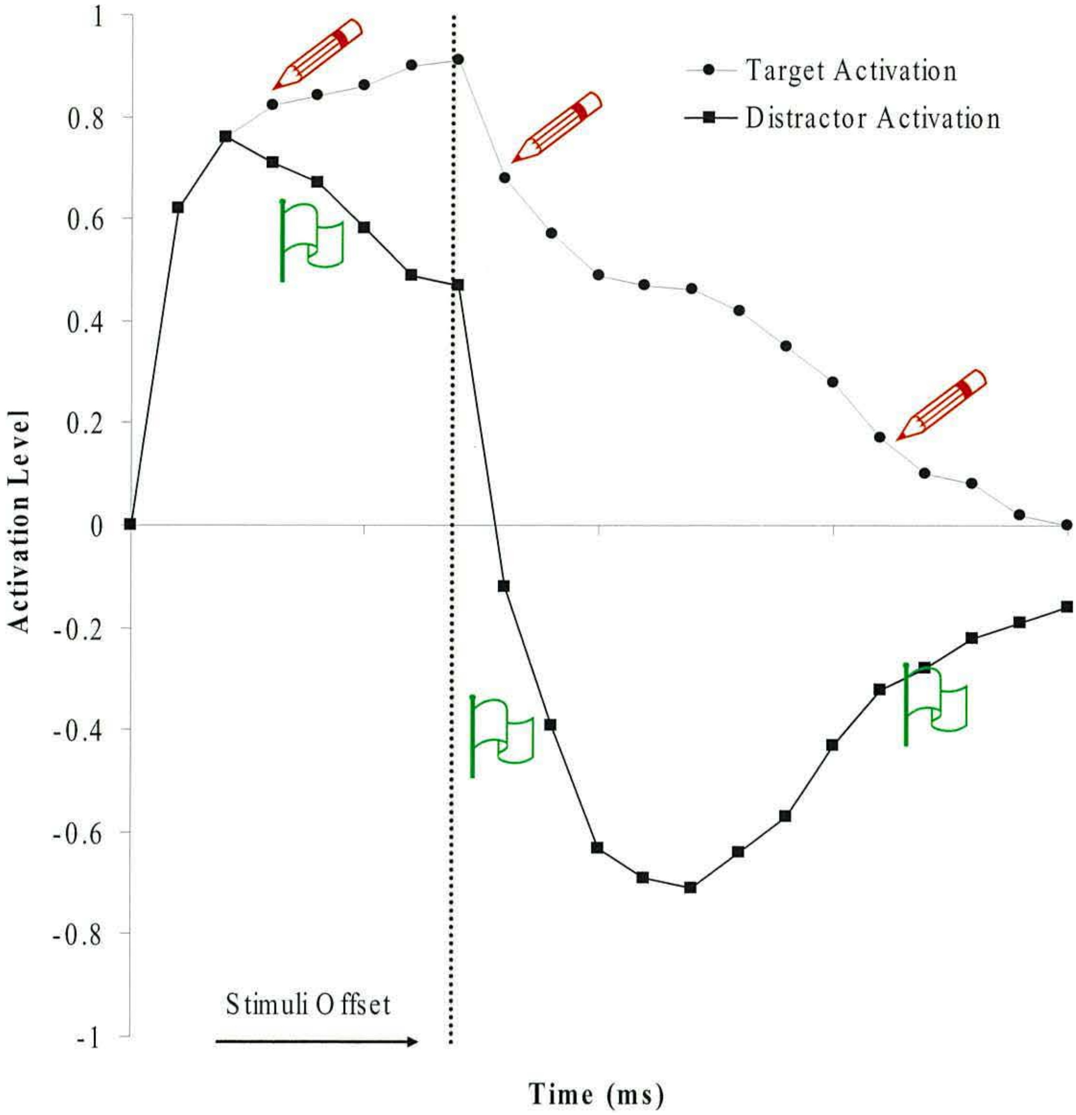

Figure 1:3. Activation levels for property nodes representing target and distractor stimuli in a prime display of a NP task (adapted from Houghton & Tipper, 1994). See text for details.

Importantly, this model accounts for probe display NP effects such as those observed by Tipper (1985, Experiment 1) in the following way. As seen above in Figure 1:3, after the stimuli shown in the prime display offset, the patterns of activation in the property nodes for the target, 'red pencil', and distractor, 'green flag', decay quickly. In particular, there is an inhibitory rebound effect for property nodes pertaining to the distractor stimulus. If the subsequent IR probe display presents the flag as a target stimulus within the period of the inhibitory rebound effect, then the property nodes pertaining to the prime distractor stimulus 'green flag' will still be below resting levels. Consequently, it will take relatively longer for property nodes to increase activation to response threshold for the flag stimulus in comparison with the length of time for the property nodes of a new item to reach response threshold. As a result, NP effects will be observed.

1.4. Long-Term NP Effects Suggest Memory for Inhibitory States

An important feature of the inhibitory processes mediating NP effects is that they are believed to be transient in nature. That is, inhibition controls ongoing behaviour in real-time to allow correct response to a relevant item in the face of a competing irrelevant item. This fact is implied first by the neural nature of these suppression mechanisms, which are thought to last for only a few seconds. The idea that inhibitory processes mediating NP effects are transient is also suggested by Houghton's model of reactive inhibition (Houghton & Tipper, 1994; Houghton et al., 1996), where inhibitory feedback results in a temporary suppression of activation below resting levels to allow correct response. However, once the goal of correct selection and response has been achieved, inhibition quickly decays, allowing activation to return to baseline levels. In addition, it is logically clear that this rapid decay of inhibition is behaviourally adaptive, whereas on-line maintenance of inhibition could interfere with on-going processes. Finally, an important implication of transience of neural inhibition is that NP effects are short-lived and will decline as the time between the prime and probe lengthens. In support of these ideas, most research has found that NP lasts for only a few seconds and decays across processing of intervening items (for reviews see Fox, 1995; May et al., 1995; and Neill & Westberry, 1987). Taken together, these ideas support the notion that transient inhibitory mechanisms mediate performance in NP tasks.

However, some controversial research has revealed the presence of NP effects that persist for relatively long delays and over processing of intervening items between the prime and probe displays (e.g., DeSchepper & Treisman, 1991; DeSchepper & Treisman, 1996; Lowe; 1998; Neumann, Iwahara, & Tajika, 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995). Because on-line neural suppression cannot be maintained without causing interference with continued processing, these effects refute the idea that transient inhibition mediates behaviour in long-term NP. Instead, they suggest that memory processes are also engaged in these tasks.

1.4.1. Lasting Effects of Transient Inhibition

The first suggestion that NP effects may last for a surprisingly long period was provided by Tipper and colleagues (Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991), who examined effects over response to stimulus intervals (RSIs) of 1350, 3100, and 6600 ms between the prime and probe displays. Participants showed NP effects to name line drawings that were previously ignored for all three RSIs, even when nearly seven seconds had passed since the prime. Furthermore, the same results were found in a spatial NP task where subjects localised an 'O' appearing in one of four locations where an ignored '+' had previously appeared. Finally, additional experiments employing these same tasks also found that NP effects persisted even when there was a predictable intervening event between the prime and probe that required processing and response. The conclusion was that inhibitory processes may not decay as quickly as originally proposed, but that there might be a stable form of inhibition. In particular, the authors suggested that inhibitory processes of attention could have long-term consequences on internal representations of irrelevant stimuli, for example, by including in the representation its status as an ignored item that did not require response. Therefore, NP effects might be observed over time if the prior experience of ignoring the stimulus is reinstated on the probe display when response is required. In support of this line of thinking, a variety of other research has found NP effects over relatively long delays, which seems to indicate that inhibitory processes can have long-lasting effects (e.g., Conway, 1999; Hasher, Zacks, Stoltzfus, Kane, & Connelly, 1996).

1.4.2. Episodic Retrieval and Trace Discrimination

Other researchers have also reported finding NP effects over longer periods of time, but have ascribed these effects to memory mechanisms instead of inhibitory processes. For example, Neill and colleagues (Neill et al., 1992) examined NP effects in a localisation task where subjects responded to the location of an 'O' appearing in one of four locations where an ignored 'X' had previously appeared. They manipulated the RSI proceeding the prime display (i.e., PRSI), which could be 500 or 4000 ms, as well as the RSI between the prime and the probe, which could again be 500 or 4000 ms. They found significant NP when the PRSI was 4000 ms regardless of whether the RSI was 4000 or 500 ms. However, when the PRSI was 500 ms, robust NP was observed when the RSI was 500, but the effect was significantly reduced when the RSI was 4000 ms. The authors interpreted these results as revealing that NP effects can persist for longer durations, but that the duration of NP depends on whether a prime display is temporally discriminable from the proceeding probe display (e.g., Neill, 1997; but also see Hasher et al., 1996).

To account for these effects, the authors proposed an episodic retrieval theory of NP (see also Neill & Valdes, 1992; for reviews see Fox, 1995; May et al., 1995). This theory was an extension of Logan's (1988; 1990) instance theory of automatisation, which described task performance as initially relying on slow, effortful algorithmic processing that automatises with practise. Each time the task is performed a separate processing episode is stored in episodic memory that includes information about the stimulus and associated response. As the number of similar instances accumulates, a target stimulus has a greater probability of retrieving instances automatically from episodic memory that will assist current response needs, thereby bypassing slower algorithmic processes.

Importantly, Neill proposed two important additions to Logan's model. First, the 'response tag' retrieved with an instance might contain information about having or not having responded to that stimulus. Accordingly, in a NP task, probe display presentation of the IR target would elicit the prime distractor episode and its associated 'do not respond' tag. Because retrieval of the 'do not respond' tag conflicts with the current need to respond to that stimulus as a target, the time taken to resolve this conflict hampers response, thus revealing NP. A second change that Neill made to Logan's (1988) theory was to suggest that the probability of successful episodic retrieval depended on factors such as recency, temporal discriminability, and the ratio of the retention interval to the interval separating the episode from prior episodes (e.g. Baddeley, 1976). Accordingly, in the above research, there was reduced NP in the 500 ms PRSI and 4000 ms RSI condition because prime trace discrimination is poor when the RSI is longer than the PRSI, which reduces the probability of episodic retrieval processes eliciting NP effects. In sum, according to Neill, NP can exist over longer durations due to the relative permanence of episodic instances that include information about prior responses in the form of 'tags'. However, observing NP effects over time depends on a variety of contextual factors that affect the probability of successful episodic retrieval.

1.4.3. Episodic Retrieval and Context Dependency

Lowe (1998) also claimed that retrieval of episodic instances mediated NP effects over time, however, he specified that the probability of successful retrieval depended on additional contextual factors. In a novel learning paradigm, Lowe presented paired words in a study phase where participants read aloud the word shown in a target colour, but ignored the other word. Each word pair was shown one, three, or six times, and in each case a given word in the pair consistently served as a target or as a distractor. After a five-minute retention interval, participants experienced a priming task where they responded to words they had either previously attended or ignored during the learning phase. Indeed, long-term NP effects were found that increased depending on whether a word was an ignored distractor one, three, or six times in the learning phase. Lowe interpreted this result as supporting the presence of episodic retrieval of prior distractor instances that included coded attributes that these items were 'nonreportable'. Importantly, these results also confirmed and extended Logan's (1988) predictions about the probability of successful retrieval increasing when there are greater numbers of similar instances stored in memory. In particular, NP increased each time an item was shown as a distractor in the learning phase because there were more stored instances, where each was *consistently associated* with a 'nonreportable' tag, which increased the probability of successful retrieval.

A second important finding in this research was that the presence of long-term NP effects also depended on the similarity of context between the study and test phases. In particular, in Experiment 1 when new items were shown in the test phase, no long-term NP was seen, but in Experiment 2 where there were no new items shown, the effect was observed. Importantly, in Experiment 3 the paired items from the learning phase were presented again in the test phase, but with their roles 'flipped' so that the distractor and target during the learning phase became the target and distractor, respectively, during the test phase. In this 'flipped' condition, robust long-term NP was seen. Lowe accounted for these findings by extending the episodic retrieval model to include the notion of context dependency, as described in Tulving's encoding specificity model of episodic memory (e.g., Tulving & Thompson, 1973; see also Logan & Etherton, 1994). In particular, Lowe's findings suggested that the relationship between the two stimuli in the learning phase created an encoding context, and that when the test phase reinstated this context, it provided cues that increased the chances for successful episodic retrieval to affect performance. In sum, Lowe's results suggested that long-term NP exists, and this effect reveals the function of episodic retrieval of instances from memory, the success of which depends on the number of compatible instances stored in memory along with reinstatement of the encoding context at retrieval.

1.4.4. Episodic Retrieval of Novel Stimuli

Indeed, a similar mechanism was proposed by DeSchepper and Treisman (1991; 1996; Treisman & DeSchepper, 1995) to explain the most surprising long-term NP effects found to date. These studies used a NP paradigm to investigate perceptual processing of object files (Kahneman & Treisman, 1984; Treisman, 1986), which are object representations that can be moved in a unified way through space. While identification and classification of objects has been theorized to depend on matching the stimulus to stored, reactivated familiar information (i.e., object types), processing of new objects is less understood. Accordingly, object perception of new items (i.e., object tokens) was investigated to answer the question of whether establishment of this temporary episodic representation depends on attentional processing (see also Rock & Gutman, 1981).

In a series of experiments (DeSchepper & Treisman, 1996), novel, meaningless 'blob-like' shapes were presented in a same-different matching task. Two overlapping shapes were presented on the left, one outlined in green and the other outlined in red, and one shape was shown on the right, outlined in white. Subjects ignored the red shape and pressed one of two keys based on whether the green and white shapes were the same or different. The critical IR condition was when the red shape that was ignored in the prime display became the attended green shape in the probe display. Across experiments, the authors found significant NP effects when there was a lag between the prime and associated probe of one, 10, 100, and 200 displays. In the final ambitious experiment, they attempted to find NP effects that persisted over a delay of one display, one day, one week, and one month. Although the data originally suggested that there was

NP at a lag of one display, the effects for the other three delay periods were not significant. However, because people tend to show individual differences in NP effects (see also Conway, Tuholski, Shisler, & Engle, 1999; Tipper & Baylis, 1987), the data was split into two groups. One group contained the data from participants who had showed NP at the shortest delay (i.e., the 'inhibitors') and the other group contained data from participants who had showed facilitation at this delay. Re-analysis of the data for the group of 'inhibitors' revealed long-term NP effects at each of the four delay intervals, where NP was still significant even when one month had passed since ignoring the item. These same subjects also failed to demonstrate any explicit recall for distractor shapes.

The authors interpreted these results as evidence that long-term NP effects can be found with new tokens, suggesting that attention is not necessary to set up a new token instance in memory. Accordingly, an implicit memory trace of novel, distractor information seemed to be created in one exposure, which lasted over 200 intervening displays, or delays of one day, one week, and even one month. As described previously (e.g., Logan, 1988; 1990; Lowe, 1998; Neill et al., 1992), included in this memory trace is the knowledge that the shapes should be ignored, perhaps in the form of a label or action tag associated with the shape. When a stimulus presented later in the experiment matched the stored episodic token, it was automatically retrieved and interfered with response if the previous role of the shape conflicted with current requirements.

1.4.5. Episodic Retrieval of Familiar Stimuli

Although DeSchepper and Treisman (1996) found strong support for the existence of long-term NP effects with new tokens of novel stimuli, in another experiment, they failed to find NP over delays of 100 and 200 intervening displays when familiar words were presented in a same-different matching task (Treisman & DeSchepper, 1995). Accordingly, Neumann and his colleagues (Neumann et al., 1999; Neumann & Russell, 2000) explored whether long-term NP can be found even for individuated tokens of familiar stimuli that already exist in memory. In particular, Neumann et al. (1999) used the same matching task, except they presented Japanese Kanji characters to Japanese participants, so these stimuli would be familiar and semantically meaningful. When these characters were presented just once as distractors, they elicited long-term NP effects even when 72 displays intervened between the prime and the probe. In a second series of experiments, Neumann and Russell (2000) confirmed finding long-term NP with familiar stimuli presented just once as distractors. In this case, two English words were presented on each display, where the target word was shown in lower-case letters and the distractor word was displayed in upper-case letters. In the prime display, participants named the target word and ignored the distractor, while on the probe display, they made a lexical decision to the target word as they ignored a distractor. They found NP effects when 100 displays and 10 minutes intervened between the prime and its associated probe display. However, they did not find the effect with 100 intervening displays when there was a delay of one week between the prime and probe. Together, these findings extended DeSchepper and Treisman's results (1996; Treisman & DeSchepper, 1995) by suggesting that the same mechanism that mediates long-term NP effects with new tokens stored in episodic memory probably also underlies the effect with individuated tokens of familiar items.

Neumann speculated that his prior research suggested a plausible mechanism for mediating this effect (Neumann & DeSchepper, 1992) based on a combination of active, capacity limited spreading inhibition processes and episodic memory retrieval. In particular, objects located near each other in space are processed in parallel, thereby creating an internal mental representation, or object file, for each item. While relevant object files stay activated for further processing, irrelevant object files are actively suppressed. Importantly, because inhibition functions late in selection, one by-product of this process is that irrelevant object files have already been automatically encoded into memory, along with response information in the form of "unwanted" action tags. Therefore, long-term NP effects can be observed later when implicit memory retrieval of irrelevant individuated tokens also retrieves the prior response requirements, which hamper performance. In sum, long-term NP effects seem to exist with familiar stimuli, which suggests that implicit memories of individuated tokens with associated action tags are extraordinarily durable.

1.4.6. Episodic Memory and Inhibitory Processing

Taken together, the experiments reviewed here suggest that there is support for the existence of NP effects that last across processing of between one and 200 intervening displays, and over delays of between six seconds and one month. In particular, the presence of long-term NP effects over delays as long as 30 days between the prime and probe displays cannot be explained by the transient inhibitory mechanisms used to explain short-term NP effects. Maintenance of on-line inhibition in tasks such as those just described would not only be neurally implausible, but it would also interfere with on-going processing of additional information and impede goal-directed behaviour. On the other hand, without evidence of decay of inhibition in the proceeding studies, one must assume that the internal representation of an ignored stimulus undergoes a more permanent change that affects behavioural performance over time. However, the question remains, what is the nature of this memory representation that mediates goal-directed behaviour in long-term NP tasks?

Much of the research providing support for the existence of long-term NP effects has suggested that the engagement of episodic memory mechanisms precludes a role for inhibitory processing in these tasks. However, the current proposal argues against such mutual exclusivity between inhibition and memory processing and instead suggests that both mechanisms may contribute to performance. Indeed, some aspects of the long-term NP effects described above are best explained by inhibitory processes. In particular, the reported finding of individual differences in long-term NP by DeSchepper and Treisman (1996) cannot be understood in terms of episodic retrieval of 'no response' tags. Recall they suggested that an episodic token of a new item was automatically stored in memory along with its associated response tag, even on the first exposure as a distractor. If this is the case, it could not have occurred that some subjects stored the distractor token with a 'no response' tag to reveal long-term NP effects, while other subjects stored the distractor token with a 'respond' tag to show long-term facilitation. By contrast, finding both long-term NP and facilitation can be understood in terms of individual differences in engagement of inhibitory processes, as described earlier, because some populations who show poor abilities to inhibit irrelevant information also show smaller NP effects (e.g., Tipper & Baylis, 1997; see Fox, 1995, for a review).

Additionally, it must be acknowledged that describing performance in long-term NP as a result of episodic retrieval of 'response tags' is generally vacuous unless there is an attempt to explain the representational nature of these tags, how they are processed, and their neural basis. DeSchepper and Treisman (1996) briefly made this attempt when they explained long-term NP effects as resulting from additional information attached to traces of irrelevant information:

> "We can think of this additional information as a label or action tag specifying the relevance of the object to the task, for example, in our experiments, the fact that this object was to be ignored or *inhibited*." (pp. 42) (emphasis added).

Similarly, Neill et al. (1992) also vaguely stated that long-term NP on the probe display may not be due to episodic retrieval of response tags per se, but rather "It remains possible that the episode retains some trace of the previous inhibition" (pp. 998). Finally, recall that Tipper, Weaver, et al. (1991) also speculated that long-term NP effects might be due to inhibitory processes having long-term consequences on internal representations of irrelevant stimuli, for example, by including in the representation its status as an ignored item that did not require response. Accordingly, it may be the case that inhibitory processes provide a way to operationalise a 'do-not-respond' tag in a biologically plausible manner.

If long-term NP effects do not discount the idea that inhibition aids performance in these tasks, and if episodic retrieval of 'response tags' may be neurally implemented as inhibitory processing, then how can we reconcile the idea that both inhibitory and memory processes could be functioning in long-term NP tasks? According to Tipper, Weaver, et al. (1991; see also Milliken et al., 1998;

Tipper, 2001; Tipper & Milliken, 1996) the answer is based on the idea that all priming effects are a product of attention and memory processes utilised on prime and probe displays to complete different aspects of the task. For example, on viewing any given display, information is retrieved from memory to complete object recognition processes as attention is engaged to select a response for the relevant item and inhibit the irrelevant item. Importantly, according to Logan (1988), attentional processing of a stimulus has the consequence of automatically encoding the information into memory for future use as well as automatically retrieving prior stored instances pertaining to that information, which might aid current response. Therefore, performance on each display is a result of both prospective inhibitory processes and retrospective memory mechanisms.

Unfortunately, up to this point, models of inhibitory processes have ignored any influence of memory-related processing occurring on prime or probe displays, such as the conditions that allow successful memory retrieval to impact performance. Similarly, while models of episodic memory accept the idea that the creation of an episode in memory depends on excitatory attentional processes, they generally refute the contribution of inhibitory processes to performance on prime or probe displays. Therefore, no research has ever explored the idea that long-term NP may be a result of both inhibitory and episodic memory processes, both of which occur on prime and probe displays. However, "Negative priming provides an ideal way to study the relation between attention and memory" (Fox, 1995, pp. 170; see also Neumann & DeSchepper, 1991; Treisman, 1992).

1.4.7. Episodic Retrieval of Inhibitory States

The proposal being investigated in the current research is that long-term NP effects may result from episodic retrieval of prior inhibitory states (Tipper, 2001). In particular, if prime display distractors are subjected to both transient inhibition and memory processing, then inhibitory states may become a component of a distractor representation automatically stored in episodic memory. When the IR probe display is experienced much later, the target could automatically cue retrieval of prior matching episodes, and if retrieval is successful, then transient inhibition associated with that stimulus may be reinstated. However, because this inhibition is associated with an item that is now the target, it must be overcome to allow correct response, which results in long-term NP effects. Importantly, it is *not* being suggested that transient inhibitory processes are maintained on-line for long periods and across processing of intervening items to affect performance. Rather, the physical aspects of inhibition, such as neural suppression, will be relatively short lasting. Instead, when the original encoding context is re-presented this might have the effect of re-activating the network of inhibitory processes associated with correct selection and response into the previous configuration. In this way, transient inhibition can once again affect behaviour.

This process might be best understood in relation to the mechanisms previously described in Houghton and his colleagues' neural network model of reactive inhibition (Houghton & Tipper, 1994; Houghton et al., 1996). Based on the ideas suggested here, the model would accommodate long-term NP effects as long as there was a way for inhibition to mediate long-term performance. One way to implement such a mechanism is by allowing stimulus properties and transient activation states represented in the Object Field to be encoded into an

Episodic Memory sub-network. Accordingly, an instance would be created for an item that mismatched the selection template along with the pattern of activation associated with inhibitory feedback. The inhibition would be part of the pattern of activity stored in memory so suppression would not be active in the system after transient processes decayed, thus preventing interference during on-going behaviour. However, retrieval of the stimulus would also allow recovery of transient activation patterns, resulting in an inhibitory state in the network that is called "reinstated". At this point the network would function in the same way as when transient inhibitory processing mediates behaviour.

There may be functional reasons for a relationship to evolve between long-term episodic memory and inhibitory processes, because correct goal-directed behaviour may rely on attentional information obtained from prior processing episodes. Indeed, according to Tipper, Weaver, et al. (1991),

> "Behaviours usually take place in particular environmental contexts, and in these contexts particular stimuli are selected for action while others are typically ignored....when these contexts are encountered, usually the same stimuli are ignored and classed as irrelevant. Therefore, if the prior experience of ignoring a stimulus in that context can be reinstated, the selective processing will be facilitated." (pp. 691).

As an example, consider the following scenario where you are at a party and examining the buffet table for something to eat. You notice some bowls of nice salads, pasta and seafood. You reach for the pasta salad because you are allergic to prawns, but are interrupted by a friend who wants to dance. Some time later, you return to the buffet. At this point, two mechanisms may help you to select an appropriate meal. The first is based on explicit recall, your conscious memory of the food that you saw on the buffet table. However, the second mechanism, which may be automatic and not available to conscious recall, could be retrieval of prior processing operations. In this case, upon approaching the buffet table, retrieval of prior inhibitory states associated with the seafood salad would prevent making a bad dinner choice, thus facilitating correct selection of an appropriate meal

If there is a behavioural advantage of having memory for inhibitory processes in achieving correct goal-directed behaviour in selective attention tasks, then one wonders whether episodic retrieval of inhibitory states may be a general mechanism that mediates performance over time. If so, then other tasks where performance depends on inhibitory processing could also reveal long-term effects due to episodic retrieval of prior inhibition.

1.5. Memory for Inhibitory States in Inhibition of Return (IOR)

In particular, the IOR paradigm (for reviews see Klein, 2000; Lupiáñez, Tudela, & Rueda, 1999; Rafal & Henik, 1994), provides another opportunity to test this proposal because inhibition is thought to mediate performance in this task. In addition, some research has revealed that these inhibitory processes are similar to those in NP tasks (Buckolz, Boulougouris, O'Donnell, & Pratt, 2002; Milliken, Tipper, Houghton, & Lupiáñez, 2000). Finally, the neural network model proposed by Houghton and colleagues (Houghton & Tipper, 1994; Houghton et al., 1996) to account for inhibitory processing in NP tasks can also explain performance in IOR as well. Therefore, the IOR paradigm provides a way to examine how generally episodic retrieval of inhibitory states mediates performance over time.

1.5.1. IOR Paradigm

In an example of a traditional IOR task, Posner and Cohen (1984) presented trials in successive pairs of displays, where the first display was the *cue* and the second was the *target.* Figure 1:4 shows how on each display, three boxes were presented, one in the centre and the others to the left and right of fixation. In the cue display, the outline of one of the two peripheral boxes was brightened for 150 ms. The target display occurred 0, 50, 100, 200, 300, or 500 ms after the cue. A target in the shape of a small square appeared most often in the centre box (60% of trials), but sometimes it appeared in one of the two peripheral boxes (10% of trials for each box), or did not appear at all (20% of trials). Participants pressed a key as quickly as possible when the target appeared. There were two important conditions, the *cued* condition, where the target appeared in the peripheral location that was previously cued, and the *uncued* condition, where the target appeared in the peripheral location that was not previously cued. When there was 200 ms or less between the cue and target, participants responded more quickly in cued versus uncued displays, revealing facilitated processing called the *cueing effect* (e.g., Posner, 1980). Importantly, when there was 300 ms or more between the cue and target, participants were slower to respond to a cued display than an uncued display, thus defining the IOR effect.

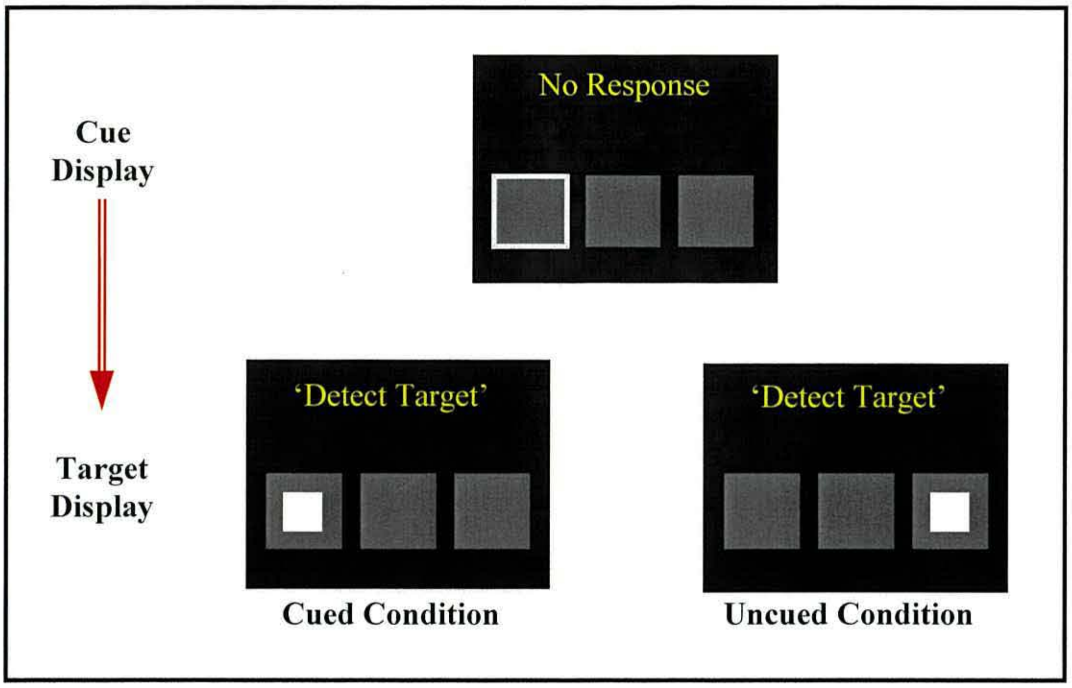

Figure 1:4. Sample cue and target displays in an IOR task (adapted from Posner & Cohen, 1984).

IOR has been demonstrated in many experimental procedures. For example, the effect has been found with stimuli such as faces (e.g., Tipper, Paul, Kessler, & Grison, 2002), colour patches (e.g., Kwak & Egeth, 1992; Law, Pratt & Abrams, 1995), line drawings (e.g., Paul & Tipper, in press), and moving objects (e.g., Abrams & Dobkin, 1994; Gibson & Egeth, 1994; Ro & Rafal, 1999; Tipper et al., 1997; Tipper, Driver & Weaver, 1991; Tipper, Jordan, & Weaver, 1999; Tipper, Weaver, Jerreat, & Burak, 1994). IOR is also seen in both exogenous cueing paradigms with activation of the oculomotor system (e.g., Rafal, Calabresi, Brennan, & Sciolto, 1989), as well as in endogenous cueing tasks with preparation or execution of a saccade (e.g., Posner, Rafal, Choate, & Vaughan, 1985; Rafal, Egly, & Rhodes, 1994; Rafal et al., 1989). In addition, the effect has been elicited using a variety of procedures, such as detection of luminance changes (e.g., Posner & Cohen, 1984), auditory targets (e.g., Mondor, Breau, & Milliken, 1998; Reuter-

Lorenz, Jha, & Rosenquist, 1996), discrimination of colour (e.g., Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997), form (e.g., Cheal, Chastain, & Lyon, 1998; Pratt, Kingstone, & Khoe, 1997), identity and orientation (e.g., Danziger, Kingstone, & Snyder, 1998; Handy, Jha & Mangun, 1999; Lupiáñez et al., 1997; Pratt, 1995; Pratt et al., 1997; Pratt & Abrams, 1999), Go/NoGo and 2-choice tasks (e.g., Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001), cue-target and target-target paradigms (e.g., Maylor & Hockey, 1985), temporal order judgements (e.g., Gibson & Egeth, 1994), lexical decision (e.g., Chasteen & Pratt, 1999), categorisation (e.g., Chasteen & Pratt, 1999), and localisation (e.g., Maylor, 1985). The effect is obtained in different modalities, such as visual (e.g., Posner & Cohen, 1984) and auditory (e.g., Reuter-Lorentz et al., 1996), as well as between modalities (for a review see Driver & Spence, 2000), such as tactile-visual (e.g., Kennett, Eimer, Spence, & Driver, 1999), auditory-visual (e.g., Spence & Driver, 1998), and auditory-tactile, visual-tactile, and tactile-auditory (e.g., Spence, Nicholls, Gillespie, & Driver, 1998). Finally, IOR can be obtained with different responses, such as simple and choice manual keypress (e.g., Maylor, 1985; Maylor & Hockey, 1985; Pratt & Abrams, 1995), reaching (e.g., Howard, Lupiáñez, & Tipper, 1999), and eye-movements (e.g., Abrams & Dobkin, 1994; Pratt, 1995).

The dominant interpretation of these effects is that early excitatory processing promotes a reflexive shift of attention to the cued location, which augments further processing when a target appears in that location. However, if there is a longer delay before the appearance of the target, attention is not merely removed from the cued location, but re-orienting to that recently attended location is more difficult than in the uncued condition. Accordingly, IOR demonstrates transient inhibition of representations associated with previously attended locations, the effects of which linger into the target display. This mechanism encourages orienting towards novel locations to promote efficient search (e.g., Klein & MacInnes, 1999), with the consequence of slowing response to a previously cued target.

Of main importance is the idea that the inhibitory mechanisms underlying IOR are similar to those elicited in NP tasks. There are three primary lines of evidence to suggest such a similarity. First, converging evidence indicates that neural suppression mediates IOR effects. Second, research indicates the similarity between NP and IOR effects and suggests a common underlying inhibitory mechanism. Finally, the reactive inhibition model that accounts for NP (Houghton & Tipper, 1994; Houghton et al., 1996) also explains IOR effects.

1.5.2. IOR Reveals Neural Inhibition Mechanisms Similar to NP

Research has provided converging evidence that inhibition is engaged in IOR tasks. For example, some neuropsychological research shows that populations with deficits in inhibitory processing also exhibit reduced IOR effects, for example people with attention deficit disorder (e.g., White, Marks, & Wilkinson, 2001) and schizophrenia (e.g., Huey & Wexler, 1994; Sapir, Henik, Dobrusin, & Hochman, 2001; but see Carter, Robertson, Chaderjian, Celaya, & Nordahl, 1992; Fuentes & Santiago, 1999). In addition, ERP studies have provided evidence of inhibitory processing in IOR tasks. Specifically, some studies have shown reduced amplitude of the P100 component in the cued versus uncued displays of IOR tasks (e.g., Hopfinger & Mangun, 1998; McDonald, Ward, & Kiehl, 1999), which can suggests suppression of sensory information in previously cued locations. Other studies have found that the lateralised readiness potential (LRP) component reveals initial activation of an incorrect response in cued versus uncued conditions (e.g., Eimer & Schlaghecken, 1998), thus indicating that response to a cued location is initially inhibited before correct behaviour can occur. Finally, single-cell recordings of neurons in the superficial and intermediate layers of the SC in rhesus monkeys during an IOR task have revealed heightened response from these cells in cued versus uncued conditions, even though the monkeys demonstrated slow behavioural responses. The authors interpreted this result as suggesting that the inhibitory processes underlying the behavioural effect originate in neural regions upstream from the SC, possibly the posterior parietal cortex (Dorris, Klein, Everling, & Munoz, 2001). Clearly, this research converges on the idea that neural suppression mediates IOR effects.

1.5.3. IOR and Location-Based NP Due to Same Mechanisms

Interestingly, most NP and IOR research assumes that the effects reveal different underlying mechanisms. This view is predominately because NP shows slowed response to previously ignored target stimuli, but IOR reveals slowed response to previously attended targets. However, Milliken and colleagues (Milliken et al., 2000) proposed that the typical procedures used to measure NP effects may mask similarities with IOR. They used localisation tasks based on the Tipper, Brehaut, and Driver (1990) spatial NP task, to explore the similarity of spatial NP and IOR.

In four experiments, two consecutive displays were shown where the letter 'X' could appear in one of four possible locations. Experiment 1 revealed that when participants responded to the location of a target while ignoring a distractor, repeating the colour used to select the target between the prime and probe masks an underlying slowed response for a target re-appearing at the same location. This result suggests that the procedures of a spatial NP task preclude observation of an IOR-like slowed response to targets appearing at a previously attended location because attention is applied to stimulus properties at that location. In Experiment 2, when subjects only responded to the target in the probe display, the facilitatory effect of repeating the target colour disappeared to reveal IOR-like slowing when target location was repeated. The final two experiments investigated whether NP found when the target location was repeated could be interpreted as an IOR effect. In particular, because IOR is not often found in discrimination tasks, the authors set out to confirm that IOR can be obtained in these tasks. Therefore, participants did not respond to the single prime, but they did respond to probe displays, which could either show a single target, or a target and a distractor. The results revealed slow response when the location of the prime was repeated as the probe target location, showing that adding a discrimination component to the task does not eliminate slowing of response to repeated target locations.

Together, these studies reveal that in the absence of attention to object-based properties, repeating target location leads to slowing that can be interpreted as location-based NP or IOR effects (see also Buckoltz et al., 2002; Christie & Klein, 2001; Nagai &Yokosawa, 2001). In conclusion, the authors suggest that spatial NP and IOR effects have a common cause, which can be explained by reactive inhibition (Houghton & Tipper, 1994; Houghton et al., 1996).

1.5.4. IOR in the Neural Network Model of Reactive Inhibition

Houghton and colleagues' neural network model (Houghton & Tipper, 1994; Houghton et al., 1996) can account for IOR effects because the inhibitory feedback mechanism that prevents response to distractors in NP tasks also prevents attention from returning to previously examined loci. In particular, the only change to the model is that the Response Binding System is replaced with an Orienting System, shown in green in Figure 1:5 below. The model is briefly summarised here, but see Houghton and Tipper (1994) for a full description.

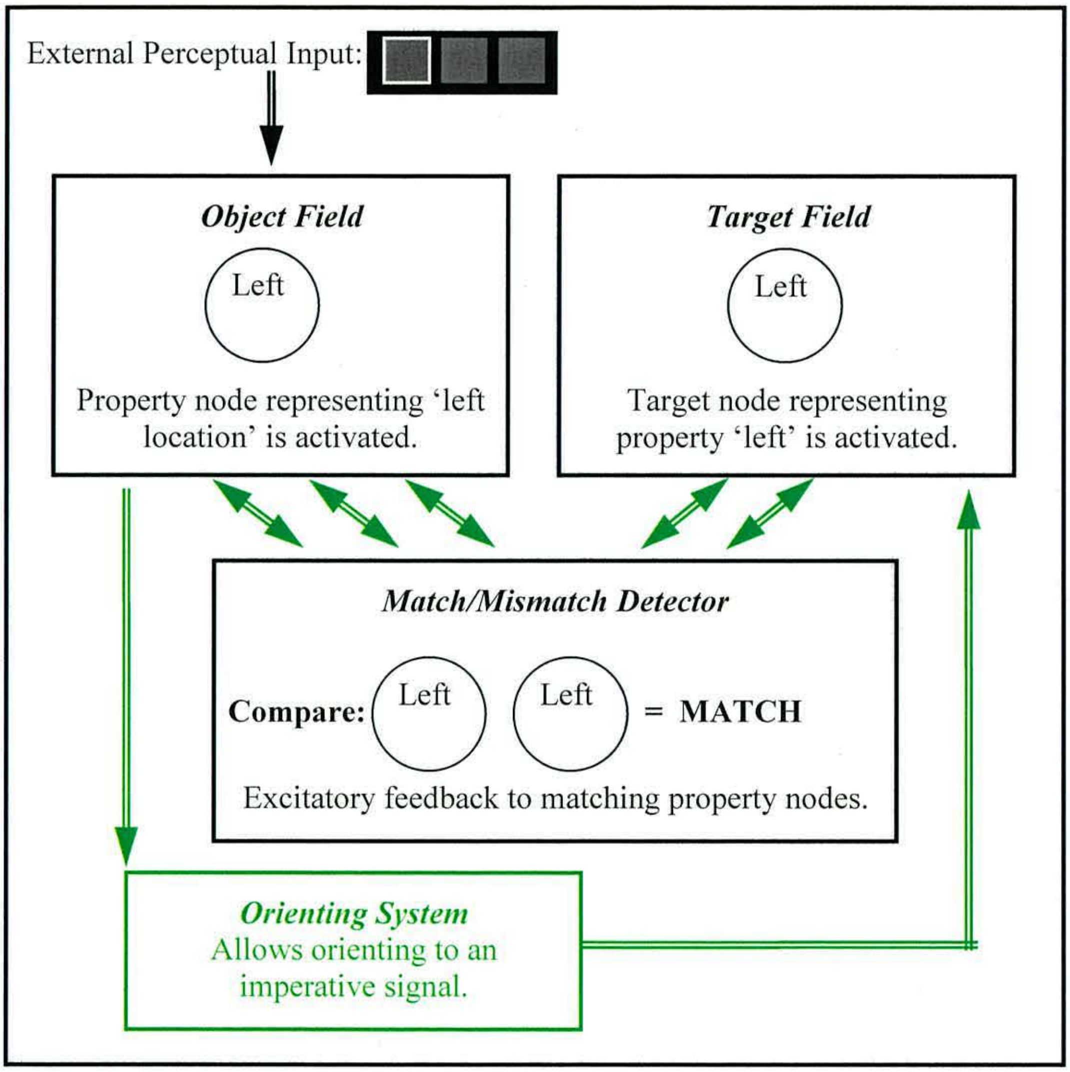

Figure 1:5. Schematic of processing in a neural network during an IOR task (adapted from Houghton & Tipper, 1994). See text for details.

First, the perceptual input of the cue, such as the brightening of the left box (e.g., Posner & Cohen, 1984), activates property nodes in the Object Field representing that information. The cue signal is processed by an *Orienting System* to allow orienting, which results in activation of an internally generated node for the target property 'left location' in the Target Field. The 'left' target node is compared with the property node for 'left location' in the Match/Mismatch Field. Because the property node matches the target node, excitatory feedback initially increases activation of all property nodes associated with the cue (see Figure 1:6).

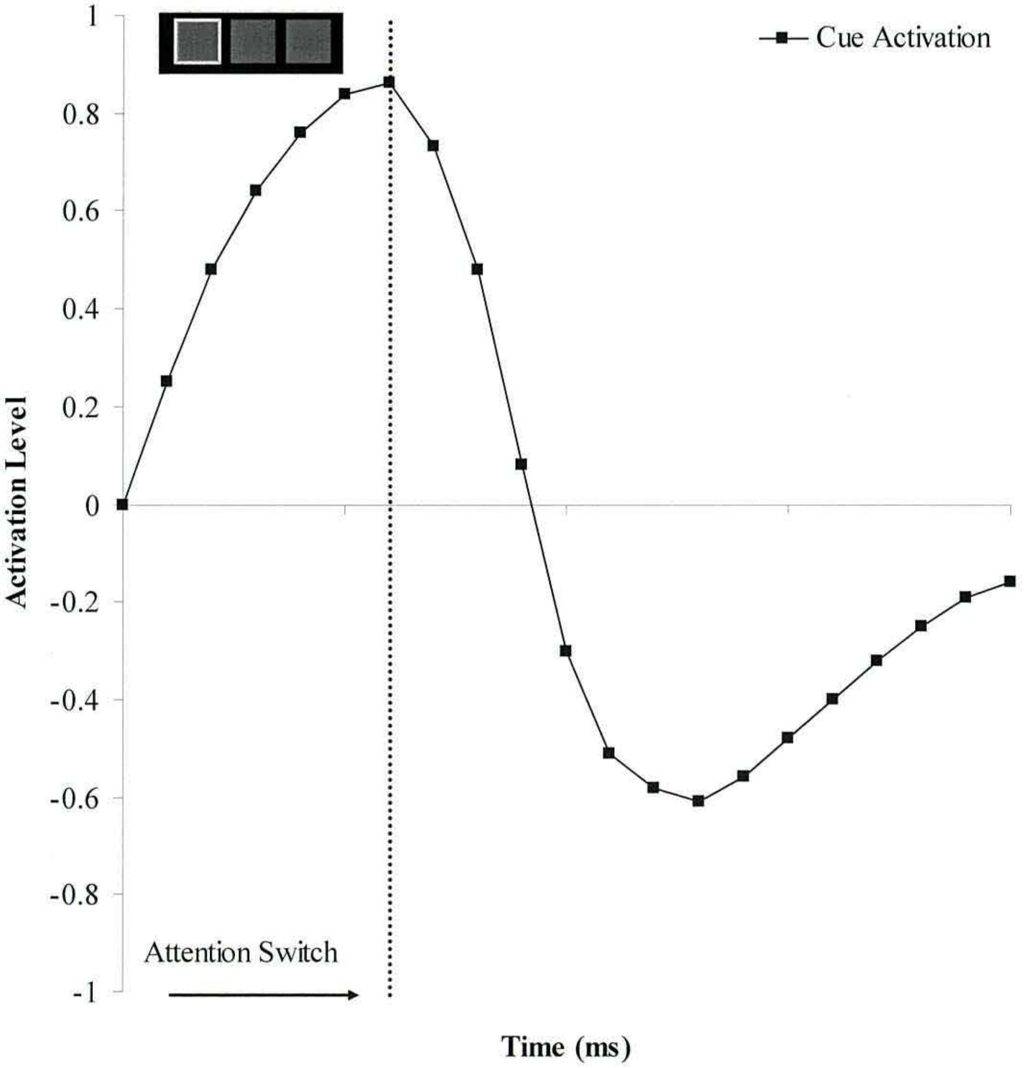

Figure 1:6. Activation level for property nodes representing a cued location in an IOR task (adapted from Houghton & Tipper, 1994). See text for details.

Importantly, this model accounts for target display IOR effects such as those observed by Posner and Cohen (1984) in the following way. When attention is switched from the left cue location, this has the effect of establishing a new target node in the Target Field. Because the new target node mismatches with the previous cue, the switch in attention results in an inhibitory rebound effect for property nodes pertaining to the left cue stimulus (see Figure 1:6 above). As long as the target signal appears in the cued location more than 300 ms after the cue signal, thereby giving inhibitory processing sufficient time to build, the property nodes for the location of the cue will be below resting levels. Accordingly, it will take longer to reach response threshold in comparison with property nodes representing an uncued location, thus revealing IOR.

1.5.5. IOR Effects over Time Due to Object-Based Inhibition

Clearly, this prior research reveals ample evidence that the NP and IOR paradigms seem to elicit similar behavioural effects and importantly, that they are both mediated by inhibitory processes. Furthermore, as with NP effects, the central assumption is that the inhibitory mechanisms engaged in IOR tasks are also transient in nature. Neural suppression prevents attention from returning to a location just examined during on-line search to allow correct action towards a target. However, once correct response has been achieved, inhibition quickly decays to allow continued processing without interference. This idea is implemented in Houghton's model of reactive inhibition (Houghton & Tipper, 1994; Houghton et al., 1996), where inhibitory feedback results in only a temporary suppression of activation below resting levels to prevent erroneous response to the cue. Once the goal of correct selection and response has been achieved, inhibition quickly decays, allowing activation to return to baseline levels. Indeed, research has found that IOR lasts for up to two seconds (e.g., Maylor, 1985; Maylor & Hockey, 1985; Posner & Cohen, 1984; Reuter-Lorenz et al., 1996; Tassinari, Aglioti, Chelazzi, Marzi, & Berlucchi, 1987; Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994; Tassinari, Biscaldi, Marzi, & Berlucchi, 1989; for reviews see Klein, 2000; Lupiáñez et al., 1999), but thereafter, the effect is generally assumed to quickly decay. Furthermore, Pratt and Abrams (1995) demonstrated that IOR was only associated with the last place attended, thus suggesting that inhibition of spatial location is overwritten by intervening displays, thus allowing processes to decay quickly, when only one or two cue displays proceed the target. Accordingly, many researchers have argued that there is no memory for inhibitory processes in search tasks (Horowitz & Wolfe, 1998) or that it is very limited (Pratt & Abrams, 1995; but see McAuliffe & Knowlton, 2000).

While this may be a reasonable proposal in terms of inhibition being applied to a spatial location in traditional IOR tasks, recent research has found that inhibition can also be applied to object-based representations in IOR tasks (e.g., Abrams & Dobkin, 1994; Becker & Egeth, 2000; Gibson & Egeth, 1994; Jordan & Tipper, 1998; Jordan & Tipper, 1999; Klein, 1988; Müller & von Mühlenen, 2000; Ogawa, Takeda, & Yagi, 2002; Oonk & Abrams, 1998; Reppa & Leek, in press; Ro & Rafal, 1999; Takeda & Yagi, 2000; Tipper, Driver, et al., 1991; Tipper et al., 1994; Tipper et al., 1999; Weaver, Lupiáñez, & Watson, 1998; but see Schendel, Robertson, & Treisman, 2001). This research is important because inhibition of object-based information could be the foundation for successful search over time (for a review, see Grison et al., 2002). Within such a framework, inhibitory processes mediating IOR may last between three and five seconds, or even longer (e.g., Tipper & Weaver, 1998) and to be associated with a number of objects (e.g., Danziger et al., 1998; Snyder & Kingstone, 2000; Snyder & Kingstone, 2001; Tipper, Weaver, & Watson, 1996).

In three experiments, Paul and Tipper (in press) investigated whether inhibition of objects in an IOR task allows processing to be maintained on-line in working memory for longer durations and over processing of more intervening trials than inhibition of spatial locations. In one experiment there were eight empty locations presented in a display, in another eight grey squares were shown, and in a third, eight different coloured line drawings of objects were displayed. Depending on the experiment, six cues were flashed in a location or object and participants detected a target presented in one of the six previously cued locations or objects. When cueing object-less locations, the results showed no overall IOR effects for the four most temporally distant cues (i.e., 6-back, 5-back, 4-back, and 3-back), thus suggesting that inhibition of pure spatial locations cannot be maintained in working memory. By contrast, when identical grey objects were cued in these same conditions, IOR was found overall, which was observed up through the 3-back and 4-back conditions, thus suggesting that inhibition of non-distinct objects can be maintained in working memory. Most importantly, cueing unique, coloured objects also resulted in an overall IOR effect for the four conditions, and IOR was obtained at the most distant point in time, for the 6-back object, which had occurred approximately 3600 ms prior to the target. Clearly, cueing unique objects appeared to increase the stability of inhibitory processes in working memory to elicit robust IOR effects. The authors concluded that the inhibitory processes underlying IOR facilitate visual search within working memory. However, this effect depends on processing of object-based representations to maintain inhibition over time and across cueing of intervening items.

In another series of experiments, Tipper et al. (2002) further investigated the nature of the object-based representations associated with inhibition in working memory. It is generally assumed that when object-based information is inhibited in IOR tasks, it pertains to low-level representations of objects encoded in parallel across a display, not higher-level representations such as the identity of an object. The possibility that inhibition can be associated with object identity was tested in three experiments by cueing naturalistic, colour, face stimuli presented just once in the experiment prior to the target display. In one experiment, the two faces could be easily recognised as they were presented upright (45 degrees from vertical) in the cue and target displays. In two other studies, however, the faces were shown inverted (90 degrees from vertical) either in the cue display or the target display, making them difficult to recognise (e.g., Kanwisher, Tong, & Nakayama, 1998; Yin, 1969). In all of the experiments, one of the two faces was cued with a red signal, which participants ignored. Then three seconds later, a green target signal appeared over one of the two faces and participants made a localisation response. The results revealed that IOR in the first experiment was significantly larger when faces were upright in comparison with the other two studies where the faces were inverted during the cue or target displays, thus suggesting that inhibition was associated with specific object identities. In particular, the larger IOR in the upright study may have been due to the additive effects of inhibition of object identity and location-based information (Jordan & Tipper, 1998). However, the IOR effects in the two experiments showing inverted faces were smaller because inhibition could only be associated with location-based information because face recognition was impaired. Interestingly, because IOR was reduced regardless of whether faces were inverted only in the cue display or only in the target display, this suggests that object identity must both be encoded and retrieved from working memory to elicit robust object-based IOR effects in this task.

Together, these experiments reveal IOR effects over several seconds and intervening displays when inhibition is associated with stable object-based representations in working memory. These findings suggest that inhibition and memory processes both function to facilitate search behaviour and avoid repeatedly returning attention to previously examined items. Indeed, taken one step further, these studies also provide the first hint that inhibition of object-based representations may provide a foundation for successful search over time.

1.5.6. Episodic Retrieval of Inhibition as a General Phenomenon

Accordingly, the current proposal is extended to suggest that long-term IOR effects may exist and furthermore, these may result from episodic retrieval of prior inhibitory states in a similar manner as previously described for long-term NP effects. In particular, during a cue display in an IOR task inhibition associated with a cued object may be encoded into episodic memory. If the target display supplies appropriate retrieval cues that reinstate the original encoding context, then episodic retrieval of the information should also reinstate prior inhibitory processing. Because the reinstated inhibition is associated with a target object that now requires response, long-term IOR effects could be observed. Accordingly, episodic retrieval of inhibitory states may generally mediate behaviour over time.

Importantly, a revised version of the Houghton and Tipper (1994; Houghton et al., 1996) neural network model of reactive inhibition could easily accommodate such a process, as was described previously for long-term NP effects. As described previously, the most important change to the model must provide a way for inhibition to mediate long-term performance, by allowing stimulus properties and transient activation states represented in the Object Field to be encoded into a new Episodic Memory sub-network. Accordingly, an instance could be created for a cued object along with its associated inhibitory feedback. The inhibition would be part of the pattern of activity stored in memory so suppression would not be active in the system after transient processes decayed, thus preventing interference during on-going behaviour. However, retrieval does not merely access a passive representation of the previously presented stimulus, but it re-establishes the state of the attentional network originally acting on the stimulus. In this way, inhibitory processes can influence behaviour in an IOR task long after originally viewing a stimulus.

The existence of such a mechanism would be behaviourally adaptive because it would allow search processes to be successfully completed even when there are long delays between the start and completion of the search. For example, consider the following scenario where you are searching the kitchen for a mislaid knife. After searching a couple of places without success, the doorbell rings. At this point, you break off the search and exit the kitchen to answer the door. After guiding the guest into the living room, you return to the kitchen where a combination of explicit recall of the previous search along with implicit retrieval of prior inhibitory processes could allow successful search completion. That is, upon re-entry into the kitchen, retrieval of prior inhibitory states would facilitate search by preventing the return of attention to previously attended objects. In this way, a link with the past is automatically achieved, and attentional orienting will possess a momentum towards searching novel, unattended objects.

1.6. Experimental Approach

Accordingly, the research reported in this thesis tested the radical proposal that in some circumstances, information associated with inhibition could be stored into long-term memory, where, given specific retrieval cues, these inhibitory states could be reactivated to affect behaviour long after encountering the information. However, research supporting the existence of long-term NP effects is spare and controversial. Additionally, no research has ever investigated the existence of long-term IOR effects. Therefore, attempting to demonstrate long-term retrieval of inhibitory processes is a highly exploratory undertaking that requires the development of new implicit paradigms that examine the existence of long-term NP and IOR effects.

To explore the idea that transient inhibition becomes a permanent part of a memory representation, the general experimental approach must encourage encoding of stimuli into long-term memory and later retrieval of this information, along with associated inhibitory processes. Interestingly, prior research (e.g., DeSchepper & Treisman, 1996; Lowe, 1998; Neill et al., 1992; Paul & Tipper, in press; Tipper, Weaver, et al., 1991; Tipper et al., 2002; Treisman & DeSchepper, 1995), has suggested several ways to design NP and IOR tasks that could increase the likelihood of observing long-term effects. These techniques, which are described below, are applied in the current research to maximise encoding of stimulus information with associated inhibitory states and to increase the chances for successful retrieval and reinstatement of inhibition, which could then result in long-term NP and IOR.

1.6.1. Presenting Novel Stimuli

Most NP research has suggested that the use of small sets of highly repeated stimuli is required in order to observe robust effects (e.g., Malley & Strayer, 1995; Strayer & Grison, 1999). Similarly, traditional IOR tasks have often obtained large effects when presenting a couple of grey boxes repeatedly for hundreds of trials on an otherwise empty computer screen. However, according to Tipper, Weaver, et al. (1991), research that uses small stimulus sets of highly repeated items is probably incapable of showing long-term effects. This concept is based on the notion of consistency in Logan's (1988) model of episodic memory (see also Lowe, 1998). In particular, recall that each time a stimulus is presented, a new instance is automatically created in episodic memory that includes response information for that stimulus. When a stimulus is repeated in an experiment, it will sometimes be task-relevant and sometimes irrelevant, therefore the stored episodes will have a variable stimulus to response mapping where a subject sometimes responded to the item, but sometimes did not. When the relationship between stored episodes is inconsistent, the probability of successful retrieval is low and so the stored information cannot affect performance. Therefore, if inhibitory states are also stored in episodes, then repeating stimuli will reduce successful retrieval, prevent reinstatement of prior inhibition, and limit observation of long-term NP and IOR effects.

Accordingly, the research described here had to develop new NP and IOR paradigms that used large stimulus sets where unique and highly memorable items were presented just once. Experimentally novel stimuli should be robustly encoded into episodic memory and because there will only be one stored instance of a stimulus along with associated inhibition, there is a higher probability of successful retrieval reinstating inhibition and allowing observation of long-term NP and IOR effects. Indeed, past research supports the idea that presenting novel stimuli might elicit long-term effects in NP and IOR tasks. For example, recall that the most surprising long-term NP effects were found when DeSchepper and Treisman (1996) when they presented 'blob' shapes that could not have had any prior representations stored in memory other than the one trace associated with the experimental presentation. Furthermore, Neumann and his colleagues (Neumann et al., 1999; Neumann & Russell, 2000) found long-term NP effects with familiar stimuli, as long as they were presented just one time in the experiment, also suggesting that information needs to be experimentally novel to elicit long-term NP effects.

Therefore, in all of the experiments, large stimulus sets were used where unique stimuli, such as naturalistic colour faces, living and non-living objects, and indoor and outdoor scenes, were shown just once in the experiment prior to the critical display. If long-term NP and IOR effects depend on robust encoding of stimuli and associated inhibition into episodic memory, along with successful retrieval of these episodes to reinstate inhibition, then these stimuli should allow observation of long-term NP and IOR effects.

1.6.2. Processing Object Representations

Some prior NP research, and the vast majority of IOR studies, have obtained short-term effects while using location-based tasks where spatial information is suppressed to elicit correct response. However, Paul and Tipper (in press) suggested that when inhibition is associated with spatial locations, it decays quickly and is overwritten by intervening displays. Therefore, if the new paradigms used here accessed purely location-based information, long-term effects probably could not be obtained.

By contrast, Tipper and his colleagues' (Paul & Tipper, in press; Tipper et al., 2002) research indicates that inhibition of stable object-based representations is maintained on-line for longer durations in working memory IOR tasks. These results suggest that inhibition of objects in particular may be robustly encoded into and successfully retrieved from episodic memory, thus allowing observation of episodic retrieval of prior inhibition in long-term NP and IOR tasks. For this reason, the new long-term NP and IOR paradigms used in this research presented object-based stimuli such as faces and living and non-living objects. Past research particularly supports the idea that presenting face stimuli might elicit long-term effects in NP and IOR tasks, because they are processed very automatically and expertly by humans (e.g., Bruce & Humphreys, 1994; Kanwisher, 1998) and tend to be stored automatically in episodic memory (Shah et al., 2001). Therefore, face stimuli may be naturally prone to allowing examination of episodic retrieval of prior inhibitory states in long-term NP and IOR tasks because they enable reinstatement of specific visual contexts. Furthermore, prior research has shown that face stimuli elicit robust short-term NP effects (e.g., Khurana, 2000) as well as IOR effects in a working memory task (e.g., Tipper et al., 2002).

Additionally, the new long-term IOR paradigms described here also allowed a direct examination of the idea that inhibition of object-based information may allow observation of long-term IOR, but inhibition of location-based information is overwritten by intervening trials and will not reveal long-term IOR. In particular, episodically salient face and scene stimuli were shown in these tasks, but when face stimuli were shown, the cue and target signals overlay either an entire face or one eye within the face. If stable object-based representations along with associated inhibition are likely to be robustly encoded into and successfully retrieved from episodic memory, then these stimuli should elicit long-term IOR effects. However, the cue and target signals in scene displays did not overlay an object, but rather appeared in an empty location in a scene. If location-based representations and associated inhibition are not robustly encoded into nor successfully retrieved from episodic memory, then these stimuli should not elicit long-term IOR effects. Consequently, finding long-term IOR effects when cueing object-based information in face stimuli but not when cueing location-based information in scenes would provide support for the idea that episodic retrieval of object-based inhibition may mediate performance over time.

1.6.3. Intervening Task

Most NP and IOR research has traditionally presented the same tasks for hundreds of trials in a row. However, when such a paradigm is placed within the domain of memory mechanisms, prior research indicates massed presentation of stimuli leads to poor memory encoding processes and consequently poor retrieval of the information at a later time (e.g., Melton, 1970). Therefore, if long-term NP and IOR effects depend on episodic retrieval of prior inhibition, then the use of massed presentation of stimuli in the new paradigms will probably fail to elicit long-term effects.

Accordingly, another way in which these new long-term NP and IOR tasks deviated from traditional tasks is because in most of the experiments here the presentation of face stimuli alternated with presentation of a second stimulus type, either objects or scenes. The use of an intervening task should help maintain the uniqueness of the stimuli and encourage retrievability for three reasons. First, as just mentioned, prior research has shown that spaced presentation of stimuli facilitates memory encoding relative to massed presentation of stimuli (e.g., Melton, 1970). Additionally, processing of object or scene stimuli on intervening displays might encourage face discrimination because these occur in neural regions distinct from processing of face stimuli (e.g. Caramazza & Shelton, 1998; Kanwisher, Downing, Epstein & Kourtzi, 2001). Finally, these intervening tasks allowed examination of the existence of long-term NP and IOR effects over twice the delay and numbers of intervening displays versus if only faces had been presented. Consequently, if long-term NP and IOR depend on robust encoding of stimuli and associated inhibition into episodic memory, along with successful retrieval of these prior episodes to reinstate inhibition, then using an intervening task should encourage observation of these effects.

1.6.4. Reinstating Context

Finally, in most previous NP and IOR experiments, the context changes between the two displays. However, according to Tipper, Weaver, et al. (1991), research in which the context changes from the first to the second presentation of a stimulus is unlikely to elicit long-term effects. This is based primarily on the notion of encoding specificity (e.g., Tulving & Thompson, 1973), where the relationship between stimuli during encoding creates a specific context, and if this context is not reinstated later then there are few cues to aid successful retrieval. In terms of the mechanisms proposed to underlie long-term NP and IOR effects, without successful retrieval, inhibitory states cannot be reinstated to affect performance over time and no long-term effects can be observed.

Accordingly, the majority of the new long-term NP and IOR tasks repeated the stimuli shown in the first display again in the second display in order to reinstate context and provide rich cues that should encourage successful retrieval. Prior research by Lowe (1998) supports this idea as he obtained robust long-term NP effects when he presented the prime display stimuli again on the probe, but with the roles of the stimuli ‘flipped’ so that the prime target became the probe distractor and the prime distractor became the probe target. When the chances of successfully retrieving the prior episode are high, so is the opportunity to reinstate prior inhibitory process and observe the effects of this process on behaviour.

1.7. Conclusions

This introduction reviewed the literature on NP effects to explain how slow response to previously ignored stimuli reveals inhibition of irrelevant information that aids correct response. A variety of neuropsychological, neuroimaging, and electrophysiological research was reviewed to provide converging evidence of transient neural suppression processes in NP tasks. Furthermore, the inhibitory processes mediating NP effects were explained in a neural network model developed by Houghton and Tipper (1994; Houghton et al., 1996).

However, controversial new research has shown the existence of NP effects over long periods of time, for example when 30 days intervene between ignoring a distractor and responding to it as a target. Clearly, if neural suppression decays quickly and over processing of intervening items then these effects cannot be mediated by on-line inhibition. Instead, memory processes must be engaged in NP tasks when performance is measured over relatively longer periods of time. Therefore, it was proposed that on viewing an irrelevant stimulus, it might be encoded into episodic memory along with associated transient inhibition. When this same item is re-presented as a target much later, it may trigger successful retrieval of the prior instance, such that the inhibitory state associated with the stimulus is re-created to slow response to this item as a target.

The generalisability of the proposal was explored in a second paradigm, IOR, where slowed response to previously cued information suggests that inhibition of attended locations facilitates on-going search. Support was provided for the idea that these inhibitory mechanisms are similar to those in NP tasks, as they are implemented through transient neural suppression, they reveal similar behavioural effects as in spatial NP tasks, and they can also be explained by Houghton and Tipper's (1994; Houghton et al., 1996), neural network model of reactive inhibition. Although there is no prior research on the existence of IOR effects over time, new studies have shown IOR effects in working memory as long as inhibition is associated with object-based representations. These new findings suggest that long-term IOR effects might be observed if inhibition associated with objects can be encoded into episodic memory and successfully retrieved much later.

Accordingly, the main goal of the current research is to search for evidence of long-term NP and IOR effects. Although there has been some support for long-term NP effects, they are controversial and require validation. In addition, no research has ever investigated the existence of IOR effects over long delays.

However, examining long-term effects in these tasks requires the development of new implicit memory paradigms that should encourage rich encoding and episodic retrieval of the inhibitory processes that mediate traditional NP and IOR effects. Accordingly, the nine experiments reported in this thesis used four new long-term NP and IOR tasks where presenting novel stimuli, processing object-based representations, using an intervening task, and reinstating encoding context should all help elicit long-term effects. Importantly, finding long-term NP and IOR effects would suggest that episodic retrieval of prior inhibitory processes might provide a foundation for successful behaviour over time.

Chapter Two

Long-Term Negative Priming:

Episodic Retrieval of Inhibition

2.1. Objectives

- Investigate existence of long-term NP effects using two new implicit memory paradigms;
- Encourage encoding and retrieval of episodic memories by presenting novel stimuli, processing object-based representations, using an intervening task, and reinstating encoding context;
- Explore whether long-term NP effects are mediated by episodic retrieval of prior inhibitory states.

2.2. Abstract

The experiments in Chapter 2 investigate the existence of long-term NP in new implicit memory paradigms designed to encourage encoding and retrieval of episodic memories and associated inhibition. Experiment 1 examines NP over six minutes and 96 intervening displays when novel faces are presented in a flanker task and participants make a same/different response to two target faces. The results show slow response to a previously ignored face in the IR probe display, which confirms the existence of long-term NP. Because performance in this task depends on episodic memory, not transient inhibition, episodic retrieval of inhibitory states may mediate behaviour. Experiment 2 replicates this effect over three minutes and 56 displays in a second paradigm where novel faces or objects alternate presentation in a flanker task and participants categorise two target faces (female or male) or objects (living or non-living). Long-term NP is shown in slow responses to the previously ignored middle face or object in a new IR+ condition, where prime stimuli are repeated on the probe. However, the effect may fail to reach significance with objects due to the difficulty of the task. While episodic retrieval of prime distractor inhibition could explain the results, the IR+ condition

may have allowed retrieval of *prime target excitation*, which could slow response when these items become probe distractors. Experiments 3 and 4 investigate these possibilities. In Experiment 3, the Attend-Ignore (AI) condition repeats prime targets as probe distractors but shows a new probe target, which elicits facilitation with faces and significant slowing with objects. In Experiment 4, the IR condition repeats the prime distractor as the probe target but shows new probe distractors, which reveals long-term NP with faces and objects. Together, the results suggest episodic retrieval of inhibition slows responses to faces and objects, but episodic retrieval of excitation also slows responses to objects. The difficulty of processing prime target objects may encourage encoding of associated excitation, which increases the likelihood that successful retrieval can reinstate excitation to affect behaviour. In sum, long-term NP exists with faces and objects, which may be mediated by episodic retrieval of prior attentional states.

2.3. Experiment 1

Experiment 1 searched for long-term NP effects when there is a long delay between prime and probe displays. As described in Chapter 1, investigating long-term NP effects requires changes to the traditional paradigm. Because emphasis must be placed on encouraging encoding and retrieval of episodic memories, the general experimental approach utilised presentation of novel, episodically salient, object-based stimuli.

Accordingly, novel, black and white faces were presented in a five-item flanker task. In prime and probe displays, subjects responded whether the target faces in the second and fourth positions were the same or different while ignoring the distractor face shown in three flanking positions. Importantly, Experiment 1 examined whether NP was obtained when six minutes and 96 displays intervened between the presentation of a prime and its associated probe (Grison et al., 2001; Grison & Tipper, 2002a).

If long-term NP effects do exist, then participants' responses should be slower in the IR condition when the prime distractor becomes the probe target versus in a control condition where all new faces were shown. Finding long-term NP would provide one of the few demonstrations of the existence of the effect. Importantly, because long-term NP cannot be explained by on-line processing of distractor faces over long delays and intervening items, these results would suggest that memory processes contribute to performance in this task.

2.3.1. Method

Participants. In Experiment 1, there were 30 participants, 15 males and 15 females, from the University of Wales, Bangor, who received course credit for their assistance. They were between 18 and 36 years of age, with an average age of 21.8 years. All tested within the normal range for visual acuity, colour vision, and stereoscopic vision.

Stimuli and Apparatus. The stimuli for Experiment 1 were 432 black and white photographs showing forward-gaze views of people's faces, each of which was randomly presented only once or twice in the IR condition, as described below. These faces drawn from the stimulus banks of researchers at other institutions [1] and thus were expected to be novel to participants. Half of the photographs depicted male faces and the other half showed female faces. Adobe Photoshop was used to crop any part of the image other than the face, from the top of the hair to the bottom of the neck, to delete any jewellery and clothing, and to place the images on a uniform grey background. On each display, five faces were presented simultaneously, centred in a horizontal row and a chin-rest was used to maintain a visual angle of 3.0 degrees vertically and 2.5 degrees horizontally for each stimulus, while the entire visual display subtended 3.0 degrees vertically and 12.5 degrees horizontally.

The experiment was performed on an IBM-compatible personal computer with a Pentium II 266 MHz processor and 160 MB RAM. The experiment was created with E-Prime software (2000), which displayed the stimuli on a 19-inch superVGA monitor, controlled timing, and logged participants' responses through the keyboard.

Design. In Experiment 1, there were 96 trials, each with one prime display and one probe display. These trials were equally made up of conditions drawn from a 2 x 2 x 2 repeated measures design (Priming Condition: [Control/IR] x Prime Response: [Same/Different] x Probe Response: [Same/Different]) (see Appendix, Figure 1, for graphic displays of all conditions). Half of the 96 trials showed a control condition where no face stimuli were the same between the prime and probe displays. The other half of the 96 trials showed an IR condition, where the prime distractor face was subsequently presented in one or both of the probe target locations, along with a new face in the three distractor locations (see Figure 2:1 below). Therefore, in the IR condition, each prime distractor face was seen a second time in the probe. Within each of the priming conditions, half of the prime displays required a 'same' response when the same face was shown in the

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[1] The author is grateful to Beena Khurana, Mike Tarr, and Shlomo Bentin, for allowing use of their face stimuli.

two target locations and half required a 'different' response when the faces in the two target locations were different from each other. Similarly, for each of the prime response conditions, half of the probe trials required a 'same' response and half required a 'different' response. Participants therefore experienced 12 trials in each of the eight conditions. However, for the two IR conditions requiring a 'different' response on the probe, six displays showed the prime distractor in the *left* probe target location and six displays showed it in the *right* probe target location. The presentation of all conditions was randomised such that they occurred in an unpredictable order.

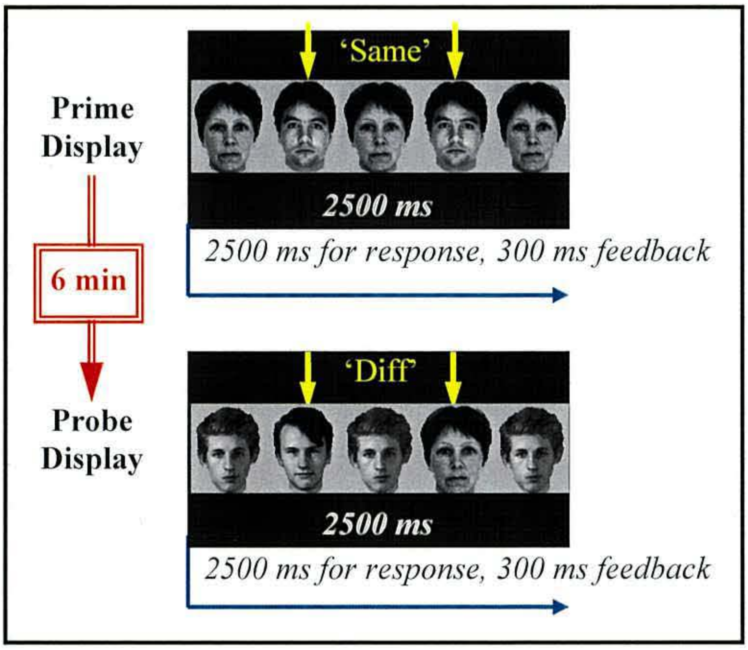

Figure 2:1. Procedure used in Experiment 1. This example shows an IR condition where the prime response is 'same' and probe response is 'different'.

Procedure. In Experiment 1, participants sat in front of the monitor, with the keyboard in front of them, under dim lighting conditions. They completed eight practice trials, one for each of the above conditions, which displayed 36 faces, half female and half male, that were not seen again in the experiment.

The experiment followed the practice session and lasted approximately 30 minutes. There were 96 experimental trials, which showed 432 faces, half female and half male. Participants first saw 96 prime displays back-to-back, which showed 240 faces, half female and half male. In a prime display, a black screen was presented for 50 ms, a central white fixation cross (e.g., +) for 400 ms, a blank screen for another 50 ms, and then the five face stimuli for 2500 ms or until response (see Figure 2:1 above). Depending on whether the two targets were the same face or different faces, participants pressed one of two keys, z or /, with the left and right index fingers. Assignment of responses to keys was counterbalanced across participants. After responding, participants received 300 ms of auditory feedback.

At the end of the 96 prime displays participants rested for three minutes. Then they saw the 96 probe displays, where the procedure was the same (see Figure 2:1 above) except that 192 new faces were presented, half female and half male. Accordingly, there was an average of six minutes and 96 displays intervening between each prime and its yoked probe display. After the experiment, participants completed a questionnaire that assessed their awareness of the experimental conditions.

2.3.2. Results

No participants committed more than 15 % errors (ER). All displays where an error was made were removed from response time (RT) analyses. Additionally, when an error was made in a prime, the yoked probe data was also removed from RT analysis. All prime and probe RTs greater or less than two and a half times the standard deviation (SD) of the mean were dropped from analyses, which resulted in removal of 2.6 % of correct trials. All inferential tests used a significance level of $p < .05$.

Experiment 1: Prime Displays. The mean prime RT and ER data, which are displayed in Table 2:1 below, were analysed using separate repeated measures analyses of variances (ANOVAs) in the following design: (Prime Response: [Same/Different]). The data show that participants responded faster for a 'same' response (790 ms) versus 'different' (817 ms), $F(1, 29) = 9.6, p < .01$. The ER data revealed no effects.

	RT (SD)	**ER (SD)**
Same	790 (68)	3.6 (3.8)
Different	817 (69)	3.9 (4.2)

Table 2:1. *Experiment 1 means and standard deviations (SD) for prime reaction times (RT) and error rates (ER).*

Experiment 1: Probe Displays. Probe RT and ER data were analysed in separate repeated measures ANOVAs, using the design: (Priming Condition: [Control/IR] x Prime Response: [Same/ Different] x Probe Response: [Same/Different]). The mean probe RT and ER data are shown below in Table 2:2. To measure long-term NP effects, difference scores were calculated by comparing probe display performance in an IR condition with the corresponding control condition. Directional *t*-tests indicated whether the difference scores were significantly less than zero, which would reveal long-term NP effects. RT and ER difference scores are shown below in Table 2:2. The data showed faster 'same' responses (768 ms) than 'different' responses in the probe display (791 ms), $F(1, 29) = 11.7, p < .01$. There was an effect of the priming condition, $F(1, 29) = 4.8, p < .05$, where responses were slower in the IR (785 ms) than the control condition

(774 ms). Importantly, as seen in Figure 2:2 below, a *t*-test confirmed that this overall -11 ms effect revealed long-term NP, $p < .05$. In addition, the priming condition interacted with probe response, $F(1, 29) = 6.0$, $p < .05$. Planned comparisons showed slower RTs in the IR versus control condition for probe 'different' responses (804 ms versus 777 ms), $p < .01$, but not for probe 'same' responses. *T*-tests confirmed that this effect revealed the presence of long-term NP for 'different' responses (-27 ms), $p < .01$, but not for 'same' responses (+4 ms). Planned comparisons also indicated faster RTs in the IR condition for 'same' versus 'different' responses (767 ms versus 804 ms), $p < .01$. Finally, ERs showed an interaction between priming condition and probe response, $F(1, 29) = 4.6$, $p < .05$. Planned comparisons only demonstrated lower ERs in the IR condition for 'same' versus 'different' probe responses (1.6 % versus 4.0 % ms), $p < .05$.

	RT (SD)	**DS (SD)**	**ER (SD)**	**DS (SD)**
Control Condition				
Prime Same				
Probe Same	775 (98)	-----	3.3 (5.6)	-----
Probe Different	776 (79)	-----	2.3 (4.5)	-----
Prime Different				
Probe Same	765 (83)	-----	3.0 (6.0)	-----
Probe Different	779 (87)	-----	2.8 (5.2)	-----
IR Condition				
Prime Same				
Probe Same	763 (84)	+12 (61)	2.1 (3.9)	+1.2 (7.2)
Probe Different	804 (91)	-28 * (69)	2.9 (5.2)	-0.6 (7.0)
Prime Different				
Probe Same	769 (76)	-4 (53)	1.1 (4.7)	+1.9 # (7.2)
Probe Different	804 (84)	-25 * (61)	5.1 (8.0)	-2.3 # (8.5)

Table 2:2. *Experiment 1 means and standard deviations (SD) for probe reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term NP and positive scores reveal long-term facilitation. * $p<.05$; # $p<.10$.*

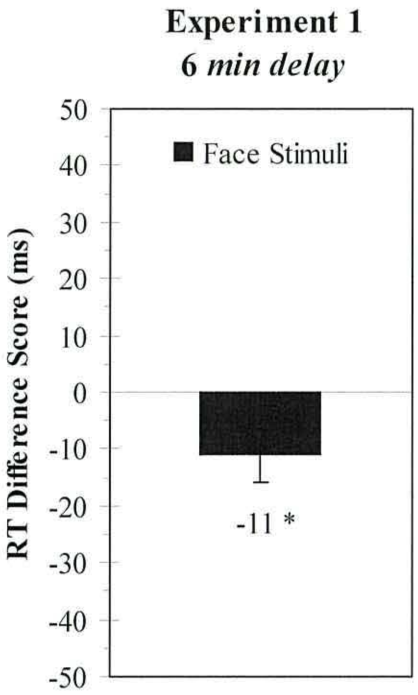

Figure 2:2. Mean overall RT difference score for Experiment 1. A negative score reveals long-term NP. * $p < .05$.

2.3.3. Discussion

The existence of long-term NP is a controversial topic (e.g., DeSchepper & Treisman, 1996; Lowe, 1998; Neumann et al., 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995). Therefore, the goal of Experiment 1 was to search for long-term NP effects, using a new implicit memory paradigm where the experimental approach used novel, object-based stimuli, to encourage encoding into and retrieval from episodic memory (Grison et al., 2001; Grison & Tipper, 2002a). If long-term NP does exist then participants should respond more slowly to a previously ignored target face in the IR condition in comparison with a new face presented in the control condition.

Indeed, -11 ms of long-term NP was seen in Experiment 1 when there were six minutes and 96 displays intervening between the prime and probe displays. Accordingly, these results support the existence of long-term NP. Although NP effects in the short-term are often explained in terms of on-line inhibitory processing of irrelevant information, clearly transient inhibition cannot be maintained over such long delays and processing of intervening displays. Therefore, this outcome can be interpreted as providing evidence that both inhibitory and memory processes mediate performance in long-term NP tasks. In particular, the candidate memory processes may be episodic in nature, given that face stimuli are processed automatically into episodic memory (e.g., Shah et al., 2001). Therefore, it is suggested that when initially encoding a distractor stimulus in a prime display, the inhibitory processes acting on the perceptual inputs may become associated with the information stored in episodic memory. When encountering the same item as a target during the probe display, retrieval of the prior stimulus not only enables object recognition but also re-activates the attentional system into its previous inhibitory state. Performance is hampered because the reinstated inhibition must be overcome before response can occur.

The finding that priming was modulated by probe response, where long-term NP occurred when the probe response was 'different', but not when it was 'same', was not predicted *a priori*. Other researchers have either failed to analyse such effects in short-and long-term NP experiments (e.g., DeSchepper & Treisman, 1996; Khurana, 2000) or they have reported no effects of prime and probe responses on short-term NP effects (e.g., Neill et al., 1990). However, it is suggested that the presence of this interaction is consistent with prior research that suggests 'different' responses are slower and less accurate than 'same' responses (e.g., Proctor, 1981). In particular, the processes causing the slow 'different' response might have hampered RTs even further in the IR condition where inhibition had to be overcome, thus seeming to elicit more long-term NP. Similarly, the processes that elicit fast 'same' responses might have speeded RTs somewhat in the IR condition to moderate the difficulty of overcoming inhibition, thus seeming to reduce long-term NP effects. Although the data reported here cannot discriminate between these interpretations, they do suggest that long-term NP effects can be modulated by factors that influence ease of processing and speed of response. Therefore, the use of same/different responses may have elicited a weak measure of long-term NP effects.

There is an additional reason to suspect that long-term NP effects were underestimated in this task. In particular, participants' responses on the debriefing questionnaire revealed that they perceived face stimuli to be repeated an average of five times whereas in reality, half of the faces were shown one time only and the other half were only seen two times. This perception of stimulus repetition may not be surprising because black and white face photographs were shown, which were manipulated to increase control. Consequently, the face stimuli may have appeared very similar to one another, leading to subjects' impression of stimulus repetition. Importantly, if long-term NP depends on inhibition and episodic memory processes, then perception of stimulus repetition may have reduced the likelihood of finding the effect. Specifically, if a face is not perceived as unique, then the item may not be robustly encoded into memory during the prime display, or if it is encoded, there may be many similar episodes stored in long-term memory. In either case, there would be a poorer chance of successful episodic retrieval of a specific face on the subsequent probe. Without retrieval of the item, the associated inhibitory states cannot be reinstated to affect performance; hence, long-term NP effects will not occur. Therefore, the perception of stimulus repetition may have also contributed to an underestimation of long-term NP effects in this study.

In sum, the results of the first experiment suggest that long-term NP does exist and that memory processes contribute to performance in this task. However, the results also suggest that finding these small effects may depend on rich encoding and successful retrieval of item-specific information and associated inhibitory operations. Accordingly, the next experiment was designed to encourage richer encoding into and more successful retrieval from episodic memory. If episodic retrieval of inhibitory states mediates long-term NP, then Experiment 2 may find effects that are more robust.

2.4. Experiment 2

Experiment 2 explored the existence of long-term NP using a second new paradigm should increase robust encoding of information and encourage retrieval from episodic memory (Grison et al., 2001; Grison & Tipper, 2002a). Therefore, as described in Chapter 1, the general experimental approach in this task utilised presentation of novel, object-based stimuli, an intervening task, and reinstatement of encoding context, among other techniques described below.

Accordingly, in Experiment 2 the stimuli were novel, colour, faces and objects shown in a flanker task. For prime displays showing faces, participants decided whether the two flanking target faces were 'female' or 'male', while ignoring the middle distractor face. In probe displays showing faces, participants decided whether the middle target face was 'female' or 'male', while ignoring the two flanking distractor faces. Importantly, the presentation of face stimuli was spaced by inserting an intervening task showing object stimuli. The prime and probe displays for objects were the same as for faces except that participants categorised objects as 'living' or 'non-living'. Importantly, context specificity was provided for probe displays showing faces or objects by using an untraditional IR+ condition, where the entire prime context was reinstated on the probe (see Lowe, 1979 and 1998, for a similar IR+ condition, called 'flipped probes'). The presence of NP effects was examined when three minutes and 56 displays intervened between presentation of each prime and its yoked probe display.

Additional changes were also made to Experiment 2 to encourage encoding and retrieval of prior inhibitory states, thus increasing the changes of observing long-term NP effects. Accordingly, each display presented only one distractor during the prime to prevent inhibitory processes from being applied to more than one representation, which could reduce long-term NP (e.g., Neumann & DeSchepper, 1992). Furthermore, in both prime and probe displays, the middle face onset 100 ms prior to the flankers, which should provide more time for deeper analysis of this stimulus, thereby increasing long-term NP (e.g., Moore, 1996; Neill, 1997). Additionally, the same/different task was eliminated in order to avoid interactions between priming effects and different responses based on the difficulty of a response. Instead, participants performed a deep-processing categorisation task that should also encourage robust encoding of the stimuli and successful retrieval (Craik & Lockhart, 1972), thus increasing the chances of finding long-term NP. Finally, the number of displays intervening between the prime and probe was reduced to avoid accumulation of many similar episodes in memory (e.g., Logan, 1988). This may have the effect of maintaining the uniqueness of any one episode, which would increase the likelihood of episodic retrieval and reinstatement of inhibition.

If long-term NP depends on episodic retrieval of an item along with associated inhibitory processing, then the experimental approach used in this new paradigm may reveal robust long-term NP. If the effect is obtained, participants' responses will be slower to the previously irrelevant probe distractor when the prime display is repeated in the probe IR+ condition versus in a control condition where all new faces are shown. This result would suggest the generalisability of long-term NP effects and support the notion that episodic retrieval of inhibitory processes underlies performance in this task.

2.4.1. Method

Participants. Twenty-four Psychology undergraduates from the University of Wales, Bangor, 12 males and 12 females, participated in Experiment 2 in return for course credit. They ranged between 18 and 37 years of age, with an average age of 21.3 years. All showed normal visual acuity, colour vision, and stereoscopic vision.

Stimuli and Apparatus. The stimuli and apparatus used in Experiment 2 were the same as in Experiment 1, except as follows. Two stimulus sets were used, faces and objects. The first stimulus set was 528 colour photographs showing forward-gaze views of people's faces drawn from Art Explosion CD-ROMs (1995). These stimuli were expected to be unfamiliar to participants and appear unique because they included different hairstyles, clothes, accessories, and backgrounds. Half of the faces were female and half were male.

The second stimulus set was 528 colour photographs of objects taken from Art Explosion CD-ROMs (1995), which were also expected to be unfamiliar and unique. Half of the objects depicted living items and half showed non-living items.

For a display showing either faces or objects, three items were centred in a horizontal row, and the visual angle was 3.0 degrees vertically and 2.5 degrees horizontally for each stimulus. The entire visual display subtended 3.0 degrees vertically and 7.5 degrees horizontally.

Design. The design of Experiment 2 was similar to Experiment 1, except as described below. There were 224 trials, half showing faces and half showing objects, which alternated presentation. Of the 112 trials showing faces, 96 were equally drawn from a 2 x 2 x 2 repeated measures design (Priming Condition: [Control/IR+] x Flanker: [Compatible/Incompatible] x Probe Response: [Female/Male]) (see Appendix, Figure 2, for graphic displays of all conditions). Half of the 96 trials showed a control condition and half showed an IR+ condition, where the middle prime distractor became the probe target and the flanking prime targets became probe distractors (see Figure 2:3 below). Therefore, in the IR+ condition, all three faces were seen again in the probe. For each of the control and IR+ priming conditions, on half of the trials the sex of the flanking faces was compatible with the middle face, and on half it was incompatible. The factor of flanker compatibility remained the same for a given control or IR+ trial between the prime and probe display. On half of the probe displays for each of the flanker conditions, the response to the middle face was 'female' and on half it was 'male'. Participants therefore saw 12 trials in each of the eight priming conditions. The remaining 16 trials showing faces presented a catch condition, which only differed from the control condition in the following ways. In both prime and probe displays, one flanker was male while the other flanker was female and the middle face was either male or female. In prime displays, participants withheld response to this catch condition, to ensure analysis of both flankers on prime displays.

The design for the 112 trials showing object stimuli was the same, with the exception that the required response was 'living' or 'non-living'.

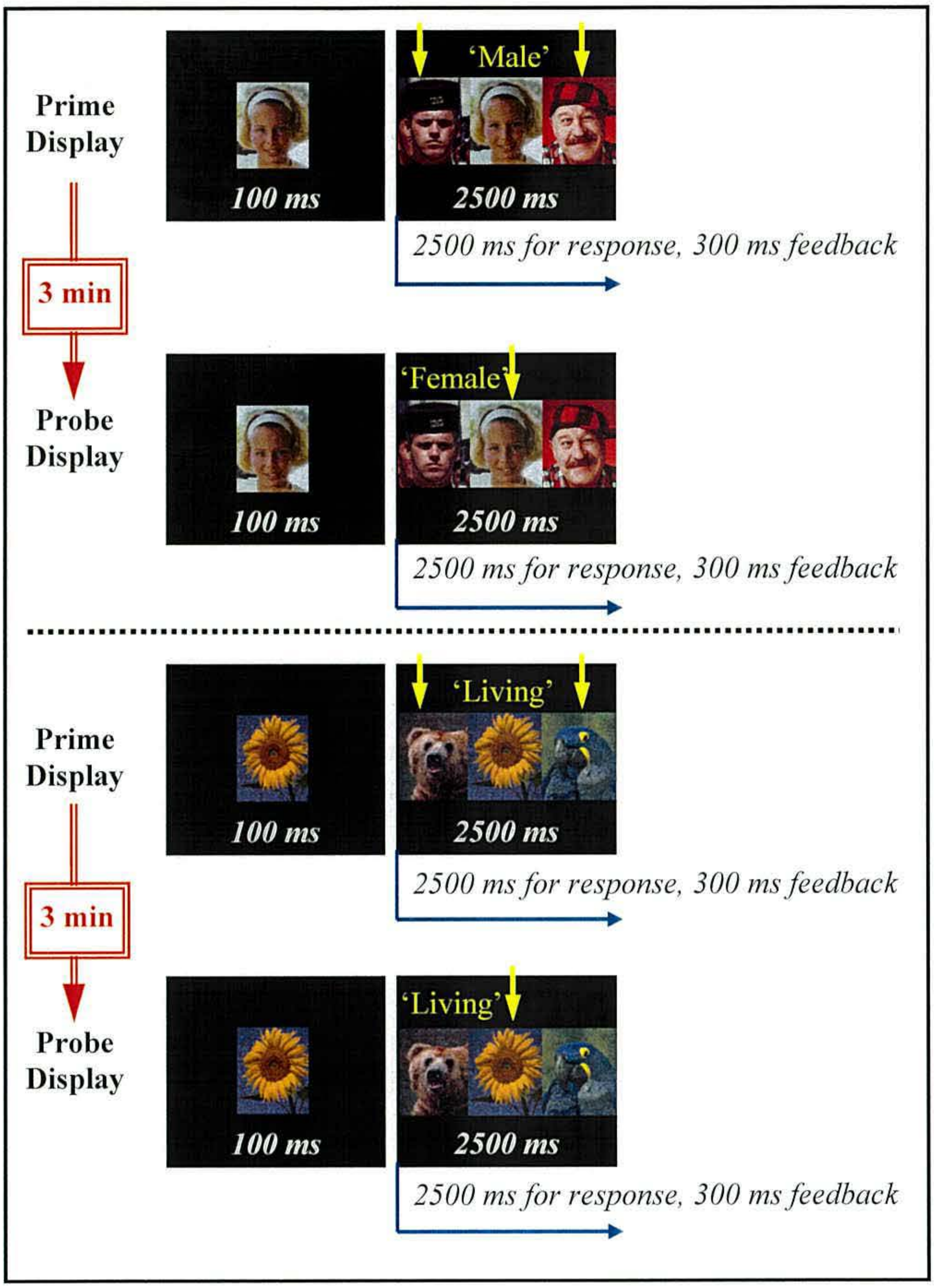

Figure 2:3. Procedure used in Experiment 2. The example for faces shows an IR+ condition with incompatible flankers where the prime response is 'male' and the probe response is 'female'. The example for objects shows an IR+ condition with compatible flankers where the prime and probe responses are 'living'.

Procedure. In Experiment 2, the procedure was the same as in Experiment 1 except as described below. Participants first completed 12 practice trials, randomly drawn from the above-mentioned conditions, half showing faces and half showing objects. Accordingly, the practice trials could present between 24 and 36 faces and between 24 and 36 objects, which were not seen again in the experiment. There were between 7 and 23 female faces with the remainder being male, and between 7 and 23 living objects with the rest being non-living.

There were 224 total experimental trials, 112 of which showed faces and 112 of which showed objects. Fifty-six prime displays were first presented back-to-back, half showing faces and half showing objects, which alternated presentation. Therefore, participants saw 84 unique faces, half female and half male, and 84 unique objects, half living and half non-living. In a prime display showing faces, the middle distractor appeared alone for 100 ms and was simultaneously joined by the flanking targets such that the three faces were viewed for 2500 ms or until response, at which point they offset simultaneously (see Figure 2:3 above). Depending on whether the flanker faces were both female or male, participants pressed one of two keys, z or /, with the left and right index fingers. If the flanker faces were of different sexes, as occurred in the catch trials, participants withheld response.

Following presentation of a prime display showing faces, participants saw a prime display showing objects (see Figure 2:3 above). The procedure was the same as just described except that depending on whether the flanker objects were both living or non-living objects, participants pressed one of two keys, z or /, with the left and right index fingers respectively. Participants did not respond when flanker objects were of different categories, as occurred in the catch trials.

After completing the 56 prime displays for faces and objects, participants experienced a 30 second break. This was followed by presentation of the 56 associated probe displays for faces and objects (see Figure 2:3 above), where the procedure was the same except that participants were told to respond on every display to the middle stimulus and to ignore the flanking distractor stimuli. Participants saw 48 new faces, half male and half male, and 48 new objects, half living and half non-living. After completion of the probes, these same procedures were repeated again three times to complete the experiment. Accordingly, there was an average of about three minutes and 56 displays between a particular prime and its yoked probe display.

2.4.2. Results

The data from Experiment 2 were analysed as in Experiment 1, except that the data from the catch condition were not analysed. Some additional differences are described below. Outlier trimming resulted in removal of 3.1 % of correct trials obtained with face stimuli and 2.6 % of the data obtained with object stimuli.

<u>Experiment 2: Prime Displays</u>. The RT and ER data from prime displays showing faces, shown below in Table 2:3, were analysed using separate repeated measures ANOVAs in the design: (Prime Flanker: [Compatible/Incompatible] x Prime Response [Female/Male]). There was an effect of flanker compatibility, $F(1, 23) = 32.4, p < .01$, where RTs were faster for compatible (1007 ms) versus incompatible flankers (1061 ms). There were no other effects in RTs or ERs.

Prime display RT and ER data for objects, also shown below in Table 2:3, were analysed in the same way as for faces, but the responses were ‘Living’ or ‘Non-Living’. Flanker compatibility again modulated response, $F(1, 23) = 7.6, p < .05$, where RTs were faster for compatible (1177 ms) than incompatible flankers

(1207 ms). There was also an effect of prime response, *F*(1, 23) = 7.3, $p < .05$, where RTs were faster to respond 'living' (1158 ms) versus 'non-living' (1226 ms). There were no effects in ERs.

	RT (SD)	**ER (SD)**
FACE STIMULI		
Compatible		
Female	1003 (99)	1.7 (3.0)
Male	1011 (116)	1.3 (2.8)
Incompatible		
Female	1059 (117)	2.0 (3.3)
Male	1063 (101)	1.2 (2.6)
OBJECT STIMULI		
Compatible		
Living	1142 (144)	2.8 (4.6)
Non-Living	1211 (172)	2.0 (3.3)
Incompatible		
Living	1173 (151)	2.3 (3.4)
Non-Living	1241 (163)	2.2 (4.3)

Table 2:3. *Experiment 2 means and standard deviations (SD) for prime reaction times (RT) and error rates (ER).*

Experiment 2: Probe Displays. The probe display RT and ER data for faces were analysed in separate repeated measures ANOVAs using the design: (Priming Condition: [Control/IR+] x Flanker: [Compatible/Incompatible] x Probe Response: [Female/Male]). The mean probe RT, ER, and difference score data are shown below in Table 2:4. There was an effect of the priming condition, *F*(1, 23) = 7.7, $p < .05$, where RTs were slower in the IR+ (688 ms) versus control condition (667 ms). Critically, a *t*-test confirmed that this -21 ms effect revealed significant long-term NP, $p < .01$, as seen in Figure 2:4 below. There were no other effects seen in the RT or ER data.

The probe RT and ER data for objects were analysed in the same way as for faces, but the responses were 'Living' or 'Non-Living'. Table 2:4 below shows the mean probe RT, ER, and difference score data. There were no effects obtained in the RT data, where Figure 2:4 shows that overall RT difference score for objects was-9 ms, or in the ER data.

	RT (SD)	DS (SD)	ER (SD)	DS (SD)
FACE STIMULI				
Control Condition				
Compatible				
Female	676 (80)	-----	3.6 (5.7)	-----
Male	672 (91)	-----	4.9 (6.5)	-----
Incompatible				
Female	656 (94)	-----	4.3 (5.8)	-----
Male	666 (87)	-----	2.3 (4.9)	-----
IR+ Condition				
Compatible				
Female	696 (112)	-20 (84)	4.2 (6.5)	-0.6 (8.3)
Male	687 (110)	-15 # (46)	3.6 (7.6)	+1.3 (10.3)
Incompatible				
Female	681 (112)	-25 # (77)	4.4 (5.3)	-0.1 (7.6)
Male	689 (95)	-23 * (53)	2.6 (5.4)	-0.3 (8.2)
OBJECT STIMULI				
Control Condition				
Compatible				
Living	755 (146)	-----	3.3 (5.0)	-----
Non-Living	766 (147)	-----	2.2 (3.9)	-----
Incompatible				
Living	780 (136)	-----	3.4 (6.9)	-----
Non-Living	751 (147)	-----	4.0 (6.4)	-----
IR+ Condition				
Compatible				
Living	771 (125)	-16 (73)	3.6 (7.1)	-0.3 (6.7)
Non-Living	776 (167)	-10 (132)	2.5 (5.4)	-0.3 (6.7)
Incompatible				
Living	771 (155)	+9 (90)	4.7 (5.7)	-1.3 (8.2)
Non-Living	771 (132)	-20 (96)	2.3 (4.8)	+1.7 (8.0)

Table 2:4. *Experiment 2 means and standard deviations (SD) for probe reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term NP. Positive scores reveal long-term facilitation. * p<.05; # p<.10.*

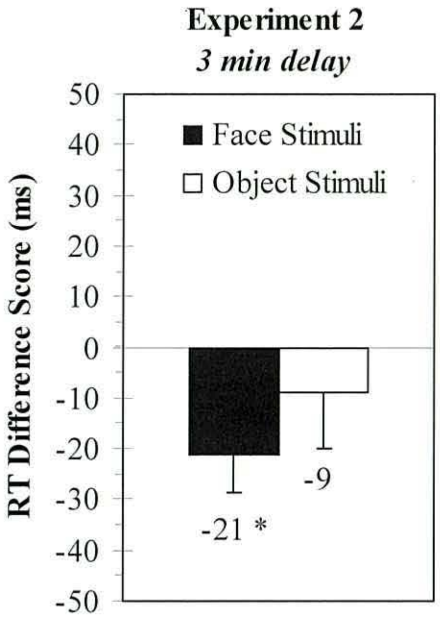

Figure 2:4. Mean overall RT difference scores in Experiment 2. Negative scores reveal long-term NP. * $p < .05$.

2.4.3. Discussion

In Experiment 2, the goal was to replicate and extend long-term NP effects to a new implicit memory paradigm designed to encourage rich encoding and successful retrieval from episodic memory (Grison et al., 2001; Grison & Tipper, 2002a). Accordingly, the experimental approach utilised methods such as presenting novel stimuli, processing object representations, displaying an intervening task, and reinstating encoding context, among other techniques. Importantly, if episodic retrieval of inhibitory states mediates performance over time, this new implicit memory paradigm should elicit robust long-term NP.

As seen in Table 2:5 below, evidence was again obtained to support the existence of long-term NP with face stimuli when three minutes and 56 displays intervened between the prime and the probe. Accordingly, these results replicate long-term NP with face stimuli in Experiment 1 and extend the effect into a new paradigm, thus making clear that these effects do exist. The results suggest that both inhibition and memory mechanisms mediate performance in this task as transient inhibition cannot be maintained on-line over this long delay and during continued processing of additional displays. Furthermore, episodic memory in particular seems to be engaged in this task. NP with faces was larger than in Experiment 1 (see Table 2:5 below) and furthermore participants reported less face repetition (an average of three and a half times versus five times in Experiment 1). It may be that in comparison with the task used in Experiment 1, this new paradigm encouraged richer encoding of faces with associated inhibition and increased the likelihood of successful retrieval, so that reinstated inhibition elicited robust long-term NP.

	Delay	**Critical Condition**	**Face Stimuli**	**Object Stimuli**
Experiment 1	6 min	IR	-11 * (28)	Not Applicable
Experiment 2	3 min	IR+	-21 * (37)	-9 (54)

Table 2:5. *Summary of RT difference scores and SDs (in parentheses). Negative scores reveal long-term NP. * p<.05.*

In Experiment 2 there was long-term NP with object stimuli in absolute magnitude, however, this effect was not significant (see Table 2:5 above). Interestingly, a comparison of data between the two sets of stimuli revealed that responses were significantly slower to objects (768 ms) than faces (678 ms), and SDs tended to be greater for objects (127 ms) than faces (84 ms). The slower and more variable responses to objects may be because perceptual analysis of objects is a less automatic process than for faces. Indeed, objects are more perceptually heterogeneous than faces and are represented in various neural regions across broad expanses of ventral temporal, and ventral and dorsal occipital cortices (e.g., Caramazza & Shelton, 1998; Haxby et al., 2001; Ishai, Ungerleider, Martin, & Haxby, 2000), whereas faces tend to be processed in one neural region, the fusiform face gyrus (Kanwisher, 1998). Additionally, slow and variable responses to objects could be due to the hard task of categorising objects, because the items in 'living' and 'non-living' categories are processed based on different criteria (e.g., Garrard, Lambon Ralph, Hodges, Patterson, 2001). By contrast, faces tend to be processed holistically and automatically (e.g., Farah, Wilson, Drain, & Tanaka, 1998). Given that this task elicits small long-term NP with faces, it may not be surprising that the effect did not reach significance with the objects.

While the effects obtained in Experiment 2 may be due to episodic retrieval of inhibitory states associated with the prime distractor, there is an alternative interpretation. In particular, because in the IR+ condition the entire prime display was repeated on the probe, this condition could have had the unintended effect of encouraging successful episodic retrieval of prior excitatory states associated with the *prime targets* re-shown in probe displays as *distractors*. The reinstatement of the prior excitation might hamper probe display performance if it takes time to overcome retrieved excitation and suppress response to these same stimuli as distractors. Therefore, long-term NP on the IR probe display may have either been due to the extra time it took to overcome prior inhibition associated with the IR+ probe target or prior excitation associated with the IR+ probe distractors.

In sum, these results confirm the existence of long-term NP effects, especially with face stimuli, and further suggest that episodic memory processes in particular may mediate performance in this task. However, while it is proposed that episodic retrieval of prior inhibitory states underlies long-term NP, these effects could have been produced by episodic retrieval of excitation. Experiments 3 and 4 were designed to distinguish between these alternatives.

2.5. Experiments 3 and 4

Experiments 3 and 4 examined whether prior inhibition or excitation are retrieved with an episode in long-term NP tasks (Grison et al., 2001; Grison & Tipper, 2002a). Accordingly, in these studies the same paradigm was used as in Experiment 2, however, the IR+ condition was replaced.

In Experiment 3, an AI condition repeated the prime targets as probe distractors and showing a new probe target. If long-term NP in Experiment 2 was due to the IR+ condition causing episodic retrieval of excitation associated with prime targets, then the AI condition should also elicit long-term behavioural slowing due to the time to overcome retrieved excitation and suppress response to these items as distractors. Therefore, finding slow responses in Experiment 3 would suggest that long-term NP in Experiment 2 was due to episodic retrieval of prior excitatory states. By contrast, if long-term NP in Experiment 2 resulted from episodic retrieval of prior inhibition, then the AI condition will not reveal behavioural slowing because the probe target is a new stimulus not previously associated with inhibition in the task.

In Experiment 4, a traditional IR condition was used, where the prime distractor reappeared as the probe target, but two new stimuli were seen as probe distractors. If long-term NP in Experiment 2 was due to episodic retrieval of inhibition associated with the prime distractor, then this IR condition should also reveal long-term NP due to the time to overcome retrieved inhibition and facilitate response to this item as a target. Therefore, finding slow responses in Experiment 4 would suggest that long-term NP with faces in Experiment 2 was due to episodic retrieval of inhibitory states. However, if long-term NP in Experiment 2 was due to episodic retrieval of excitatory states associated with the prime targets then no behavioural slowing should be observed because the distractors are new items not previously associated with excitation in the experiment.

Together, the results of Experiments 3 and 4 should clarify the mechanisms that mediate long-term NP, by providing information about what attentional processes are retrieved from episodic memory to slow response over time.

2.5.1. Method

Participants. In Experiment 3, there were 24 participants, 12 males and 12 females, between 20 and 38 years old, with an average age of 25.8 years. In Experiment 4, the 24 new participants were 12 females and 12 males, between 18 and 22 years old, with an average age of 20.2 years. All subjects were Psychology students from the University of Wales, Bangor, who received course credit for their help. They showed normal visual acuity, and colour and stereo vision.

Stimuli and Apparatus. The stimuli and the apparatus in these two experiments were the same as in Experiment 2, except that there were more stimuli. In Experiment 3, there were 576 faces, half female and half male, and 576 objects, half living and half non-living. In Experiment 4, there were 624 faces, half female and half male, and 624 objects, half living and half non-living.

Design. The design of these two studies was the same as Experiment 2 except that in Experiment 3, an AI condition was used, where the prime distractor was replaced by a new probe target but the prime targets became the probe distractors (see Figure 2:5 below). Accordingly, only the two prime targets were seen again on the probe. In Experiment 4, a traditional IR condition was used, where the prime distractor became the probe target but the prime targets were replaced by new probe distractors (see Figure 2:5 below). Therefore, only the prime distractor was presented again on the probe.

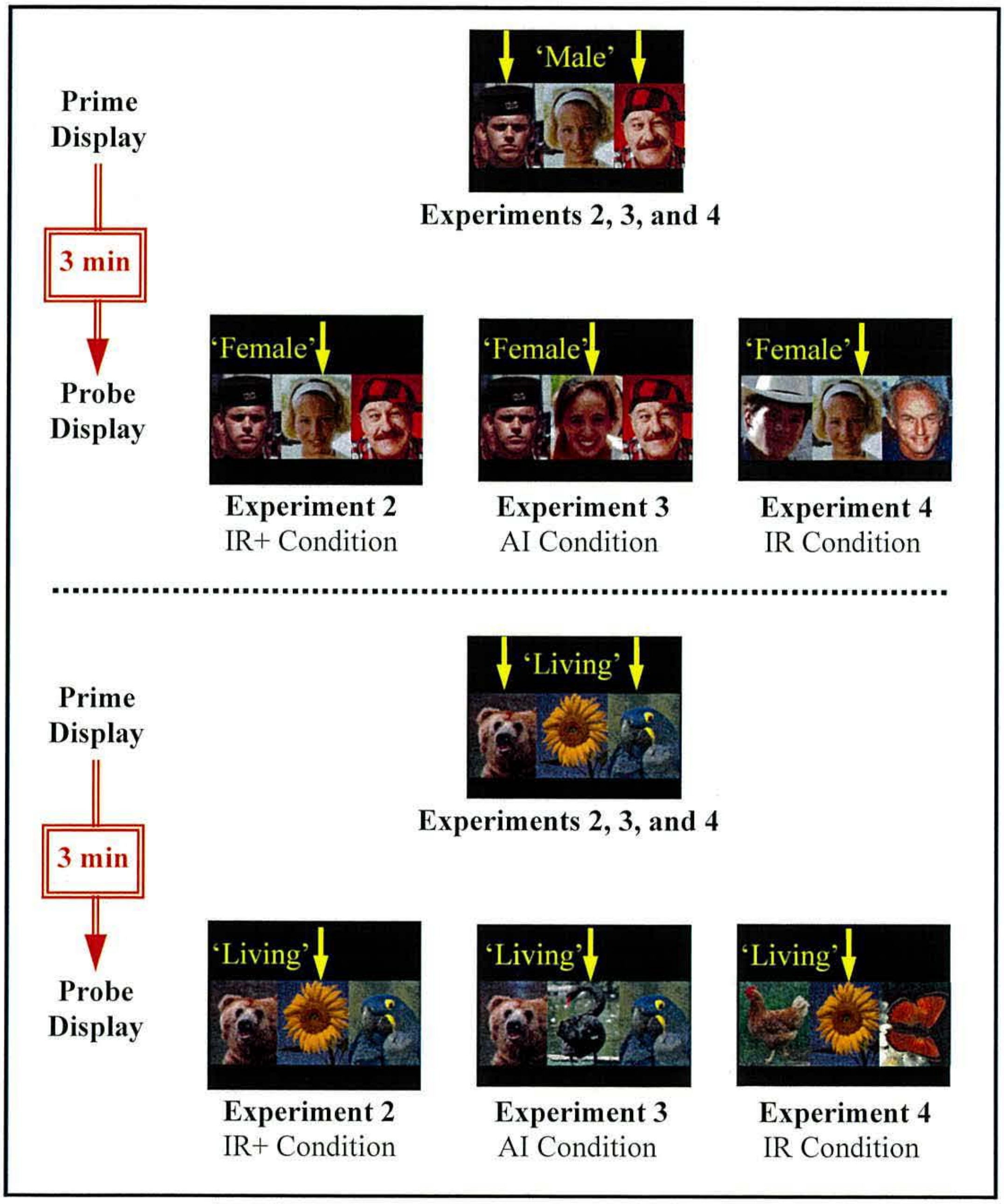

Figure 2:5. Comparison of the critical conditions used in Experiments 2, 3, and 4.

Procedure. The procedure used in these two experiments was the same as in Experiment 2, except that there were more stimuli. In the practice trials of Experiment 3, participants saw between 28 and 36 unique faces and the same number of objects. Of these, between 8 and 24 were female with the rest being male, and the same applied for living and non-living objects. In the experiment, there were 576 faces, half female and half male, and 576 objects, half living and half non-living. For Experiment 4, the practice trials presented between 32 and 36 unique faces and the same number of objects. Between 7 and 27 of the faces were female and the remainder were male, and the same was true for the living and non-living objects. The experimental trials showed 624 faces, half female and half male, and 624 objects, half living and half non-living.

2.5.2. Results

The data from Experiments 3 and 4 were analysed in the same way as in Experiment 2, except as described below. In Experiment 3, outlier trimming caused removal of 2.7 % of correct trials from the face data and 2.5 % of trials from the object data. In Experiment 4, 3.2 % and 4.0 % of correct trials were removed from data obtained with faces and objects, respectively.

Experiment 3: Prime Displays. The prime display RT and ER data for faces are shown in Table 2:6 below. RTs were modulated by flanker compatibility, $F(1, 23) = 13.1, p < .01$, where responses were quicker to compatible (1054 ms) than incompatible flankers (1099 ms). There were no other effects in RTs or ERs.

The prime RT and ER data for objects are also presented below in Table 2:6. The flankers once again affected RTs, $F(1, 23) = 10.9, p < .01$, where compatible flankers elicited faster responses (1221 ms) than incompatible flankers (1259 ms). The ER data showed an interaction between flanker compatibility and response,

$F(1, 23) = 4.9, p < .05$. Planned comparisons indicated greater ERs when flankers were incompatible versus compatible and the prime response was 'non-living' (3.8 % versus 1.6 % ms), $p < .05$.

	RT (SD)	ER (SD)
FACE STIMULI		
Compatible		
Female	1068 (159)	2.7 (4.1)
Male	1040 (165)	1.3 (2.5)
Incompatible		
Female	1097 (157)	3.0 (4.4)
Male	1100 (168)	1.3 (2.1)
OBJECT STIMULI		
Compatible		
Living	1205 (174)	3.2 (4.4)
Non-Living	1237 (150)	1.6 (3.0)
Incompatible		
Living	1245 (172)	2.5 (3.1)
Non-Living	1274 (166)	3.8 (5.8)

Table 2:6. *Experiment 3 means and standard deviations (SD) for prime reaction times (RT) and error rates (ER).*

Experiment 3: Probe Displays. For probe displays showing face stimuli, the analyses of RT and ER data included the AI condition. The mean RT, ER, and difference score data are seen in Table 2:7 below. However, there were no effects observed in the RT data, where the overall RT difference score was +5 msec (see Figure 2:6 below), or in the ER data.

For probe displays showing object stimuli, the RT and ER data were analysed in the same way as for faces, but responses were 'living' and 'non-living'. Table 2:7 below shows the mean RT, ER, and difference score data. The effect of the priming condition was marginally significant, $F(1, 23) = 3.3, p < .09$, where RTs were slower in the AI (813 ms) versus control condition (793 ms). A *t*-

test confirmed that this -20 ms overall effect revealed significant behavioural slowing, $p < .05$, as seen in Figure 2:6 below. There were no other effects in the RT or ER data.

	RT (SD)	**DS (SD)**	**ER (SD)**	**DS (SD)**
FACE STIMULI				
Control Condition				
Compatible				
Female	709 (119)	-----	4.1 (8.2)	-----
Male	711 (113)	-----	3.2 (5.6)	-----
Incompatible				
Female	729 (143)	-----	5.7 (6.4)	-----
Male	712 (129)	-----	4.8 (6.7)	-----
AI Condition				
Compatible				
Female	706 (135)	+3 (67)	5.5 (7.2)	-1.4 (9.1)
Male	710 (139)	+1 (91)	1.8 (4.5)	+1.4 (6.1)
Incompatible				
Female	712 (122)	+17 (85)	3.7 (6.2)	+2.0 (7.6)
Male	715 (142)	-3 (80)	4.3 (5.5)	+0.5 (8.4)
OBJECT STIMULI				
Control Condition				
Compatible				
Living	765 (158)	-----	2.7 (4.3)	-----
Non-Living	805 (139)	-----	2.2 (4.7)	-----
Incompatible				
Living	790 (170)	-----	4.2 (8.3)	-----
Non-Living	813 (143)	-----	2.8 (5.4)	-----
AI Condition				
Compatible				
Living	805 (135)	-40 * (95)	2.0 (4.7)	+0.7 (6.7)
Non-Living	830 (146)	-25 (96)	2.7 (4.2)	-0.5 (6.8)
Incompatible				
Living	814 (156)	-24 (116)	2.2 (4.0)	+2.0 (9.1)
Non-Living	805 (154)	+8 (139)	3.5 (5.9)	-0.7 (8.8)

Table 2:7. *Experiment 3 means and standard deviations (SD) for probe reaction times (RT), error rates (ER), and difference scores (DS).* $p<.05$.

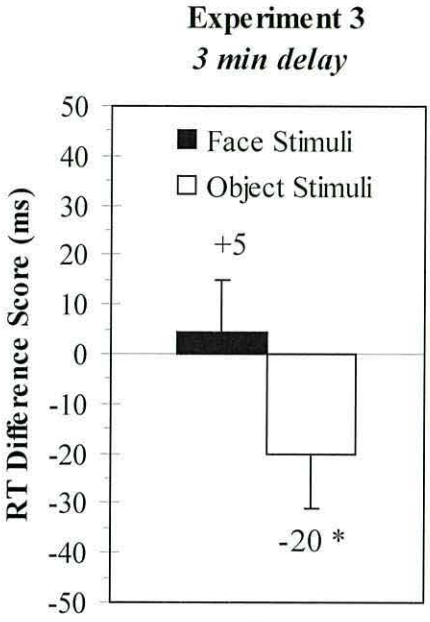

Figure 2:6. Mean overall RT difference scores for Experiment 3. * $p < .05$.

Experiment 3 versus 2. To see if the AI condition in Experiment 3 elicited different effects than the IR+ condition in Experiment 2, RT difference scores for faces were compared in a mixed design analysis. Experiment was the between-subjects factor and the within-subjects factor was a 2 x 2 design (Flanker: [Compatible/Incompatible] x Probe Response: [Female/Male]). The data showed a trends towards a main effect of experiment, $F(1, 46) = 3.9, p < .06$, as there was long-term NP in Experiment 2 (-21 ms), but no slowing in Experiment 3 (+5 ms).

The same analysis was conducted on probe RT difference scores for objects, but with 'living' or 'non-living' responses. There were no differences between experiments, so the data were combined. The combined RT difference scores revealed a marginally significant effect of priming, $F(1,46)=3.5, p<.07$, and a *t*-test confirmed that this -15 ms effect revealed significant behavioural slowing, $p<.05$.

Experiment 4: Prime Displays. The prime RT and ER data for faces are in Table 2:8 below. Flanker compatibility affected response, $F(1, 23) = 72.0, p < .01$, where RTs were quicker to compatible (1059 ms) than incompatible flankers

(1122 ms). The ER was greater when the prime response was ‘female’ (2.8 %) than ‘male’ (1.4 %), $F(1, 23) = 5.3, p < .05$.

Prime RT and ER data for objects are also presented below in Table 2:8. Prime responses for ‘living’ were faster (1241 ms) than for ‘non-living’ (1302 ms), $F(1, 23) = 10.5, p < .01$. There were no other effects in the RT or ER data.

	RT (SD)	**ER (SD)**
FACE STIMULI		
Compatible		
Female	1073 (147)	2.7 (5.3)
Male	1046 (133)	1.2 (3.3)
Incompatible		
Female	1130 (139)	2.9 (3.9)
Male	1114 (119)	1.5 (2.7)
OBJECT STIMULI		
Compatible		
Living	1235 (186)	2.2 (3.4)
Non-Living	1288 (172)	2.6 (3.9)
Incompatible		
Living	1246 (163)	2.6 (3.5)
Non-Living	1316 (178)	2.1 (3.3)

Table 2:8. *Experiment 4 means and standard deviations (SD) for prime reaction times (RT) and error rates (ER).*

Experiment 4: Probe Displays. Analyses of probe RTs and ERs for faces used the traditional IR condition. Average probe display RT, ER, and difference score data are below in Table 2:9. There was a trend towards an effect of priming, $F(1, 23) = 2.6, p < .13$, with slower RTs in the IR (754 ms) versus control condition (740 ms). Figure 2:7 below shows that a *t*-test confirmed this -14 ms effect as marginally significant long-term NP, $p < .07$. ERs were higher when the probe response was ‘female’ (6.5 %) versus ‘male’ (3.5 %), $F(1, 23) = 7.8, p < .05$.

Probe display RTs and ERs for objects were analysed in the same way, but with ‘living’ and ‘non-living’ responses. Average probe RT, ER, and difference score data are below in Table 2:9. There was a trend towards an effect of priming, $F(1, 23) = 2.6, p < .13$, where RTs were slower in the IR (882 ms) than the control condition (860 ms). This effect revealed marginal long-term NP (-22 ms) via a *t*-test, $p < .07$ (see Figure 2:7 below). No other effects were seen in RTs or ERs.

	RT (SD)	DS (SD)	ER (SD)	DS (SD)
FACE STIMULI				
Control Condition				
Compatible				
Female	752 (121)	-----	6.2 (7.8)	-----
Male	729 (111)	-----	4.2 (6.8)	-----
Incompatible				
Female	739 (124)	-----	6.5 (7.7)	-----
Male	741 (140)	-----	2.5 (4.1)	-----
IR Condition				
Compatible				
Female	764 (127)	-12 (77)	5.6 (6.4)	+0.6 (8.3)
Male	740 (153)	-11 (93)	3.1 (6.5)	+1.1 (10.1)
Incompatible				
Female	768 (157)	-29 * (75)	7.5 (9.8)	-1.0 (11.5)
Male	746 (146)	-5 (80)	4.2 (6.5)	-1.7 (7.6)
OBJECT STIMULI				
Control Condition				
Compatible				
Living	848 (158)	-----	2.2 (5.0)	-----
Non-Living	860 (164)	-----	2.5 (5.6)	-----
Incompatible				
Living	859 (144)	-----	4.4 (7.5)	-----
Non-Living	874 (128)	-----	3.8 (5.4)	-----
IR Condition				
Compatible				
Living	881 (174)	-33 # (102)	4.5 (6.8)	-2.3 (8.6)
Non-Living	880 (173)	-20 (113)	2.3 (4.9)	+0.2 (6.9)
Incompatible				
Living	870 (170)	-11 (96)	3.2 (5.7)	+1.2 (6.1)
Non-Living	897 (181)	-23 (137)	5.4 (6.7)	-1.6 (8.5)

Table 2:9. *Experiment 4 means and standard deviations (SD) for probe reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term NP. Positive scores reveal long-term facilitation.* $* p<.05$; $\# p<.10$.

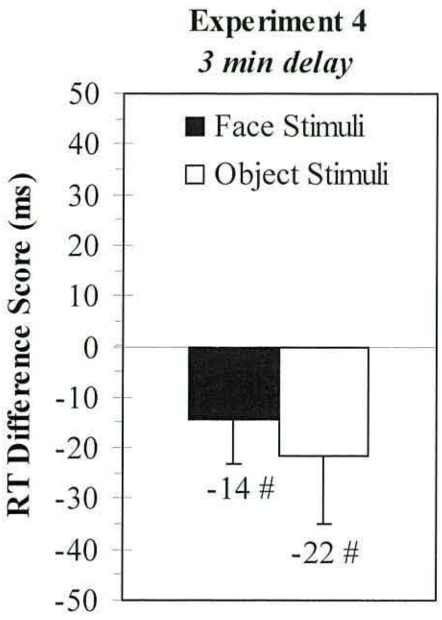

Figure 2:7. Mean overall RT difference scores in Experiment 4. Negative scores reveal long-term NP. # $p < .10$.

Experiment 4 versus 2. To see if the IR condition in Experiment 4 elicited different effects than the IR+ condition in Experiment 2, probe RT difference scores for faces were compared in a mixed design analysis. Experiment was the between-subjects factor and the within-subjects factor was a 2 x 2 design (Flanker: [Compatible/Incompatible] x Probe Response: [Female/Male]). There were no differences between experiments, so the data were combined, revealing a robust effect of priming, $F(1,46)=9.1$, $p<.01$. A *t*-test confirmed the presence of -17 ms of long-term NP with faces, $p<.01$.

The same analysis was conducted on probe RT difference scores for objects except that the responses were 'living' or 'non-living'. These scores showed no differences between experiments, so the data were combined. Interestingly, the combined RT difference scores revealed a marginally significant effect of priming, $F(1,46)=3.1$, $p<.09$, and a *t*-test confirmed that this -15 ms effect revealed significant long-term NP with objects, $p<.05$.

2.5.3. Discussion

The goal of Experiments 3 and 4 was to clarify whether the long-term NP effects in Experiment 2 were due to episodic retrieval of excitatory states associated with prime targets or retrieval of inhibitory processes affiliated with the prime distractor (Grison et al., 2001; Grison & Tipper, 2002a). Therefore, the same implicit memory paradigm was used as in Experiment 2, however the IR+ condition was replaced.

In Experiment 3, an AI condition was used where the two prime targets were re-presented as probe distractors, but a new probe target was shown. If long-term NP with faces in Experiment 2 was due to episodic retrieval of excitation associated with prime targets, Experiment 3 should elicit robust behavioural slowing when three minutes and 56 displays intervened between the prime and probe. However, if the previous long-term NP effect was due to episodic retrieval of inhibitory states then no behavioural slowing should be observed in Experiment 3 because the target is a new item, which was not previously inhibited. Importantly, the results of Experiment 3 showed no behavioural slowing with face stimuli in the AI condition (see Table 2:10 below). Indeed, the absolute magnitude of the effect with faces showed some facilitation and was marginally different from the robust long-term NP obtained with the same face stimuli in Experiment 2. Interestingly, the opposite effect was obtained with object stimuli, where the observed long-term behavioural slowing was no different from the small long-term NP found with objects in Experiment 2 (see Table 2:10 below). Indeed, together the effects obtained with objects revealed significant behavioural slowing across the two experiments.

	Delay	**Critical Condition**	**Face Stimuli**	**Object Stimuli**
Experiment 2	3 min	IR+	-21 * (37)	-9 (54)
Experiment 3	3 min	AI	+5 (50)	-20 * (55)
Experiment 4	3 min	IR	-14 # (44)	-22 # (66)
Combined 2 and 3			Not Applicable	-15 * (54)
Combined 2 and 4			-17 * (40)	-15 * (60)

Table 2:10. *Summary of RT difference scores and SDs (in parentheses). With the exception of Experiment 3, negative scores reveal long-term NP. * p<.05; # p<.10.*

In Experiment 4, a traditional IR condition was used where the prime distractor reappeared as the probe target, but two new stimuli were seen as probe distractors. If long-term NP in Experiment 2 was due to episodic retrieval of prior inhibition associated with the prime distractor, then Experiment 4 should also elicit robust NP effects when there are three minutes and 56 displays between the prime and probe. However, if the previous long-term NP effect was due to episodic retrieval of excitation then no behavioural slowing should be observed because the distractors are new items not previously associated with excitation. Importantly, long-term NP observed with face stimuli was marginally significant and did not differ from the effect found in Experiment 2 (see Table 2:10 above). Indeed, the combined data between the two experiments revealed robust overall long-term NP with faces. Similar effects were found with the object stimuli, where long-term NP was marginally significant and did not differ from the effect found in Experiment 2 (see Table 2:10 above). Instead, the combined data again showed robust long-term NP with objects between the two experiments.

The results obtained across the two experiments are intriguing. For face stimuli, there was no behavioural slowing in the AI condition of Experiment 3, but significant long-term NP was seen in the IR condition of Experiment 4. This suggests that when faces were shown, excitatory states associated with prime targets were either not encoded into episodic memory or not retrieved with an episode to reinstate prior excitation. However, clearly inhibitory states associated with the prime distractor face were encoded into and retrieved from episodic memory to affect performance over time. By contrast, for object stimuli, there was robust behavioural slowing in Experiment 3 as well as significant long-term NP in Experiment 4. These outcomes indicate that both excitation associated with prime target objects and inhibition associated with the prime distractor object are encoded into episodic memory and can be retrieved much later to affect behaviour.

It is suggested that this pattern of data may be explained by differences in prime display processing of face and object stimuli which affects the richness of encoding into episodic memory and consequent later retrieval (e.g., Craik & Lockhart, 1972). Prior research supports the idea that faces are processed automatically based on a holistic representations (e.g., Farah et al., 1998), while object stimuli may be more difficult to process (e.g., Garrard et al., 2001). Indeed, support for these ideas comes from the fact that responses to objects were significantly slower than to faces in Experiment 3 (803 versus 713 ms, respectively) and in Experiment 4 (871 versus 747 ms, respectively), just as they were in Experiment 2. Accordingly, if faces are processed automatically, then target faces may not require much excitatory processing to allow correct response. Although such a mechanism would aid fast on-line performance, it might have the consequence of poorly encoding information into episodic memory. This would result in decreased likelihood of later successful retrieval, such that prior excitation cannot affect performance. However, if a face is presented as a distractor, then inhibitory processes may need to be robustly applied to prevent incorrect response. This robust inhibition may allow rich encoding into episodic memory, which increases the likelihood that the face and associated inhibition will be successfully retrieved to affect behaviour later on. By contrast, because object stimuli are processed relatively slowly and with difficulty, when an object is shown as a target, it may require robust excitatory processing to allow correct response, thus allowing rich encoding of target objects and associated excitation into episodic memory. In this case, episodic retrieval may be more likely to succeed later on, thus reinstating prior excitation, which can then affect performance. When an object is shown as a distractor, it may be relatively easy to ignore this information, such that inhibition is somewhat less engaged than with faces. This process may result in less encoding of distractor objects and affiliated inhibition, which should reduce successful episodic retrieval so that prior inhibition may not consistently affect performance.

In sum, the results of Experiments 3 and 4 confirm that long-term NP exists with both face and object stimuli. Importantly, the results of Experiment 4 together with Experiment 2 provide strong support for the idea that episodic retrieval of prior inhibitory states can mediate long-term NP effects with both faces and objects. Interestingly, the results of Experiment 3 suggest that the original proposed mechanism must be extended, because depending on the nature of prime trial processing, episodic retrieval of prior excitation can contribute to slowed response in an IR+ condition.

2.6. Conclusions

The experiments reported here used two new implicit memory paradigms to examine the existence of long-term NP effects. Importantly, the results revealed that long-term NP does exist with both face and object stimuli, thus suggesting the engagement of memory mechanisms in this task. In addition, long-term NP may be mediated by episodic memory in particular, because the degree to which the effect was obtained depended on the robustness of encoding and the probability of successful retrieval. Accordingly, long-term NP may be subserved by episodic retrieval of previously irrelevant stimuli along with associated inhibitory states. Interestingly, in certain situations, episodic retrieval of previously relevant stimuli and associated excitation may also contribute to long-term NP effects. In sum, these findings indicate that episodic retrieval of prior attentional states may generally underlie correct goal-directed behaviour over time.

2.6.1. Long-Term NP Exists

Prior research investigating the existence of long-term NP has found inconsistent support for this small and elusive effect (DeSchepper & Treisman, 1996; Lowe, 1998; Neumann et al., 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995). In the current research, two new implicit memory paradigms were developed to be sensitive to revealing inhibition over time as they should encourage rich encoding and successful retrieval of episodic memories. Indeed, across three experiments, this new research reports long-term NP with irrelevant face and object stimuli when either six minutes and 96 displays or three minutes and 56 displays intervened between the prime and the probe (see Table 2:11 below). Although short-term NP effects are often explained in terms of on-line transient inhibition of irrelevant information, the long-term effects seen in these experiments cannot be explained by the maintenance of on-line processing of irrelevant items over several minutes and many intervening displays to cause conflict and slow response on the IR probe display. Consequently, the only plausible explanation is that memory processes contribute to performance in these long-term NP tasks.

	Delay	**Critical Condition**	**Face Stimuli**	**Object Stimuli**
Experiment 1	6 min	IR	-11 *	Not Applicable
Experiment 2	3 min	IR+	-21 *	-9
Experiment 3	3 min	AI	+5	-20 *
Experiment 4	3 min	IR	-14 #	-22 #

Table 2:11. *Summary of RT difference scores. With the exception of Experiment 3, negative scores reveal long-term NP. * p<.05; # p<.10.*

2.6.2. Long-Term NP Mediated by Episodic Memory

Importantly, the results reported here also suggest the specific nature of the memory mechanisms that underlie long-term NP. Recall that prior research suggests when rich encoding and successful episodic retrieval are likely, such as when: an episode is novel (e.g., Logan, 1988), processing object-based representations (e.g., Paul & Tipper, in press; Tipper et al., 2002), showing an intervening task, (e.g., Melton, 1970), and reinstating the encoding context (e.g., Tulving & Thompson, 1973). Accordingly, Experiment 1 used a new implicit memory paradigm designed to encourage encoding and retrieval of episodic memories by presenting novel face stimuli that require processing of object-based information. Indeed, long-term NP effects were small, but significant, in this experiment (see Table 2:11 above). In addition, a second new implicit memory paradigm was developed for Experiments 2, 3, and 4 that was expected to encourage robust encoding and increase successful episodic retrieval by presenting novel face and object stimuli, requiring categorisation of objects, using an intervening task, and employing context specificity, among other techniques. Indeed, across these three studies, robust long-term NP effects were obtained with both face and object stimuli. Accordingly, these results suggest that long-term NP depends on episodic memory mechanisms because the effect was found when the experimental methods encouraged robust encoding and successful episodic retrieval of stimuli.

2.6.3. Episodic Retrieval of Inhibitory States

Taken together, the finding from Experiments 1, 2, and 4 illuminate the nature of the processes underlying long-term NP effects. It is suggested that long-term NP effects in these tasks must be mediated by memory processes, which are thought to be episodic in nature. Furthermore, the engagement of memory mechanisms does not eliminate the possibility that inhibitory processes contribute to these effects; it merely refutes that maintenance of on-line inhibition explains the outcomes. Accordingly, long-term NP effects may result from implicit episodic retrieval of inhibitory states associated with irrelevant information. On viewing the prime display, both episodic memory and inhibitory processes are engaged to help complete different aspects of the task (e.g., Neumann & DeSchepper, 1992; Tipper, 2001; Tipper, Weaver, et al., 1991). For example, even as inhibition of the irrelevant distractor aids correct response, information about the prime display may be automatically encoded into episodic memory. Importantly, the specific transient inhibitory states associated with the prime stimuli may also be encoded into memory. When the IR probe display is presented much later, the stimuli cue retrieval of the matching episode. Critically, if episodic retrieval is *successful*, then the stimuli are recalled and associated inhibition may be reinstated. However, because in the IR probe display this inhibition is associated with a stimulus that is now the target, it must be overcome to allow correct response, which results in NP in the form of slower RTs in the IR versus the control condition. In this way, long-term NP effects may be a result of both episodic memory and inhibitory processes functioning together to allow correct behaviour to occur over time.

2.6.4. Episodic Retrieval of Excitatory States

Finally, the results of Experiment 3 suggest that episodic retrieval of prior inhibition may not be the only mechanism that contributes to long-term NP effects. In this study, responses were slow to object stimuli, but not face stimuli, when there were long delays between presenting prime target objects and repeating these items as probe distractors along with a new probe target. It seems that in a manner similar to episodic retrieval of prior inhibition, excitatory states associated with prime targets can be encoded into episodic memory and later retrieved to reinstate prior excitation. However, if the retrieved excitation is affiliated with distractor stimuli that should be ignored, it must be overcome to prevent erroneous response, which results in slowed response to the probe target object. In this way, episodic retrieval of prior excitation can contribute to long-term NP effects when untraditional IR+ conditions repeat the prime stimuli in ‘flipped’ roles on the probe display. However, the results of Experiment 3 also make clear that the degree to which episodic retrieval of prior excitation affects later response depends on ease of processing in the prime display. Because target faces are processed automatically, they may not require much excitation to allow correct response. This might result in poor encoding into and less successful retrieval from episodic memory, which would prevent prior excitation from influencing behaviour over time. By contrast, because target objects are not processed automatically, they may need much greater excitation to aid correct behaviour. The consequence of this processing could be richer encoding into and more successful retrieval from episodic memory, where reinstated excitation influences behaviour over time.

In sum, there may be functional reasons for a relationship to evolve between long-term episodic memory and attentional processes, because correct goal-directed behaviour can rely on attentional information obtained from prior processing episodes. Accordingly, one wonders whether episodic retrieval of inhibitory and excitatory states are general mechanisms that mediate goal-directed performance over time. If so, then other tasks where performance depends on the engagement of these attentional processes may also reveal effects over the long-term. Therefore, investigating the existence of long-term effects in a second attentional paradigm, IOR, was the primary goal of the experiments reported in Chapter 3.

Chapter 3

Long-Term Inhibition of Return:

Episodic Retrieval of Inhibition

3.1. Objectives

- Explore generalisability of episodic retrieval of inhibition in IOR using two new implicit memory paradigms;
- Promote encoding and retrieval of episodic memories by presenting novel stimuli, cueing object representations, showing an intervening task, and reinstating encoding context;
- Examine whether short-term IOR is obtained when cueing object- and/or location-based representations;
- Investigate whether long-term IOR depends on episodic retrieval of stable object-based representations.

3.2. Abstract

The experiments in Chapter 3 are the first to investigate long-term IOR effects and therefore utilise new implicit memory paradigms that should be sensitive to revealing inhibition over time. Experiment 5 examines IOR over 1800 ms and zero displays where novel faces and scenes alternate presentation in a cueing task and participants localise an imperative signal on an object (i.e., a face) or in a location (i.e., in a scene). The results show short-term IOR in slow target responses to previously cued objects and locations, thus revealing traditional IOR effects. Experiments 6 and 7 use the same task to search for IOR over 3 min and 48 displays, and 13 min and 192 displays, respectively. The results reveal the first evidence of long-term IOR. Responses are consistently slow to previously cued objects appearing in the left visual field (LVF). Long-term IOR is only found inconsistently for previously cued locations. Because inhibition cannot be maintained on-line in this task, performance may be mediated by episodic retrieval of inhibition associated with stable object representations. Experiments 8 and 9

further examine IOR over 1800 ms and zero displays and 18 min and 96 displays, respectively, when imperative signals appear on an object (i.e., an eye in a face) or in a location (i.e., in a scene). Experiment 8 replicates short-term IOR with previously cued objects and locations, and when combined with Experiment 5, reveals greater IOR for objects cued in the LVF. Transient inhibition of objects and locations mediates short-term IOR, where object-based inhibition is specifically processed in the right hemisphere (RH). Experiment 9 replicates long-term IOR for objects cued in the LVF, and fails to find long-term IOR for locations. Interestingly, long-term facilitation is seen for objects cued in the right visual field (RVF). When combined with Experiments 6 and 7, these outcomes confirm that long-term IOR exist for objects cued in the LVF, whereas long-term facilitation is significant for objects cued in the RVF. In the absence of location-based inhibition, long-term IOR and facilitation may be mediated by episodic retrieval of object-based inhibition and excitation, which are differentially processed across hemispheres.

3.3. Experiments 5, 6, and 7

Experiments 5, 6, and 7 used a new IOR paradigm to examine short-term IOR and to determine whether IOR exists when there are long delays between cue and target displays (Grison et al., 2002; Grison & Tipper, 2001; Tipper et al., in press). As mentioned in Chapter 1, searching for long-term IOR requires a departure from the traditional paradigm because emphasis must be placed on encoding episodically salient stimuli into long-term memory and successfully retrieving this information, along with associated inhibition. Therefore, the experimental approach used novel, unique stimuli, cueing of object-based representations, presentation of an intervening task, and reinstatement of encoding context.

Experiment 5 explored whether the standard IOR effect is found in this new implicit memory paradigm when 1800 ms and no displays intervene between the cue and target. A second aim was to determine the internal representations associated with short-term IOR in this task. Participants localised an imperative signal in displays showing novel, colour face or scene stimuli. Importantly, in cue and target displays showing two faces, the imperative 'go' or 'no go' signal overlay an entire face object, such that the signal would be associated with that object. The presentation of face stimuli was spaced by showing an intervening task with scene stimuli. In cue and target displays showing a scene, the imperative 'go' or 'no go' signal appeared in an empty location above or below fixation. Finally, context specificity was provided in target displays by repeating the face or scene stimuli previously shown in the cue display. Prior research suggests that short-term IOR should be found when cueing object- or location-based information (e.g., Tipper et al., 1994; Tipper et al., 1999; Weaver et al., 1998). Accordingly, IOR would be found if target responses were slower to an object or a location that was previously cued with a 'no go' signal, in comparison with responses to uncued information. These results would suggest that transient object- and location-based inhibition underlie short-term IOR in this new task.

The goal of Experiment 6 was to examine whether IOR is obtained in this new task when three minutes and 48 displays intervened between the cue and target. An additional aim was to explore the internal representations associated with the effect. Finding long-term IOR would be the first demonstration of the existence of the effect. Because the delays are far beyond any prior estimates of the duration of transient inhibition in IOR, these results would suggest that both inhibition and memory could contribute to performance in this task. Furthermore, if long-term IOR depends on episodic memory processes, prior research suggests that the effect may only be found when stable object representations are cued, not when locations are cued (Paul & Tipper, in press; Tipper et al., 2002). These results would suggest that long-term IOR exists, and that it is mediated by episodic retrieval of inhibition associated with stable object information.

Finally, the aim of Experiment 7 was to replicate long-term IOR effects across different representations and extend their duration to longer delays of 13 minutes and 192 intervening displays. Once again, transient inhibition cannot mediate performance in this task, therefore finding IOR would suggest engagement of both inhibition and memory mechanisms. Furthermore, long-term IOR may only be obtained when cueing object-based information in face stimuli, not when cueing location-based information in scenes. This would further support the idea that long-term IOR depends on rich encoding and successful episodic retrieval of stable object based representations along with associated inhibition.

3.3.1. Method

Participants. In Experiment 5, there were 16 participants, seven males and nine females, who ranged in age from 18 to 39 years, with an average age of 21.1 years. In Experiment 6, there were 16 different participants, eight males and eight females, aged between 18 and 24 years, where the average age was 20.1 years. Finally, in Experiment 7, there were 16 new participants, eight males and eight females, between 18 and 36 years old, with an average age of 23.4 years. All the participants were Psychology undergraduate students at the University of Wales, Bangor, who received course credit for their assistance. They all demonstrated normal visual acuity, colour vision, and stereoscopic vision.

Stimuli and Apparatus. The three experiments used the same stimuli and apparatus. There were two sets of stimuli, faces and scenes, and each stimulus was randomly presented only twice in one of the conditions described below. The first stimulus set was 192 colour photographs of faces taken from Art Explosion 250,000 (1995) CD-ROMs, which should be unfamiliar and unique to participants. Half of the faces were female and half were male. For displays showing face stimuli, two faces were presented simultaneously, centred in a horizontal row, where a chin-rest was used to maintain a visual angle of 10.8 degrees vertically and 7.4 degrees horizontally for each of the two faces. The visual angle for the entire display subtended 10.8 degrees vertically and 14.8 degrees horizontally. The imperative signals were a semi-transparent red oval (i.e., 'no go' signal) or green oval (i.e., 'go' signal), measuring 3.9 degrees vertically and 3.4 degrees horizontally (see Figure 3:1 below). A signal was placed on a face, so it would be seen as a property of that object. Depending on the location of the face in the display, the cue was approximately 3.7 degrees to the left or right of fixation.

The second stimulus set was 96 colour photographs of scenes, also taken from Art Explosion 250,000 (1995) CD-ROMs, which were expected to be unfamiliar and unique to participants. Half of these showed an indoor scene and half showed an outdoor scene. In these displays, one scene was centrally presented so that the visual angle subtended 14.8 degrees vertically and 10.8 degrees horizontally. The imperative signal was a two-degree opaque black square with a white letter 'X' (i.e., 'no go' signal) or 'O' (i.e., 'go' signal) (see Figure 3:1 below). This signal appeared in a location in a scene, so that it could not be associated with any object, 3.7 degrees above or below fixation.

The experiments were performed on an IBM-compatible personal computer with a Pentium II 266 MHz processor and 160 MB RAM. E-Prime programming software (2000) was used to create the experiment, display the stimuli on a 19-inch superVGA monitor, control timing, and log responses through a keyboard.

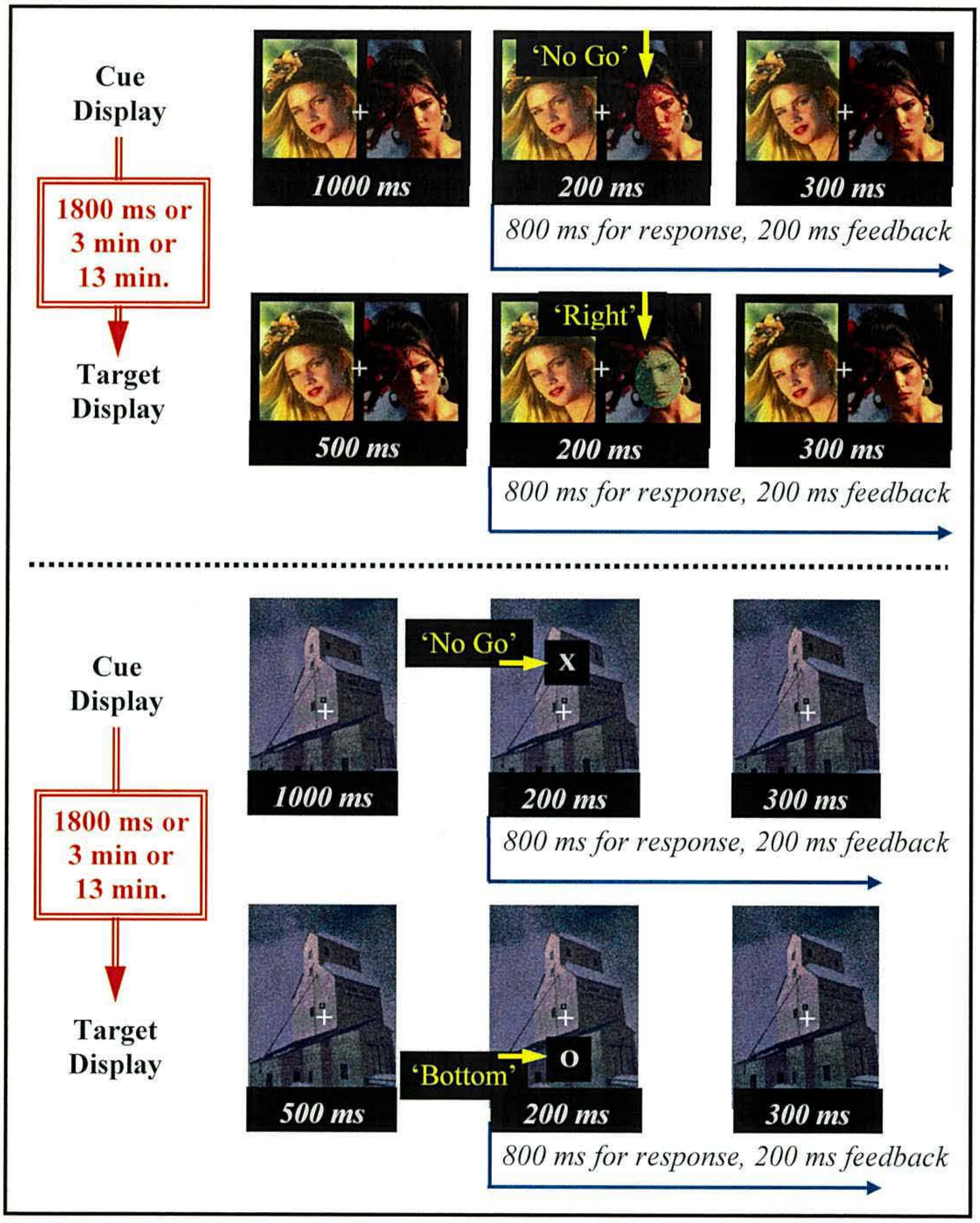

Figure 3:1. Procedure used in Experiments 5, 6, and 7. The example for faces shows an IOR condition with a cued target in the right face. The example for a scene shows an IOR condition with an uncued target at the bottom location.

Design. The same design was used for all three experiments. There were 192 trials, each with a cue and a target display. Half of these trials showed face stimuli and half showed a scene, which alternated presentation. In all of the trials, the cue display stimuli were seen again in the target display. The 96 trials showing face stimuli were drawn from a 3 x 2 x 2 repeated measures design (Condition: [IOR/Go Catch/No Go Catch] x Target Cueing: [Uncued/Cued] x Target Location: [Left/Right]) (see Appendix, Figure 3, for graphic displays of all conditions). Sixty-four of these trials showed an IOR condition, where a red imperative signal on cue displays required a 'no go' response and a green imperative signal on target displays required a 'go' response. The remaining 32 trials showed catch conditions, which were included to force participants to respond on half of all of the 192 cue displays and to reduce the predictability of the cue-target relationship. In 16 trials showing a Go Catch condition, a green 'go' signal was shown on cue displays and a red 'no go' signal was shown on target displays. In another 16 trials showing a No Go Catch condition, a red 'no go' signal was presented on both the cue and target displays. For each of these conditions, on half of the trials, the target appeared on a face that had not previously been cued, while on half of the trials the target appeared on the face that was previously cued. Finally, for each of the cueing conditions, half of the time the target signal appeared over the left face and half of the time it was shown over the right face. Participants experienced 16 trials in each of the four IOR conditions, four trials in each of the four Go Catch conditions, and four trials in each of the four No Go catch conditions. These conditions were randomised and presented in an unpredictable order.

The same design was used for the 96 trials showing scene stimuli with the exception that the location of the target was at the bottom or top of a scene.

Procedure. The procedure was the same for the three experiments, except as described below. Participants sat before the computer monitor, with the keyboard before them, in a dimly lit room. They first completed 24 practice trials, one for each of the above conditions, where half showed faces and half showed a scene. Therefore, the practice trials presented 24 faces, half female and half male, and 12 scenes, half indoor and half outdoor, which were not seen again in the experiment.

The experiment lasted approximately 40 minutes. In Experiment 5, there were 192 total trials, 96 of which showed faces and 96 of which showed a scene, which alternated presentation. The 192 cue-target trials were shown back-to-back. Before seeing a cue display showing faces, participants placed their index fingers on the appropriate response keys for faces, '4' and '6'. After self-initiating the cue display, a central white fixation cross (i.e., +) appeared for 300 ms, then the faces appeared for 1000 ms, one face was overlaid by the cue signal for 200 ms, and finally the original faces were seen for a further 300 ms (see Figure 3:1 above). There was 800 ms available for response from the onset of the cue signal. If one of the faces turned red, participants withheld response. If the left face turned green, they pressed the '4' key on the number pad with the left index finger, but if the right face became green, they pressed the '6' key with the right index finger. After responding, there was 200 ms of auditory feedback for a correct or an incorrect response. The target display immediately followed and the procedure was identical except that the initial faces were shown for only 500 ms (see Figure 3:1 above). Accordingly, for the critical IOR trials, there was a stimulus onset asynchrony (SOA) of 1800 ms and zero displays intervening between the cue and target. Following a cue-target trial showing faces, participants experienced a cue-target trial showing a scene, where the procedure was the same except as follows. Before self-initiating the start of the cue display, participants placed their fingers on the appropriate response keys for scenes, '2' and '8'. If an 'X' appeared on the scene, they withheld response. If an 'O' appeared at the bottom, they pressed the '2' key on the number pad with the left index finger, but if an 'O' appeared at the top, they pressed the '8' key with the right index finger. After the experiment, participants completed a questionnaire that assessed awareness of the experimental conditions.

The procedure of Experiment 6 (see Figure 3:1 above) only differed because 48 cue displays were first presented back-to-back, 24 of which showed faces that alternated presentation with 24 others that showed a scene. After completion of these cues, participants experienced a 20 second break. Then they saw the 48 associated target displays, where the order of the stimuli was the same as previously. Accordingly, there was an average of three minutes and 48 displays between presentation of the cue and its yoked target display. The same procedure was followed three additional times to complete the experiment.

The procedure of Experiment 7 (see Figure 3:1 above) was the same as Experiment 6, except that 192 cue displays were shown back-to-back, 96 of which showed faces that alternated with 96 others that presented a scene. After the cues, participants had a three-minute break, and then completed the 192 target displays. An average of 13 minutes and 192 displays intervened between the cue and target.

3.3.2 Results

The data from the three experiments were analysed in the same manner. No participants had greater than a 15% ER. All displays where an error was made were removed from RT analyses. When an error was made in a cue display, the associated target data was removed from RT analysis. The data from catch displays were not analysed. All inferential tests used $p < .05$.

Experiment 5: Target Displays. The RT and ER data from target displays showing faces were analysed using separate repeated measures ANOVAs in the following design: (Target Cueing: [Uncued/Cued] x Target Location: [Left/Right]). The mean RT and ER data are shown below in Table 3:1. In addition, to measure short-term IOR effects for faces, difference scores were calculated by comparing target display performance in a cued condition with the corresponding uncued condition. Directional *t*-tests indicated whether the difference scores were significantly less than zero, which would reveal short-term IOR. The RT and ER difference scores for faces are shown below in Table 3:1. The target data revealed an effect of cueing, $F(1, 15) = 58.4$, $p < .01$, where RTs in the cued condition were slower (399 ms) than in the uncued condition (361 ms). Importantly, a *t*-test confirmed that this overall effect (-38 ms) revealed significant short-term IOR with faces, $p < .01$. Figure 3:2 below shows that additional *t*-tests confirmed short-term IOR for the left face (-41 ms), $p < .01$, and the right face (-35 ms), $p < .01$. There were no other effects in the RT or ER data.

For target displays showing a scene, the RT and ER data were analysed in the same way as for faces, but the target signals appeared at the bottom or top. The average RT, ER, and difference score data for scenes are shown below in Table 3:1. RTs were affected by the target location, $F(1, 15) = 10.8$, $p < .01$, where responses were faster to the top (391 ms) versus the bottom (414 ms). There was also an effect of cueing, $F(1, 15) = 72.7$, $p < .01$, where RTs were slower in the cued (428 ms) versus the uncued condition (376 ms). A *t*-test confirmed that this overall -52 ms effect was significant short-term IOR for scenes, $p < .01$. Additional *t*-tests also confirmed short-term IOR for the bottom (-46 ms), $p < .01$, and top locations (-58 ms), $p < .01$, as seen in Figure 3:2 below. There were no other effects in RTs or ERs.

	RT (SD)	**DS (SD)**	**ER (SD)**	**DS (SD)**
FACE STIMULI				
Uncued Condition				
Left	363 (34)	-----	0.4 (1.5)	-----
Right	358 (29)	-----	0.4 (1.5)	-----
Cued Condition				
Left	404 (41)	-41 * (22)	0.0 (0.0)	+0.4 (1.5)
Right	393 (32)	-35 * (24)	0.5 (1.8)	-0.1 (2.4)
SCENE STIMULI				
Uncued Condition				
Bottom	390 (37)	-----	1.9 (3.8)	-----
Top	362 (33)	-----	0.8 (2.2)	-----
Cued Condition				
Bottom	436 (44)	-46 * (28)	0.7 (2.0)	+1.2 (4.7)
Top	420 (28)	-58 * (33)	0.8 (2.2)	0.0 (2.4)

Table 3:1. *Experiment 5 means and standard deviations (SD) for target reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal short-term IOR. Positive scores reveal short-term facilitation.* * $p < .05$.

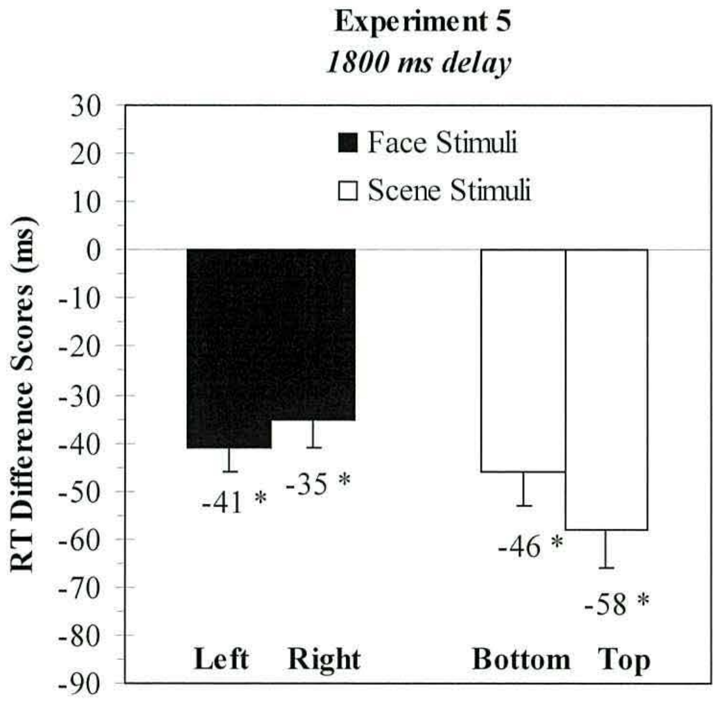

Figure 3:2. Mean RT difference scores in Experiment 5. Negative scores reveal short-term IOR. * $p < .05$.

Experiment 6: Target Displays. The mean target display RT, ER, and difference score data for face stimuli are shown below in Table 3:2. RTs were modulated by target location, *F*(1, 15) = 6.7, $p < .05$, where participants were faster to respond to the right face (364 ms) than the left face (379 ms). There was also an interaction between target cueing and location, *F*(1, 15) = 7.3, $p < .05$. Planned comparisons revealed slower responses for cued versus uncued targets appearing in the left face (387 ms versus 371 ms), $p < .05$, but not in the right face. As shown in Figure 3:3 below, a *t*-test confirmed that this effect revealed significant long-term IOR for the left face (-16 ms), $p < .01$, while there was some long-term facilitation for the right face (+6 ms). Planned comparisons also revealed that RTs were faster for cued targets appearing in the right versus the left face (361 ms versus 387 ms), $p < .01$. The ER data showed no effects.

The mean RT, ER, and difference score data from target displays showing scene stimuli are shown below in Table 3:2. Target location modulated RTs, *F*(1, 15) = 18.7, $p < .01$, where participants were faster to respond to the top (382 ms) than the bottom location (412 ms). There were no other effects in the RT data, where there was very little long-term IOR for the bottom (-4 ms) or the top locations (-4 ms) (see Figure 3:3 below). The ER data revealed no effects.

	RT (SD)	DS (SD)	ER (SD)	DS (SD)
FACE STIMULI				
Uncued Condition				
Left	371 (40)	-----	2.7 (5.5)	-----
Right	367 (31)	-----	1.1 (2.4)	-----
Cued Condition				
Left	387 (30)	-16 * (22)	1.1 (3.3)	+1.6 (4.2)
Right	361 (31)	+6 (25)	0.7 (2.0)	+0.4 (3.4)
SCENE STIMULI				
Uncued Condition				
Bottom	410 (39)	-----	3.2 (5.6)	-----
Top	380 (33)	-----	4.3 (6.4)	-----
Cued Condition				
Bottom	414 (53)	-4 (29)	3.5 (6.3)	-0.3 (7.5)
Top	384 (37)	-4 (26)	1.9 (3.6)	+2.4 (7.9)

Table 3:2. *Experiment 6 means and standard deviations (SD) for target reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation. * p < .05.*

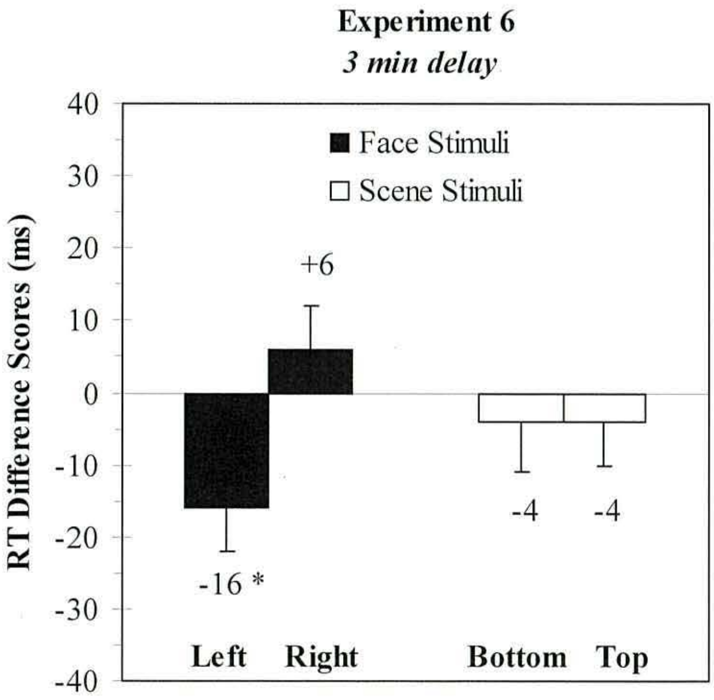

Figure 3:3. Mean RT difference scores in Experiment 6. Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation. * $p < .05$.

Experiment 7: Target Displays. Target display RTs, ERs, and difference scores for faces are in Table 3:3 below. Target location affected RTs, *F*(1, 15) = 13.6, $p < .01$, which were faster for the right (357 ms) than the left face (375 ms). Cueing was again modulated by target location, *F*(1, 15) = 5.0, $p < .05$. Planned comparisons showed slower RTs for cued than uncued targets in the left face (380 ms versus 369 ms), $p < .01$, but not in the right face. Once again, a *t*-test confirmed significant long-term IOR for the left face (-11 ms), $p < .01$, but some long-term facilitation was seen for the right face (+4 ms) (see Figure 3:4 below). Planned comparisons also showed faster RTs for cued targets in the right versus the left face (355 ms versus 380 ms), $p < .01$. The ER data revealed an effect of target location, *F*(1, 15) = 6.8, $p < .05$, where there were more errors for the right (0.9 %) versus the left face (0.0 %).

Table 3:3 below shows mean RTs, ERs, and difference scores for scenes. Target location affected RTs, *F*(1, 15) = 53.2, $p < .01$, which were faster for the top (365 ms) than the bottom location (400 ms). Cueing was modulated by target location, *F*(1, 15) = 11.5, $p < .01$. Planned comparisons showed slower RTs for cued than uncued targets at the top location (370 ms versus 358 ms), $p < .05$. As shown in Figure 3:4 below, a *t*-test revealed this effect was significant long-term IOR at the top location (-12 ms), $p < .01$. There was also a trend towards faster RTs for cued versus uncued targets in the bottom location (396 ms versus 404 ms), $p < .13$. Interestingly, a t-test revealed this was marginally significant long-term facilitation for the bottom location (+8 ms), $p < .07$ (see Figure 3:4 below). Planned comparisons also showed faster RTs for cued targets at the top than the bottom location (370 ms versus 396 ms), $p < .01$. Finally, planned comparisons revealed quicker responses for uncued targets appearing at the top than at the bottom (358 ms versus 404 ms), $p < .01$. There were no effects in the ER data.

	RT (SD)	DS (SD)	ER (SD)	DS (SD)
FACE STIMULI				
Uncued Condition				
Left	369 (36)	-----	0.0 (0.0)	-----
Right	359 (37)	-----	0.4 (1.5)	-----
Cued Condition				
Left	380 (35)	-11 * (14)	0.0 (0.0)	0.0 (0.0)
Right	355 (30)	+4 (22)	1.5 (2.7)	-1.1 (3.3)
SCENE STIMULI				
Uncued Condition				
Bottom	404 (40)	-----	0.9 (2.4)	-----
Top	358 (30)	-----	0.8 (2.2)	-----
Cued Condition				
Bottom	396 (34)	+8 # (19)	1.6 (2.9)	-0.7 (3.2)
Top	370 (32)	-12 * (18)	1.6 (2.9)	-0.8 (4.0)

Table 3:3. *Experiment 7 means and standard deviations (SD) for target reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation. * p < .05; # p < .10.*

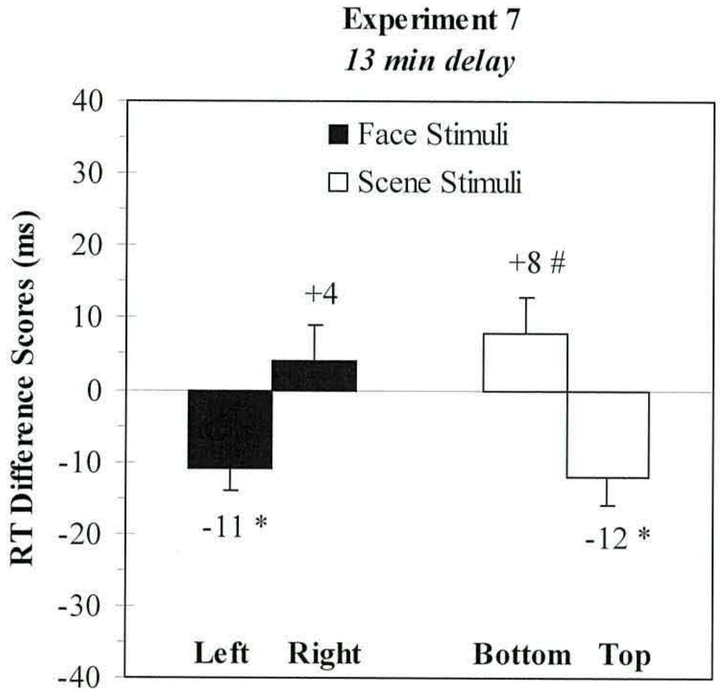

Figure 3:4. Mean RT difference scores in Experiment 7. Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation. * *p* < .05; # *p* < .*10*.

3.3.3. Discussion

To date, no research has ever investigated the existence of long-term IOR effects. Therefore, the goal of the first three experiments was to explore short- and long-term IOR effects in a new implicit memory paradigm designed to encourage rich encoding of stimuli into and successful retrieval from episodic memory (Grison et al., 2002; Grison & Tipper, 2001; Tipper et al., in press). Accordingly, in these studies, the experimental approach included presentation of novel stimuli, cueing object-based representations, presentation of an intervening task, and reinstatement of encoding context. If episodic retrieval of inhibitory states mediates response over time, then this paradigm should elicit robust long-term IOR effects.

Experiment 5 aimed to confirm that short-term IOR is found in this unique paradigm. A second aim was to determine whether IOR is seen when cueing object- and location-based representations in this task (e.g., Tipper et al., 1994; Tipper et al., 1999; Weaver et al., 1998). Indeed, the data showed robust IOR when an object was cued in a face or a location was cued in a scene (see Table 3:4 below). Clearly, the transient inhibition that mediates traditional IOR effects is observed here when inhibition is applied to object- or location-based information.

	Delay	**Left**	**Right**	**Bottom**	**Top**
Experiment 5	1800 msec	-41 * (22)	-35 * (24)	-46 * (28)	-58 * (33)
Experiment 6	3 min	-16 * (22)	+6 (25)	-4 (29)	-4 (26)
Experiment 7	13 min	-11 * (14)	+4 (22)	+ 8 # (19)	-12 * (18)

Table 3:4. *Summary of RT difference scores and SDs (in parentheses). Negative scores reveal IOR. Positive scores reveal facilitation. * $p < .05$; # $p < .10$.*

Experiment 6 used the same implicit memory paradigm to determine whether long-term IOR exists when three minutes and 48 displays intervened between the cue and target. An additional aim was to explore the nature of the internal representations associated with the effect. If long-term IOR depends on rich encoding and episodic retrieval of stimuli, then the effect may only be found when cueing stable object-based information, not when cueing object-less locations (e.g., Paul & Tipper, in press; Tipper et al., 2002). Importantly, the results revealed long-term IOR when objects were cued in face stimuli, but not when locations were cued in scenes (see Table 3:4 above). Interestingly, long-term IOR effects with faces differed between the two visual fields. In particular, long-term IOR was found when the left face was cued, but some long-term facilitation was observed when the right face was cued (see Table 3:4 above). Accordingly, Experiment 6 demonstrated for the first time that long-term IOR effects do exist.

Finally, Experiment 7 attempted to replicate long-term IOR across different representations and extend their duration to longer delays of 13 minutes and 192 intervening displays. If long-term IOR is seen only when cueing objects, not when cueing locations, this will further support the idea that performance in this task depends on rich encoding and successful retrieval of episodic memories. Indeed, long-term IOR was observed when cueing object representations in face stimuli. However, this effect was only seen when the left face was cued, as some long-term facilitation was seen when the right face was cued (see Table 3:4 above). Interestingly, long-term IOR was also obtained with scenes when the top location was cued, but there was a trend towards long-term facilitation when the bottom location was cued (see Table 3:4 above). These outcomes confirm that long-term IOR exists when cueing stable object-based representations. Additionally, the results suggest that inhibition may also be associated with less stable location-based representations in these long-term tasks.

Together, the results from Experiments 6 and 7 are important because they reveal the first evidence of long-term IOR effects. Although IOR in short-term tasks like Experiment 5 is explained by on-line inhibition of cued information, clearly transient inhibition cannot be maintained over long delays and processing of intervening displays. Therefore, these outcomes suggest that both inhibitory and memory processes mediate performance in long-term IOR tasks. In particular, the candidate memory processes may be episodic in nature, given that the effect was consistently found when cueing stable object-based information (e.g., Paul & Tipper, in press; Tipper et al., 2002) that is easily encoded into and retrieved from episodic memory (e.g., Shah et al., 2001). Therefore, it is suggested that information pertaining to objects searched in the cue display may be encoded into an episodic memory trace, along with the associated inhibitory processes acting on those perceptual inputs. When encountering the same object later in the target display, successful retrieval of stable representations may re-activate the associated inhibitory state, which hampers response to that object. However, because long-term IOR was inconsistently found when cueing locations, the possibility that location-based inhibition can be stored into and retrieved from episodic memory to affect behaviour over time will have to be further investigated in this chapter.

An additional important outcome of these three experiments is revealed by the consistent pattern of object-based IOR effects between the visual fields. Indeed, as shown in Table 3:4 above, IOR was greater for a face cued in the LVF in all three tasks, although this effect was especially robust in the two long-term experiments. By contrast, there was some facilitation observed when the right face was cued in the two long-term tasks. These visual field differences were not predicted a priori, and indeed, IOR research commonly collapses cueing effects across visual fields. However, there are several precedents for finding larger short-term IOR effects for information cued in the LVF versus the RVF (e.g., Berlucchi, Aglioti, & Tassinari., 1997; Handy, Jha, Kingstone, & Mangun, 1995; Jordan & Tipper, 2001; McDonald et al., 1999; Nelson, Early, & Haller, 1993; White et al., 2001). For example, Jordan and Tipper (2001) found that short-term IOR was larger in the LVF when cueing object-based information across changes in location. By contrast, cueing location-based representations without objects led to equivalent IOR across the visual fields. The authors suggested that the larger IOR in the LVF was due to RH specialisation for inhibitory processing of object-based representations, whereas inhibition of location-based information is processed in both hemispheres. Importantly, this mechanism may account for only finding long-term IOR when an object was cued in the LVF. In particular, the effects of cueing objects and locations in face stimuli were not technically dissociated in these long-term tasks as they were in Jordan and Tipper's (2001) research, because a cued object always appeared in the same location in a display. However, it is suggested that the effects of cueing the two representations were *effectively dissociated* because there was very little support for the presence of location-based inhibition in the long-term tasks. If location-based inhibition could not consistently be encoded into or retrieved from episodic memory, then long-term IOR for an object cued in the LVF might solely reflect inhibitory processing of objects in the RH.

Interestingly, it is possible that the use of face stimuli in particular may have contributed to the visual field differences in IOR effects in the short- and long-term. Specifically, there is ample evidence of RH specialisation for processing of faces (Gilbert & Bakan, 1973; Leehey, Carey, Diamond, & Cahn, 1978; McCarthy, Puce, Gore, & Allison, 1997; Rossion et al., 2000). Furthermore, when viewing faces, imaging studies tend to show activity in the RH fusiform face area (e.g., Kanwisher, McDermott, & Chun, 1997), and lesions producing prosopagnosia, deficits in face processing, are most associated with the RH (e.g., De Renzi & Spinnler, 1966; Milner, 1968). Finally, prior research has also shown that faces lend themselves to be automatically stored in episodic memory (Shah et al., 2001), and indeed, episodic memory processing of faces may be localised to the RH as well (e.g., Zarate, Sanders, & Garza, 2000). Therefore, it may be that faces presented to the LVF receive richer initial processing in the RH during encoding, resulting in more stable memory representations of the face and associated inhibition. Consequently, prior inhibition associated with the face can more easily be retrieved and reinstated when the stimuli are again re-presented to the LVF, resulting in more robust long-term IOR in the LVF versus the RVF. In this situation, processing of the face itself may not be impaired after inhibitory states are retrieved, but retrieval of the face information and associated inhibition may reactivate cortical systems to hamper orienting of attention. Thus, orienting to the object may be impaired, whilst perceptual processing of the face is unaffected by prior cueing.

In sum, traditional short-term IOR effects are obtained in the unique implicit memory paradigm designed to reveal long-term IOR. Furthermore, transient inhibition of object- and location-based representations, which are differentially processed across the hemispheres, seem to mediate short-term IOR effects in this new implicit memory task. Importantly, two experiments revealed for the first time that long-term IOR effects exist when cueing objects, and possibly when cueing locations as well. It is suggested that episodic retrieval of inhibitory processes associated with stable object-based face representations in the RH may elicit the most consistent long-term IOR effects in these tasks. Accordingly, two additional studies were conducted with the aim of clarifying the short- and long-term IOR effects obtained with different representations and across the visual fields.

3.4. Experiments 8 and 9

Experiments 8 and 9 attempted to replicate short- and long-term IOR effects in a second implicit memory task (Grison et al., 2002; Grison & Tipper, 2001; Grison & Tipper, 2002b). Because finding long-term IOR requires rich encoding and successful retrieval of episodically rich stimuli and associated inhibition, the experimental approach again used novel stimuli, cueing of object representations, presentation of an intervening task, and reinstatement of encoding context.

The goal of Experiment 8 was to explore short-term IOR effects across visual fields when cueing objects and locations in a new implicit memory task. Therefore, this study searched for short-term IOR where there were 1800 ms and no displays intervening between the cue and target. Participants again localised an imperative signal in displays showing novel, colour face and scene stimuli. In cue and target displays showing one face, the 'go' or 'no go' signal overlay an eye to the left or right of fixation, so that the signals would be associated with that object. Alternating with presentation of each face, an intervening task showed a scene stimulus, where the 'go' or 'no go' signal appeared in an object-less, empty location above or below fixation. Finally, the encoding context of a cue display showing a face or a scene was reinstated in the target display by repeating the prior stimulus. The outcomes should replicate Experiment 5, demonstrating short-term

IOR when cueing objects and locations (e.g., Tipper et al., 1994; Tipper et al., 1999; Weaver et al., 1998). In addition, there may be differences in IOR across visual fields, suggesting hemispheric asymmetries in transient inhibition of object-based representations.

Experiment 9 used this new implicit memory task to investigate IOR effects with objects and locations across the visual fields, when 18 minutes and 96 displays intervened between the cue and target. The results are generally expected to replicate Experiments 6 and 7. If long-term IOR is found when object representations are cued, but not when object-less locations are cued, this would confirm that long-term IOR depends on rich encoding and retrieval of stable objects to reinstate prior inhibition (e.g., Paul & Tipper, in press; Tipper et al., 2002). In addition, if long-term IOR were only found when an eye is cued in the LVF, this would suggest that inhibitory processing of object representations is biased across the visual fields, possibly due to RH specialisation for this process.

3.4.1. Method

Participants. In Experiment 8, there were 16 participants, eight males and eight females, aged between 18 and 28 years, with a mean age of 20.9 years. There were 24 participants in Experiment 9, 12 males and 12 females, who ranged in age from 19 to 42 years, with an average age of 24.5 years. All participants were undergraduate students at the University of Wales, Bangor, who received course credit in exchange for their assistance. They all showed normal visual acuity, colour vision, and stereoscopic vision.

Stimuli and Apparatus. The stimuli and apparatus used in Experiments 8 and 9 were the same as in the previous experiments except as described below. The first stimulus set included 48 colour photographs showing forward-gaze views of faces of students, staff, and faculty from the School of Psychology at the University of Wales, Bangor. The faces were expected to be unfamiliar because the participants were not Psychology students. Half of the faces were female and half were male. The photographs were manipulated in Adobe Photoshop to crop any part of the image other than the face, from the top of the hair to the bottom of the neck and to mount each face on a uniform grey background. Each face was shown centred and a chin rest was used to maintain a visual angle of 12.6 degrees vertically and 10.8 degrees horizontally. The imperative signals were a 1.4-degree semi-transparent red circle (i.e., 'no go' signal) or blue circle (i.e., 'go' signal) (see Figure 3:5 below). A signal was shown on an eye in a face, so it would be seen as a property of the object. Depending on the location of the eye, the signal appeared approximately 2.0 degrees to the left or right of fixation.

The second stimulus set was 48 colour photographs of scenes taken from England and Wales, which were also expected to be unfamiliar to participants. Half of these showed an indoor scene and half showed an outdoor scene. In these displays, one scene was centrally presented with a visual angle of 12.6 degrees vertically and 10.8 degrees horizontally. The imperative signal could be a 1.4-degree semi-transparent red circle (i.e., 'no go' signal) or blue circle (i.e., 'go' signal) (see Figure 3:5 below). This signal appeared in an 'object-less' location in a scene, to prevent association with any object, 3.2 degrees above or below fixation.

Both experiments were performed on a Power Macintosh 8600/200 personal computer with a one GB hard drive and 32 MB RAM. PsyScope programming software (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to create the experiment, display the stimuli on a 15-inch superVGA monitor, control timing, and log participants' responses through a PsyScope button box.

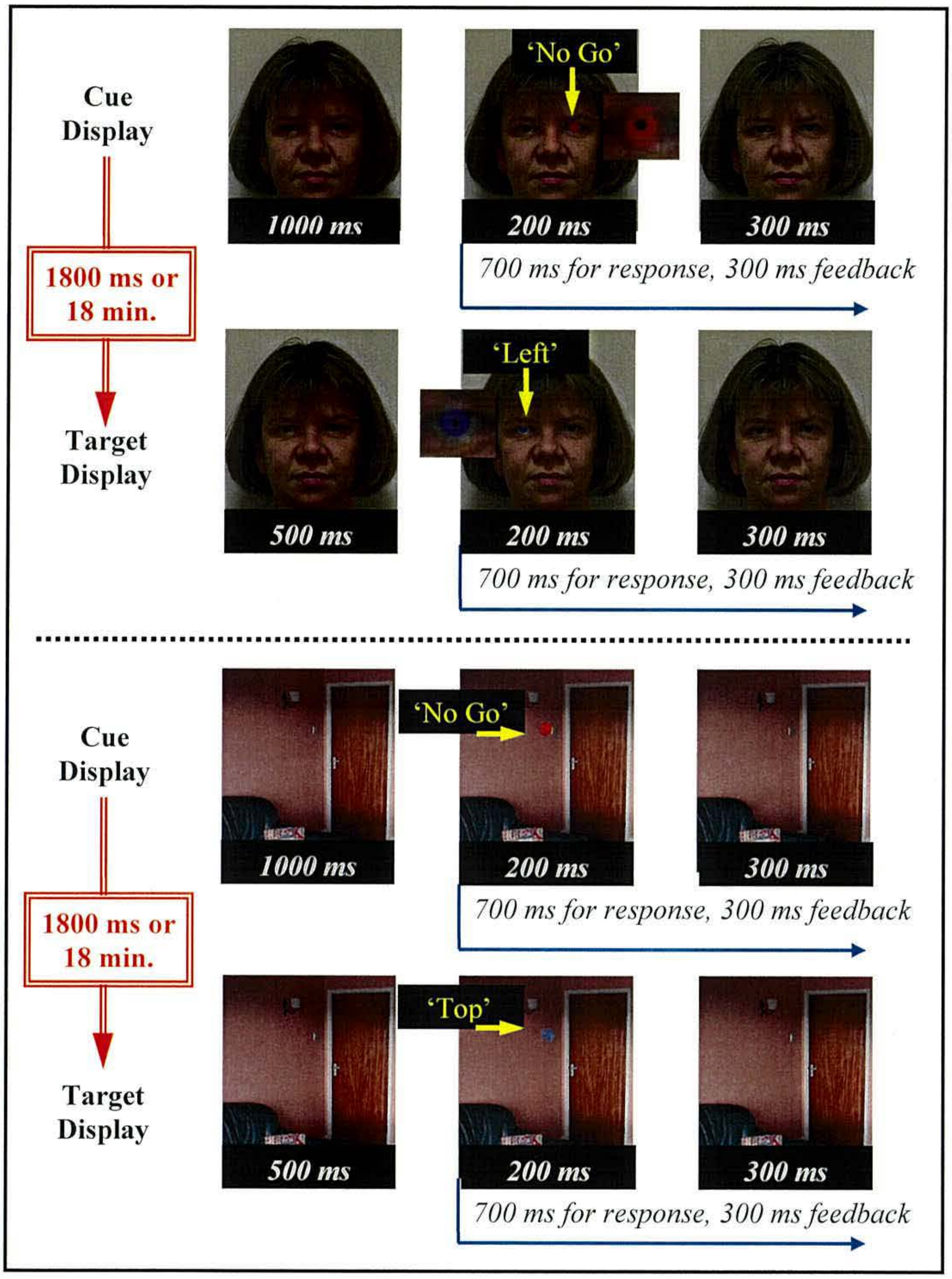

Figure 3:5. Procedure used in Experiments 8 and 9. The example for a face shows an IOR condition with an uncued target in the left eye. Enlargements display the cue and target signals for the left eye for clarity only. The example for a scene shows an IOR condition with a cued target at the top location.

Design. The design of Experiments 8 and 9 was the same as in the prior experiments, except as described below. There were 96 trials, with a cue and a target display in each. The 48 trials showing face stimuli were drawn from a 2 x 2 x 2 repeated measures design (Condition: [IOR/Go Catch] x Target Cueing: [Uncued/Cued] x Target Location: [Left/Right]) (see Appendix, Figure 4, for graphic displays of all conditions). Half of these trials showed an IOR condition, where a red signal on cue displays required a 'no go' response and a blue signal on target displays required a 'go' response. Another half of the trials showed a Go Catch condition, where a blue 'go' signal was shown on cue displays and a red 'no go' signal was presented on target displays. For each of the conditions, on half of the trials, the target was shown on an eye that had not previously been cued with an imperative signal and on half of the trials, the target appeared on an eye that was previously cued. Finally, for each of the cueing conditions, half of the time the target signal was shown over the left eye and half of the time it appeared over the right eye. Accordingly, participants saw six trials in each of the four IOR conditions and six trials in each of the four Go Catch conditions.

The 48 trials showing scene stimuli used the same design, but the target appeared at either the bottom or top location in a scene.

Procedure. Experiments 8 and 9 used the same procedure as in the previous experiments, except as differs below. Participants first completed 16 practice trials that presented eight faces, half male and half female, and eight scenes, half indoor and half outdoor. The experiment followed the practice session and lasted about 50 minutes. In Experiment 8, there were 96 total trials, 48 showing a face, which alternated presentation with 48 showing a scene. Before seeing a cue display showing a face, participants put their index fingers on the appropriate left and right response buttons. During the trial, the cue signal suddenly overlaid an eye in a face for 200 ms (see Figure 3:5 above). There was 700 ms available for response from the onset of the cue signal. If one of the eyes turned red, participants did not respond. If the left eye turned blue, they pressed the left button with the left index finger, but if the right eye became blue, they pressed the right button with the right index finger. After responding, participants received 300 ms of auditory feedback for a correct or an incorrect response. Accordingly, for the critical IOR trials, there was a stimulus onset asynchrony (SOA) of 1800 ms and zero displays intervening between the cue and target. Following a cue-target trial showing a face, participants experienced a cue-target trial that presented a scene, which used the same procedure, with a few exceptions. Before participants self-initiated the start of the cue display, they placed their fingers on the bottom and top response buttons. If a red circle appeared on a scene, participants withheld response. If a blue circle appeared at the bottom, they pressed the bottom button with their left index finger, but if a blue circle appeared at the top, they pressed the top button with their right index finger.

The procedure of Experiment 9 (see Figure 3:5 above) differed from that of Experiment 8 because 96 cue displays were presented back-to-back, 48 of which showed a face that alternated presentation with 48 that showed a scene. After completing the 96 cues, participants rested for three minutes, then completed the 96 associated target displays. Therefore, an average of 18 minutes and 96 displays intervened between the cue and its yoked target.

3.4.2. Results

The data from Experiments 8 and 9 were analysed in the same manner as the previous three studies.

Experiment 8: Target Displays. Table 3:5 below shows the mean RT, ER, and difference score data from target displays showing face stimuli. Performance was affected by target cueing, $F(1, 15) = 25.5$, $p < .01$, such that RTs were slower in the cued (390 ms) versus the uncued condition (354 ms). A *t*-test confirmed that this overall effect (-36 ms) was significant short-term IOR with faces, $p < .01$. Additional *t*-tests confirmed the presence of significant short-term IOR for both the left eye (-45 ms), $p < .01$, and the right eye (-26 ms), $p < .01$, as shown in Figure 3:6 below. The target location affected errors, $F(1, 15) = 5.0$, $p < .05$, where ERs were greater when the target appeared in the right eye (2.1%) versus the left eye (0.0%).

Table 3:5 below also shows the average target display RT, ER, and difference score data for scenes. Target cueing affected responses, $F(1, 15) = 19.2$, $p < .01$, where RTs in the cued condition were slower (394 ms) than in the uncued condition (353 ms). A *t*-test confirmed that this -41 ms of overall slowing was significant short-term IOR with scene stimuli, $p < .01$. As seen in Figure 3:6 below, *t*-tests also confirmed significant short-term IOR for both the bottom location (-37 ms), $p < .01$, and the top location (-45 ms), $p < .01$. There were no other effects in RTs or ERs.

	RT (SD)	DS (SD)	ER (SD)	DS (SD)
FACE STIMULI				
Uncued Condition				
Left	351 (43)	-----	0.0 (0.0)	-----
Right	358 (41)	-----	1.1 (4.3)	-----
Cued Condition				
Left	396 (39)	-45 * (31)	0.0 (0.0)	0.0 (0.0)
Right	384 (39)	-26 * (40)	3.2 (6.9)	-2.1 (8.5)
SCENE STIMULI				
Uncued Condition				
Bottom	356 (50)	-----	0.0 (0.0)	-----
Top	350 (39)	-----	0.0 (0.0)	-----
Cued Condition				
Bottom	393 (50)	-37 * (45)	3.2 (6.9)	-3.2 * (6.9)
Top	395 (42)	-45 * (42)	1.1 (4.3)	-1.1 (4.3)

Table 3:5. *Experiment 8 means and standard deviations (SD) for target reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal short-term IOR. * p < .05.*

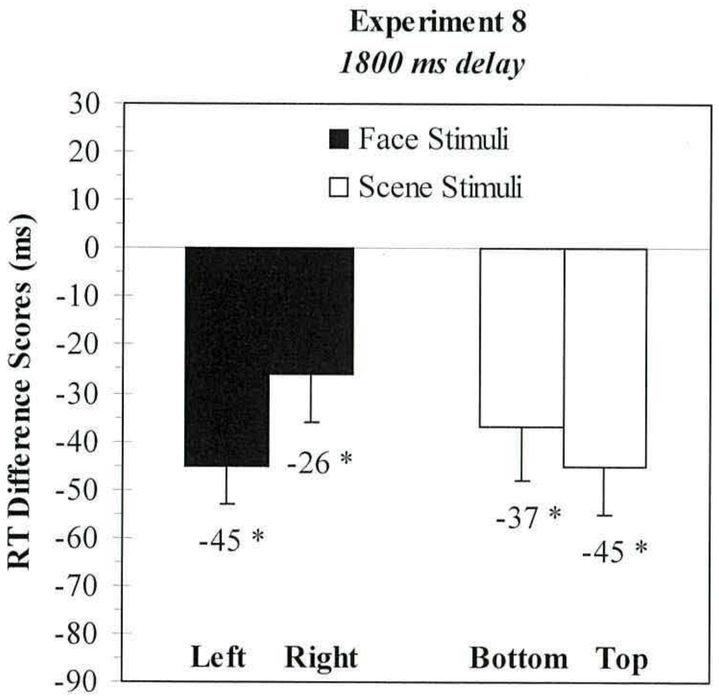

Figure 3:6. Mean RT difference scores in Experiment 8. Negative scores reveal short-term IOR. * *p* < .05.

Experiment 8 versus 5. To explore whether short-term IOR effects in Experiments 5 and 8 differed between the visual fields, the target display RT difference scores for faces were compared in a mixed design analysis. The experiment was the between-subjects factor and target location, left or right, was the within-subjects factor. Importantly, there were no differences in IOR effects with face stimuli between the experiments. Accordingly, the combined RT difference scores are reported. The data showed a trend towards short-term IOR with faces being modulated by target location, $F(1, 30) = 4.0, p < .06$. Specifically, this effect revealed that short-term IOR for faces cued in the LVF (-43 ms), $p < .01$, was marginally greater than that in the RVF (-31 ms), $p < .01$.

The same analysis was conducted on target display RT difference score data for scenes, but the target could appear in the bottom or top location. Importantly, there were no differences in IOR effects with scenes between the experiments, so the combined RT difference scores are reported. The combined data only revealed an overall effect of -46 ms short-term IOR with scenes, $F(1, 30) = 69.6, p < .01$, as *t*-tests confirmed significant short-term IOR for the bottom (-41 ms), $p < .01$, and the top location (-51 ms), $p < .01$.

Experiment 9: Target Displays. The average RT, ER, and difference score data from target displays showing a scene are shown below in Table 3:6. RTs were modulated by target cueing and location, $F(1, 23) = 5.1, p < .05$. Planned comparisons revealed a marginally significant effect of slower RTs for cued versus uncued targets appearing in the left eye (391 ms versus 383 ms), $p < .10$. Importantly, as shown in Figure 3:7 below, a *t*-test confirmed that this effect showed significant long-term IOR for the left eye (-8 ms), $p < .05$. Interestingly, there was also a marginally significant effect of faster responses for cued versus uncued targets appearing in the right eye (371 ms versus 385 ms), $p < .09$. A t-test confirmed that this +14 ms effect revealed significant long-term facilitation for the right eye, $p < .05$ (see Figure 3:7 below). Finally, planned comparisons showed that RTs were faster for cued targets appearing in the right versus the left eye (371 ms versus 391 ms), $p < .05$. There were no effects in the ER data.

The mean RT, ER, and difference score data for target displays showing a scene are displayed below in Table 3:6. There were no effects in the RT data, where Figure 3:7 indicates there was very little long-term IOR at the bottom location (-2 ms) and some long-term facilitation at the top location (+5 ms). The ER data revealed no effects

	RT (SD)	**DS (SD)**	**ER (SD)**	**DS (SD)**
FACE STIMULI				
Uncued Condition				
Left	383 (62)	-----	0.0 (0.0)	-----
Right	385 (52)	-----	0.0 (0.0)	-----
Cued Condition				
Left	391 (65)	-8 * (21)	0.0 (0.0)	0.0 (0.0)
Right	371 (38)	+14 * (37)	0.0 (0.0)	0.0 (0.0)
SCENE STIMULI				
Uncued Condition				
Bottom	384 (46)	-----	3.8 (7.6)	-----
Top	386 (62)	-----	2.3 (6.1)	-----
Cued Condition				
Bottom	386 (60)	-2 (40)	4.1 (8.3)	-0.3 (11.4)
Top	381 (50)	+5 (53)	2.5 (6.8)	-0.2 (7.2)

Table 3:6. *Experiment 9 means and standard deviations (SD) for target reaction times (RT), error rates (ER), and difference scores (DS). Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation.* $* p < .05$

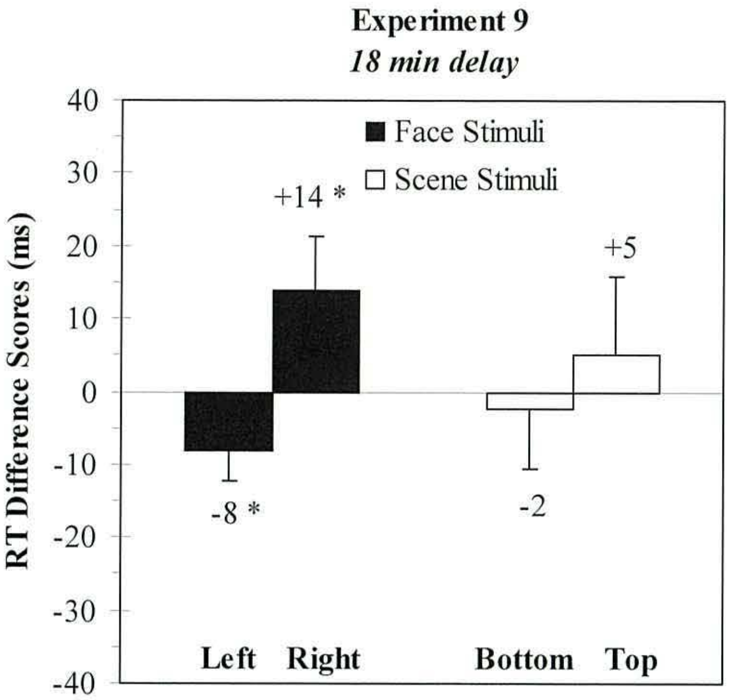

Figure 3:7. Mean RT difference scores in Experiment 9. Negative scores reveal long-term IOR. Positive scores reveal long-term facilitation. * $p < .05$.

Experiment 9 versus 6 and 7. To investigate whether long-term IOR effects in Experiments 6, 7, and 9 differed between visual fields, target RT difference scores for faces were compared in a mixed design analysis. The between-subjects factor was the experiment and target location, left or right, was the within-subjects factor. Across the experiments, no differences were found in long-term IOR with faces. Therefore, analyses were conducted on the weighted average of the combined RT difference scores. The combined data indicated that long-term IOR with faces was modulated by target location, $F(1, 53) = 14.1, p < .01$. In particular, there was significant long-term IOR when face stimuli were cued in the LVF (-11 ms), $p < .01$, but significant long-term *facilitation* when face stimuli were cued in the RVF (+9 ms), $p < .05$.

The same analysis was conducted on target display RT difference score data for scenes, but the target appeared at the bottom or top location. There were no differences in long-term IOR effects with scenes between the experiments, so the weighted average of the combined RT difference scores was analysed. However the combined data also failed to reveal any effects, as there was no long-term IOR for the bottom (0 ms) or top locations (-2 ms).

3.4.3. Discussion

Experiments 8 and 9 attempted to replicate and extend the previous short- and long-term IOR effects into a second implicit memory task that encouraged encoding and retrieval of episodic memories by presenting novel stimuli, cueing objects, showing an intervening task, and reinstating encoding context (Grison et al., 2002; Grison & Tipper, 2001; Grison & Tipper, 2002b).

Specifically, Experiment 8 used this new paradigm to explore short-term IOR with objects and locations and how these effects differ across the visual fields, when 1800 ms and zero displays intervened between the cue and target. The results of Experiment 5, along with prior research (e.g., Tipper et al., 1994; Tipper et al., 1999; Weaver et al., 1998), suggest that traditional IOR effects are elicited when transient inhibition is applied to object- and location-based information. Therefore, short-term IOR should be obtained in this task when cueing either object- or location-based representations. Indeed, the results revealed robust short-term IOR when an object was cued in a face and when a location was cued in a scene (see Table 3:7 below). Furthermore, the combined data from Experiments 5 and 8 revealed that short-term IOR was marginally greater when objects were cued in the LVF versus the RVF. Therefore, these findings replicated the pattern of data obtained in Experiment 5. Short-term IOR effects seem to be mediated by transient inhibition of object- and location-based representations, but these processes are biased across visual fields.

	Delay	**Left**	**Right**	**Bottom**	**Top**
Experiment 5	1800 msec	-41 * (22)	-35 * (24)	-46 * (28)	-58 * (33)
Experiment 8	1800 msec	-45 * (31)	-26 * (40)	-37 * (45)	-45 * (42)
Combined		**-43 * (26)**	**-31 * (33)**	**-51 * (38)**	**-41 * (37)**
Experiment 6	3 min	-16 * (22)	+6 (25)	-4 (29)	-4 (26)
Experiment 7	13 min	-11 * (14)	+4 (22)	+ 8 # (19)	-12 * (18)
Experiment 9	18 min	-8 * (21)	+14 * (37)	-2 (40)	+5 (53)
Combined		***-11 * (20)***	***+9 * (30)***	***0 (32)***	***-2 (39)***

Table 3:7. *Summary of RT difference scores and SDs (in parentheses). Negative scores reveal IOR. Positive scores reveal facilitation. The combined RT difference scores and SDs in italics show weighted means.* $* p < .05$; $\# p < .10$.

Experiment 9 examined whether the long-term IOR obtained with different representations and across visual fields would be replicated in the new task when 18 minutes and 96 displays intervened between the cue and target. The findings of Experiments 6 and 7 generally suggested that long-term IOR depends on rich encoding and retrieval processes to reinstate prior inhibition. Therefore, the effect should be found when cueing stable object-based information, but not when cueing less stable location-based representations (e.g., Paul & Tipper, in press; Tipper et al., 2002). However, visual field differences were also expected, where long-term IOR may only be found for an object cued in the LVF, but some long-term facilitation may be seen for an object cued in the RVF. The results did conform to expectations, because long-term IOR was obtained when cueing an object in a face, not when cueing a location in a scene (see Table 3:7 above). Furthermore, long-term IOR was only observed for a previously cued object presented in the LVF. However, unlike in previous experiments, these results revealed *significant* long-term facilitation for a previously cued object shown in the RVF. Indeed, the combined data from Experiments 6, 7, and 9 revealed an identical pattern of results. Long-term IOR was only seen with objects in the LVR, long-term facilitation was significant for objects in the RVF, but no long-term IOR was seen with locations. These outcomes extend the previous research by suggesting that *inhibitory and excitatory processes* were engaged in these unique long-term IOR tasks, and that both can be encoded and retrieved with episodic traces to affect performance over time. However, inhibition and excitation are only successfully encoded into and retrieved from episodic memory when they are associated with stable object-based representations. Furthermore, these processes seem to be biased across the visual fields.

The pattern of data obtained in Experiments 8 and 9, especially when combined with the results of the three previous studies, provide further support for the existence of hemispheric biases in inhibitory and excitatory processing of object representations in short- and long-term IOR tasks. As described previously, other research has found larger short-term IOR in the LVF versus the RVF (e.g., Berlucchi et al., 1997; Handy et al., 1995; Jordan & Tipper, 2001; McDonald et al., 1999; Nelson et al., 1993, White et al., 2001). These effects may be due to RH specialisation for inhibition of objects, while both hemispheres contribute to inhibition of locations (e.g., Jordan & Tipper, 2001). Importantly, prior research has also found left hemisphere (LH) specialisation for excitatory processing of objects. For example, using a modified version of Posner's (1980) cueing task, Egly and colleagues (Egly, Driver, & Rafal, 1994; Rafal, 1996) presented a target at a different location within a previously cued object, or at an equally distant location in an uncued object. Patients with left parietal lesions did not show the typical cost of shifting attention between objects when the target object was shown in the RVF. Similar results suggesting LH specialisation for between-object shifts of attention have also been found in a commissurotomized patient (Egly, Rafal, Driver, & Starrveveld, 1994). These effects may be due to LH specialisation for excitatory processing (e.g., Berlucchi et al., 1997; Kinsbourne, 1987; Kinsbourne, 1993; Mangun et al., 1994; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990) or to dual representations of excitatory processing in the LH. In particular, recent research using positron emission tomography (PET) has shown increased activity in bilateral superior parietal lobes for rightward shifts of attention, but attention shifts to the left only revealed increased activity in the left superior parietal lobe (Corbetta, Miezin, Shulman, & Petersen, 1993; see also Heilman, Watson, & Valenstein, 1985). This research suggests how hemispheric specialisation for object-based inhibition and excitation may account for the pattern of short- and long-term IOR effects across the visual fields found in these five experiments.

With respect to the pattern of data in the short-term tasks, recall that Experiments 8 and 5 showed IOR when objects were cued in faces and when locations were cued in scenes. Additionally, recall that in both experiments there was a pattern of greater short-term IOR for objects cued in the LVF, where the combined data revealed this effect to be marginally significant. Based on these results, the presence of larger short-term IOR in the LVF might be explained by robust transient inhibition of *both* object- and location-based information processed in the cortical areas of the RH. By contrast, smaller short-term IOR in the RVF could be due to transient inhibitory processing of only location-based information in the LH. Alternatively, excitatory processing of object-based representations in the LH might have reduced the effect of location-based inhibition to elicit smaller short-term IOR in the RVF. In this way, short-term IOR may be mediated by transient object-based inhibition in the LH and inhibition of locations that is processed by both hemispheres, possibly along with object-based excitation processed in the RH.

By contrast, remember that in the long-term tasks there was robust IOR when cueing objects in the LVF in Experiments 6, 7, and 9. Furthermore, these experiments revealed a general lack of long-term IOR when cueing locations in scenes, which was confirmed in a between-experiments analysis. Finally, there was significant long-term facilitation for objects cued in the RVF in Experiment 9, and combining the data from the three experiments revealed the same effect. Together, these results suggest that long-term IOR in the LVF could have been due to episodic retrieval of object-based inhibition processed in the RH. Long-term IOR may not have been seen in the RVF if inhibitory processing of location-based information in the LH is overwritten by intervening trials. Instead, long-term facilitation in the RVF may have been due to episodic retrieval of excitatory processing of object-based representations in the LH. Accordingly, long-term IOR effects seem to be solely mediated by episodic retrieval of object-based inhibition processed in the LH and object-based excitation processed in the RH.

In sum, Experiment 8 confirms that short-term IOR is mediated by transient inhibitory processing of objects and locations in this implicit memory paradigm. The results of Experiment 9 also verify that long-term IOR exists, but only when inhibition is applied to stable object-based representations that are robustly encoded into and retrieved from episodic memory to affect performance much later. Interestingly, long-term facilitation effects also exist in the same task that elicits long-term IOR, thus suggesting episodic retrieval of excitation associated with object representations. Together, results all of the experiments also suggests that hemispheric asymmetries in processing object-based inhibition and object-based excitation contributed to the pattern of short- and long-term IOR effects across the tasks.

3.5. Conclusions

The experiments reported here provide two new implicit memory paradigms for examining short- and long-term IOR effects. The results of two experiments revealed that transient inhibitory processing of object- and location- based information mediates performance in short-term tasks. Interestingly, the particular pattern of short-term IOR effects across the visual fields may be explained by hemispheric biases in inhibitory and excitatory processing of object-based representations. Importantly, three additional experiments revealed the first evidence of long-term IOR effects. Long-term IOR was consistently obtained when cueing object-based information in the LVF. However, long-term facilitation was also observed in the same tasks when cueing objects in the RVF. Although long-term IOR was inconsistently found when cueing location-based representations, this effect was not significant over the three experiments. These results suggest that episodic memory mechanisms contributed to performance, because long-term effects depended on cueing stable, episodically salient object representations. The pattern of long-term effects may be explained by episodic retrieval of inhibitory and excitatory processing of object-based information, which is biased across the hemispheres. In sum, episodic retrieval of prior attentional states may generally mediate correct behaviour over time.

3.5.1. Short-Term IOR Mediated By Biased Attention Processes

Prior research has shown that transient inhibitory processes can be applied to either object- or location-based representations to mediate performance in short-term IOR tasks (e.g., Tipper et al., 1994; Tipper et al., 1999; Weaver et al., 1998). Two studies reported here, Experiments 5 and 8, examined whether these traditional IOR effects could also be obtained in new implicit memory paradigms developed to test the existence of long-term IOR. Indeed, the results revealed robust short-term IOR when objects were cued in face stimuli and when locations were cued in scenes (see Table 3:8 below). Therefore, these findings are consistent with prior research, and suggest that transient inhibitory processing of object- and location-based representations mediates performance in these short-term tasks.

Interestingly, the pattern of short-term effects revealed larger IOR when objects were cued in the LVF versus the RVF, where the analysis of the combined data from the two experiments confirmed this effect. Prior research suggests that this unique pattern of effects might be explained by hemispheric differences in inhibitory and excitatory processing of object-based representations (e.g., Egly, Driver, et al., 1994; Egly, Rafal, et al., 1994; Jordan & Tipper, 2001). In particular, the larger effect with objects in the LVF may have been due to robust inhibition of both object- and location-based representations processed in the cortical areas of the RH. By contrast, smaller short-term IOR found when cueing objects in the RVF could be explained by inhibitory processing of only location-based information in the cortical areas of the LH, perhaps along with excitatory processing of object-based representations in the LH.

	Delay	**Left**	**Right**	**Bottom**	**Top**
Experiment 5	1800 msec	-41 *	-35 *	-46 *	-58 *
Experiment 8	1800 msec	-45 *	-26 *	-37 *	-45 *
Experiment 6	3 min	-16 *	+6	-4	-4
Experiment 7	13 min	-11 *	+4	+ 8 #	-12 *
Experiment 9	18 min	-8 *	+14 *	-2	+5

Table 3:8. *Summary of RT difference scores. Negative scores reveal IOR. Positive scores reveal facilitation.* * $p < .05$; # $p < .10$.

3.5.2. Long-Term IOR and Facilitation Exist

Until now, no research has ever investigated the existence of long-term IOR effects. Accordingly, two new implicit memory paradigms were developed to reveal the effects of inhibition over time by encouraging rich encoding and successful retrieval of episodic memories. Indeed, across three experiments, these tasks revealed the first demonstrations of long-term IOR effects for a face that was cued between three minutes and 48 displays and 18 minutes and 96 displays previously (see Figure 3:8 above). These results therefore provide an existence proof of long-term IOR effects. Interestingly, in the same experiments that revealed long-term IOR, there was also evidence for the presence of long-term facilitation (see Table 3:8 above). Furthermore, an analysis of these three studies together confirmed that long-term facilitation was significant for objects in the RVF. Importantly, the long-term effects seen in these experiments cannot be explained by the maintenance of on-line processing of a cued face over several minutes and many intervening displays. Consequently, the only plausible explanation is that memory processes contribute to performance in these long-term IOR tasks.

3.5.3. Long-Term Effects Mediated By Episodic Memory

Furthermore, the results reported here suggest that episodic memory in particular may have mediated long-term effects. Recall that prior research has found IOR in a working memory task when cueing object-based information, but not location-based representations (e.g., Paul & Tipper, in press; Tipper et al., 2002). Based on these outcomes, the authors suggested that inhibition of objects might provide a basis for search over time, because these representations are maintained stably in memory. By contrast, because location-based information can change rapidly, it is less likely to provide a foundation for inhibitory processes to aid behaviour over time.

Accordingly, the long-term IOR tasks reported here cued either a novel object in a display showing face stimuli or an object-less location in a scene. Because stable object-based representations along with associated inhibition are likely to be robustly encoded into and successfully retrieved from episodic memory, the face stimuli should elicit long-term IOR when cueing an object. However, because location-based representations and associated inhibition are not robustly encoded into nor successfully retrieved from episodic memory, possibly due to being overwritten by intervening trials, there should be no long-term IOR when cueing a location in a scene. Indeed, in Experiments 6, 7, and 9, long-term effects were only observed when cueing object-based representations in face stimuli. By contrast, long-term effects were not consistently observed when cueing location-based information in scenes. Even when the data from the three long-term tasks was combined, they failed to show location-based long-term IOR.

Therefore, it appears that episodic memory processes mediated performance in these tasks because long-term effects were only observed when cueing stable object representations, but not when less stable location information was cued.

Alternatively, one might consider that long-term effects were only found with face stimuli because in these displays an object was always cued *in the same location*. Therefore, it is possible that the memory trace for face stimuli was more episodically rich because it contained information about two representations (i.e., an object appearing in a specific location). However, the memory trace for scene stimuli may have been less episodically rich because it only contained information about one representation (i.e., an object-less location). Importantly, this interpretation also supports the idea that episodic memory processes mediated performance in these tasks, because long-term effects were only observed when cueing two representations simultaneously, but not when cueing one lone representation, such as a fixed location without object-based information.

3.5.4. Episodic Retrieval of Biased Attentional Processes

Taken together with findings from previous research, the results also extend understanding of the processes that mediate long-term performance. It is suggested that long-term NP effects in these tasks must be mediated by memory processes, which are thought to be episodic in nature. However, the engagement of memory mechanisms does not eliminate the possibility that inhibitory processes contribute to these effects, only that maintenance of on-line inhibition explains the outcomes. Therefore, it is suggested that these long-term effects may be due to episodic retrieval of both inhibitory and excitatory states associated with object-based representations. As previously suggested, on viewing the cue display, attentional processes allow correct selection and response to the cued item. The information about the cue stimulus may be automatically encoded into episodic memory along with associated transient attentional states. During the target display, the stimulus may prompt retrieval of the episode and if successful then the associated attentional states may have been reinstated to affect performance.

Importantly, the specific pattern of target effects suggests the nature of the attention states that were encoded and retrieved to affect performance. Because there were no effects of location-based inhibition, the presence of long-term IOR only in the LVF may reveal purely object-based inhibition that is localized to processing in the RH. In the target display, this inhibition is associated with a stimulus that must now receive a response, inhibition must be overcome, which results in long-term IOR. Similarly, without any possible effects of location-based inhibition, long-term facilitation in the RVF may reveal purely object-based excitation biased to processing in the LH. Accordingly, face stimuli displayed in the RVF may have elicited retrieval of excitatory processing of object-based representations processed in the LH. Because in the target display this excitation is associated with a stimulus that must receive a response, it augments processing, resulting in long-term facilitation.

In sum, these findings are consistent with those reported in Chapter 2 because they support a role for episodic retrieval of inhibitory states in long-term IOR tasks in addition to long-term NP tasks. Accordingly, the evidence suggests that episodic retrieval of inhibitory states may generally mediate goal-directed performance over time. However, based on the findings in Chapter 3, the original proposal must be extended to suggest that excitatory states can also be retrieved from episodic memory to affect performance over time. In this way, long-term behaviour may be a result of episodic memory and inhibitory and excitatory processes functioning together to encourage correct response. Clearly, future research will have to investigate the relationship between memory and attention processes in goal-directed behaviour. One intriguing possibility described in Chapter 4, is to use converging techniques, such as computer simulations of neural network models, ERPs, and measures of eye-movements, to search for more direct evidence of episodic retrieval of attentional states in long-term tasks.

Chapter Four

Episodic Retrieval of Attention Mediates Behaviour Over Time

4.1. Objectives

- Summarise the empirical results of the thesis, that long-term NP and IOR exist, but excitatory processes are also engaged in these tasks;
- Explain the implications for understanding how episodic retrieval of inhibitory and excitatory states underlie correct behaviour over time;
- Propose a new neural network model to account for these effects based on episodic retrieval of prior attentional processes;
- Describe future research that uses computer simulations, ERPs, and measures of eye-movements to search for converging evidence of episodic retrieval of attentional states in long-term tasks.

4.2. Abstract

Chapter 4 summarises the pattern of empirical findings from the nine thesis experiments exploring the existence of long-term NP and IOR effects, and then discusses the implications of these outcomes for understanding correct goal-directed behaviour over time. In three experiments, NP effects were found with face and object stimuli when three or six minutes and 56 or 96 displays intervened between the prime and probe displays, thus confirming the existence of long-term NP. Importantly, the first evidence of long-term IOR was seen in three studies when object representations were cued in face stimuli between three and 18 minutes and 48 and 192 displays previously. These results suggest that both inhibition and memory processes are engaged in long-term NP and IOR, where episodic retrieval of inhibitory states may mediate performance. However, there was also evidence that excitatory mechanisms contributed to behaviour in both long-term NP and IOR tasks. These outcomes require an extension of the original proposal to suggest that episodic retrieval of prior excitatory states also mediates

performance in long-term NP and IOR tasks. Furthermore, a new neural network model is proposed to account for long-term NP and IOR effects based on automatic encoding of stimuli and associated transient inhibition and excitation into episodic memory. Later, implicit episodic retrieval can reinstate prior attentional processes to affect performance. The aim of future research is to test the viability of this new model using computer simulations that should elicit effects similar to those observed in this thesis. However, future research must also use converging techniques, such as ERPs and measures of eye-movements, to search for more direct evidence of episodic retrieval of attentional states in long-term tasks. In sum, the findings reported here, along with a new neural network model of episodic retrieval of attentional states and future research, will increase our understanding of how goal-directed behaviour occurs over time.

4.3. Summary and Implications of Experimental Outcomes

The primary aim of this research was to explore whether long-term NP and IOR effects exist and whether episodic retrieval of transient inhibitory states could mediate performance over time in these tasks. An additional aim was to examine the nature of the internal representations that could be stored into and retrieved from episodic memory with associated inhibition. Together, the pattern of data obtained across all of the experiments has implications for understanding the processes that allow correct goal-directed behaviour over time.

4.3.1. Long-Term NP and IOR Exist

A variety of research has shown that NP (e.g., Tipper, 1985; for reviews see Fox, 1995; May et al., 1995) and IOR effects (e.g., Posner & Cohen, 1984; for reviews see Klein, 2000; Lupiáñez et al., 1999; Rafal & Henik, 1994) reveal how inhibitory processing aids response in short-term tasks. However, there is very little research to support the existence of long-term NP (DeSchepper & Treisman, 1996; Lowe, 1998; Neumann et al., 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995) and no research has ever investigated IOR effects over long periods of time. Therefore, across nine experiments, the existence of long-term NP and IOR was examined in four new implicit memory paradigms designed to encourage encoding and retrieval of episodic memories by presenting novel stimuli (e.g., Logan, 1988), requiring processing of object-based representations (e.g., Paul & Tipper, in press; Tipper et al., 2002), presenting an intervening task (e.g., Melton, 1970), and reinstating encoding context (e.g., Tulving & Thompson, 1973). Accordingly, it was hoped that these new paradigms would be sensitive to revealing whether inhibitory processes can mediate correct goal-directed behaviour over time.

Indeed, in Experiment 1, responses were slow to face stimuli that were ignored six minutes and 96 displays previously, thus revealing long-term NP effects. This outcome was replicated and extended in Experiments 2 and 4, which consistently revealed long-term NP for previously irrelevant face stimuli, but inconsistently showed the effect with object stimuli, when three minutes and 56 displays intervened between the prime and probe. An examination of the combined data confirmed that long-term NP effects were obtained with both sets of stimuli. These outcomes are important because very little research has examined long-term NP effects, and the outcomes of this work tend to be contradictory, sometimes showing the effect (e.g., DeSchepper & Treisman, 1996; Lowe, 1998; Neumann et al., 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995) and sometimes not (e.g., Neumann and Russell, 2000; Treisman & DeSchepper, 1995). Therefore, by finding support for long-term NP, this research contributes to the debate about the existence of this elusive effect.

Importantly, the first evidence of long-term IOR effects was also obtained in Experiments 6 and 7 where responses were slow to previously cued object-based information in face stimuli when three minutes and 48 displays, or 13 minutes and 192 displays, intervened between the cue and target. Interestingly, these long-term IOR effects were consistently observed when cueing an object shown in the LVF. When an object was cued in the RVF, there was some long-term facilitation. Finally, across these two experiments, long-term IOR was not consistently obtained when cueing location-based information in scene stimuli. The existence of long-term IOR with face stimuli was replicated and extended in Experiment 9, where responses were again slow to objects that were cued in the LVF over 18 minutes and 96 displays previously. In this study, however, there was also significant long-term facilitation when an object was cued in the RVF. Finally, no long-term IOR was observed when cueing location-based information in scenes. A comparison of the effects obtained between the three long-term tasks confirmed the presence of long-term IOR when objects were cued in the LVF, but long-term facilitation was seen after cueing objects in the RVF. However, there was no long-term IOR observed when cueing locations. These outcomes are important because they are the first to demonstrate the existence of long-term IOR effects.

4.3.2. Implications of Long-Term NP and IOR

There are several implications of finding long-term NP and IOR effects. First, the outcomes suggest that both inhibition and memory processes mediate performance in these long-term tasks. Second, the results indicate that inhibitory processing has the automatic consequences of encoding irrelevant stimuli into episodic memory and retrieving episodic traces pertaining to this information. Third, while some models might describe long-term NP and IOR as being due to episodic retrieval of 'do not respond' tags, it is suggested that inhibitory processes can be applied to specific processing instances of irrelevant information encoded into and later retrieved from episodic memory to elicit long-term effects. Finally, it seems that episodic retrieval of prior inhibitory processes may function differently, depending on the nature of the stimuli representations and how automatically they are processed. These issues are described in turn below.

First, because behavioural slowing was obtained in these long-term NP and IOR experiments, this suggests that inhibitory processes mediated the effect, as they do in short-term versions of the tasks. However, slowed response was observed when several minutes and dozens of new displays intervened between ignoring a stimulus that was irrelevant to the task and later responding to that stimulus. The existence of NP and IOR effects over such long delays cannot be explained by maintenance of on-line inhibition because converging evidence suggests that cognitive inhibition in both of these tasks is implemented through neural suppression mechanisms that function on a timescale of milliseconds and that decay quickly, thereby avoiding interference with continued processing. Consequently, the results from these experiments seem to confirm the suggestion made in Chapter 1 that performance in attention tasks is a product of both inhibition and memory processes (e.g., Tipper, Weaver, et al., 1991). In particular, the candidate memory processes may be episodic in nature, given that long-term NP and IOR effects were found when the experimental methods encouraged robust encoding and successful episodic retrieval of stimuli.

Indeed, recall that Logan (1988) has described how correct task performance depends on both attention (i.e., excitation) and episodic memory processes. In particular, he described two consequences of attentional processing engaged to aid appropriate response: automatic encoding of the information into memory for future use and automatic retrieval of prior stored episodes relevant to the current stimuli. However, a second implication of the current results is that they suggest inhibitory processing of *irrelevant stimuli* also results in automatic encoding into episodic memory and retrieval of stored episodes pertaining to this information. In particular, it must be the case that irrelevant information is stored into and retrieved from memory, otherwise no long-term NP or IOR effects could have been observed. There may be adaptive reasons for a relationship to evolve between episodic memory and inhibition, because correct goal-directed behaviour may rely on information obtained from prior processing episodes when an item did not receive a response. If prior experiences about ignoring a stimulus in a specific context can be reinstated then appropriate behaviour is more likely to occur.

Accordingly, the current results have implications for understanding how episodic memory processes can aid correct goal-directed behaviour over time. There is a wide range of episodic memory models designed to explain performance over time (see Tenpenny, 1995, and Bowers, 2000 for reviews on this topic). However, the episodic retrieval processes thought to mediate performance in these tasks may be tied most closely to models that are derived from Logan's

(1998) instance theory. In particular, one class of such models have previously been used to explain long-term NP effects as being due to episodic retrieval of 'response tags' (e.g., DeSchepper & Treisman, 1996; Lowe, 1998; Neill et al., 1992; Neumann et al., 1999; Neumann & Russell, 2000; Treisman & DeSchepper, 1995). In general, these models propose that during the prime display of a NP task, an irrelevant distractor is stored with associated response information that is variously described as: a 'do not respond tag' (e.g., Neill et al., 1992), 'nonreportable' (e.g., Lowe, 1998), an 'ignore label' or 'ignore tag (e.g., DeSchepper & Treisman, 1996), and an 'unwanted tag' (Neumann & DeSchepper, 1992). According to all of these models, when the same stimulus becomes a target on an IR probe display, the prior episode is retrieved, along with the affiliated 'response tag'. Therefore, episodic retrieval causes slow responses in NP tasks because it takes time to resolve the conflict caused by the retrieved tag being inconsistent with the current requirement to respond to the item.

There are several lines of evidence that support these models of episodic retrieval processes in mediating short- and long-term NP effects (for a review, see Fox, 1995; May et al., 1995; Neill et al., 1995). However, experiments that rely solely on behavioural measures of performance probably cannot confirm or disconfirm the existence of 'do not respond' tags. Additionally, it must be recognised that notion of 'response tags' suffers from being poorly defined, infinitely flexible, and without any neural basis. Indeed, several proponents of episodic retrieval models have suggested that episodes may retain some trace of the previous inhibition that affects performance later on (e.g., DeSchepper & Treisman, 1996; Neill et al., 1992; Tipper, 2001; Tipper, Weaver, et al., 1991). Therefore, it is suggested that 'do-not-respond' tags may be operationalised in models of episodic retrieval in terms of neurally plausible inhibitory processes. Although the concept of inhibitory processing has traditionally been assumed to refer to a reduction in activation-levels of logogens (i.e., Morton, 1969; 1979), inhibition is not necessarily implemented in abstract representations of information. Recent research has suggested that inhibition can aid perceptual selection and response processes in distributed representations of population codes (e.g., Tipper, Howard, & Houghton, 2000). Therefore, it is suggested here that episodic retrieval can access specific processing episodes (i.e., Jacoby & Brooks, 1984) along with associated inhibitory states.

In particular, when initially encoding an irrelevant stimulus in a NP or IOR task, the inhibitory processes acting on the perceptual inputs not only aid transient response, but also become associated with information stored in episodic memory. When encountering the same item later, retrieval of the prior stimulus aids object recognition and also re-activates the attentional system into its previous inhibitory state. Performance is hampered because the reinstated inhibition must be overcome before response to the previously irrelevant item can occur. Accordingly, these long-term effects may be explained by episodic retrieval of prior inhibitory states.

A final implication of the results obtained in these long-term NP and IOR tasks is that episodic retrieval of inhibition seems to be processed differently in different circumstances. For example, the pattern of data in the long-term NP tasks suggests that the effect was more consistent with face stimuli than with object stimuli. If episodic retrieval of prior inhibitory states mediates these effects, then these results suggest that this process may have been more robustly engaged when processing faces than objects. In particular, the degree to which episodic retrieval of prior inhibition affects later response may depend on the ease of processing in the prime display. Prior research suggests that faces are processed automatically (e.g., Bruce & Humphreys, 1994; Farah et al., 1998), therefore when presented as prime distractors, they may require robust inhibition to prevent erroneous response. This could result in richer encoding of episodic traces (e.g., Craik & Lockhart, 1972) that can be successfully retrieved later to reinstate prior inhibition and elicit long-term NP. By contrast, because objects are not processed automatically (e.g., Garrard et al., 2001), they may not require robust inhibition to prevent response in the prime display. This might result in poor encoding of episodic traces (e.g., Craik & Lockhart, 1972), that can only be inconsistently retrieved to reinstate prior inhibition. Hence, long-term NP may not be consistently observed with objects.

Similarly, the pattern of data in the long-term IOR tasks also suggests that episodic retrieval of inhibition is processed in different ways depending on the circumstances. Recall that long-term IOR was only found when cueing objects, but not when cueing locations. Again, if episodic retrieval of prior inhibitory states underlies performance in these tasks, then the outcomes indicate that this mechanism was only engaged when processing object-based representations, but not when cueing location-based information. Prior research indicates that inhibition of objects is more stably maintained in working memory than inhibition of spatial location, because location information can change rapidly (e.g., Paul & Tipper, in press; Tipper et al., 2002). Therefore, stable object-based representations along with associated inhibition are likely to be robustly encoded into and successfully retrieved from episodic memory, eliciting long-term IOR effects. On the other hand, because location-based information is overwritten by subsequent events, it could be stored in episodic memory with associated inhibition, but it is not likely to be retrieved to affect performance. Interestingly, the consequence of these processes is that long-term IOR effects are only observed for objects cued in the LVF. This is because without episodic retrieval of location-based inhibition, which may be processed in both hemispheres (e.g., Jordan & Tipper, 2001), episodic retrieval of object-based inhibition processed in the RH (e.g., Jordan & Tipper, 2001), is solely responsible for behaviour.

In sum, the results of the long-term NP and IOR tasks clearly reveal that to understand the processes mediating correct behaviour over time, inhibition and memory mechanisms must be investigated together in long-term NP and IOR tasks. In particular, future research must utilise more direct methods to explore the nature of the information retrieved from episodic memory in long-term tasks.

4.3.3. Long-Term NP and IOR Reveal Excitatory Processes

While the main goal of this research was to verify the existence of long-term NP effects and obtain an existence proof of long-term IOR, the pattern of data that emerged also revealed surprising evidence for the presence of excitatory processing in these tasks.

Recall that Experiment 2 found long-term NP effects in the IR+ condition, where the prime targets became probe distractors and the prime distractor became the probe target. It was acknowledged that this effect might not have been due to episodic retrieval of prior inhibition, but rather due to episodic retrieval of excitation associated with prime targets, which had to be overcome to prevent response when they became probe distractors. Experiment 3 tested whether prior excitation slows probe responses by repeating prime targets as probe distractors, but presenting a new probe target. Indeed, this condition elicited significant behavioural slowing for object stimuli, although not for face stimuli. This result suggests that the excitatory processes previously associated with prime targets impacted performance in the AI probe display when these objects became distractors. Interestingly, because this same condition did not elicit behavioural slowing with faces, prior excitatory states clearly did not impact probe display performance. Although this outcome was unexpected, previous research has found evidence that excitation may contribute to performance in long-term NP tasks (e.g., DeSchepper & Treisman, 1996). Furthermore, there is also evidence for the presence of transient excitatory processes in short-term NP tasks (e.g., DeSchepper & Treisman, 1996; Lowe, 1979; Lowe, 1998; Neill, 1977; Neill, 1979; Neill & Westberry, 1987; Neumann & DeSchepper, 1992; Tipper & Cranston, 1985; Tipper, Weaver, & Houghton, 1994).

Even more surprising were the outcomes from the long-term IOR tasks. In the same experiments that elicited long-term IOR when cueing object-based information in faces appearing in the LVF, long-term facilitation was seen when objects were cued in faces appearing in the RVF. While this long-term facilitation effect appeared as a trend in Experiments 6 and 7, it was significant in Experiment 9. Furthermore, analysis of the combined effects from the three tasks revealed significant long-term facilitation for faces cued in the RVF. On the one hand, no research has ever investigated long-term IOR effects, so there is no precedent for finding long-term facilitation effects in this task. However, as with NP tasks, prior research suggested that both inhibitory and excitatory processes mediate performance in short-term IOR tasks (e.g., Maylor & Hockey, 1985; Houghton &

Tipper, 1994; Lupiáñez & Weaver, 1998; Posner & Cohen, 1984; Tipper et al., 1997).

4.3.4. Implications of Excitation in Long-Term NP and IOR

There are several implications of finding evidence of excitatory processing in long-term NP and IOR tasks. The first is that excitation seems to work with inhibition and memory mechanisms to mediate behaviour in these tasks. Second, the results indicate that the mechanism proposed to mediate long-term NP and IOR effects must be revised to include the idea that excitatory processes can also be encoded into and later retrieved from episodic memory to contribute to long-term effects. Third, it seems that episodic retrieval of prior inhibitory processes may function differently, based on the stimuli representations and how automatically they are processed. Each of these ideas is addressed below.

First, finding evidence for excitatory processing in long-term NP and IOR tasks seems to indicate that in the same tasks where inhibition and memory processes aid performance, excitatory processes are also engaged. Indeed, as mentioned previously, there is some evidence in both the NP and IOR literature to suggest that dual inhibitory and excitatory attentional processes both contribute to correct response. Furthermore, Houghton's (Houghton & Tipper, 1994; Houghton et al., 1996) neural network model of reactive inhibition specifically explains both NP and IOR effects through engagement of dual excitatory and inhibitory feedback mechanisms. According to their model, the presence of both processes aids fast and efficient response because it effectively doubles the rate at which the signals pertaining to relevant and irrelevant information can be discriminated. If it accepted that transient excitation can work with inhibition to aid correct behaviour in short-term NP and IOR tasks, then it is plausible that excitatory processes may also aid behaviour over time in these same paradigms.

A second implication of finding excitatory processing in long-term NP and IOR tasks is that these attentional states may also be stored into and retrieved from episodic memory to affect long-term performance in a manner similar to that proposed for inhibitory processes. In particular, on viewing a display, information may be stored in an episodic trace along with transient excitation. When this same item must receive a response later on, the prior episode could be retrieved to reinstate excitation. Interestingly, performance could be affected in one of two ways depending on whether the stimulus associated with the retrieved excitation must now be ignored, or receive a response. Response could be hampered if retrieved excitation must be overcome to prevent erroneous response. Alternatively, response might be facilitated if retrieved excitation further augments processing. Interestingly, the processes engaged in the latter situation might explain long-term repetition priming effects (RP), where response is faster to a previously attended target in an attended repetition (AR) condition versus a control condition where new stimuli are shown (see Anderson, 1983; Kintsch, 1988; McNamara, 1994; Neill & Mathis, 1998; Ratcliff, Hockley, & McKoon, 1985; Whittlesea & Jacoby, 1990, for possible links between excitation and episodic memory in RP).

Finally, the results of the long-term NP and IOR experiments suggest that episodic retrieval of excitation is also processed differently in various situations. For example, recall that in Experiment 3, there was evidence that excitatory processes contributed to behaviour with object stimuli, because response was slowed when prime target objects were re-shown in the AI probe display as distractors, even though there was a new target object. However, the same condition did not elicit slowed responses with face stimuli. If episodic retrieval of prior excitatory states contributes to this effect, then these results suggest that this process was only engaged when processing objects, but not when processing faces. As described previously, the degree to which episodic retrieval of prior excitation affects later response may depend on how easily prime display information is processed. Specifically, because faces are processed automatically (e.g., Bruce & Humphreys, 1994; Farah et al., 1998), when they are shown as prime distractors, inhibition may not need to be robustly engaged to prevent incorrect response. Therefore, without rich prime processing, episodic traces might be poorly encoded (e.g., Craik & Lockhart, 1972) and less likely to be retrieved, so there will be no influence of prior excitation on probe response. However, because object stimuli are more difficult to process (e.g., Garrard et al., 2001), they may require robust excitation to allow correct response in the prime display. The effect of this processing could be rich encoding of episodic traces (e.g., Craik & Lockhart, 1972), that can successfully be retrieved later to reinstate prior excitation. However, because in this task, excitation is reinstated with stimuli shown as probe distractors, it must be overcome to prevent incorrect response, which results in slow performance.

The pattern of data in the long-term IOR tasks also suggests that episodic retrieval of excitation is processed differently in various situations. Specifically, in the exact same way that long-term IOR was only found when cueing objects, not locations, long-term facilitation effects were also only seen when cueing objects. As described previously, if episodic retrieval of excitatory states underlies long-term facilitation, then clearly this mechanism was only engaged when stable object-based representations are robustly encoded into and successfully retrieved from memory. By contrast, less stable location-based information may be encoded into memory but overwritten by intervening displays (e.g., Paul & Tipper, in press; Tipper et al., 2002), so there can be no episodic retrieval of prior excitation. One result of these processes is that long-term facilitation is only seen when objects are cued in the RVF. Without episodic retrieval of location-based inhibition that should be processed in both hemispheres (e.g., Jordan & Tipper, 2001), episodic retrieval of object-based excitation processed in the LH (e.g., Egly, Driver, et al., 1994) solely mediates behaviour.

In sum, these results indicate that in addition to inhibition and memory mechanisms, excitatory processing also contributes to performance in long-term NP and IOR tasks. While long-term behaviour is mediated by episodic retrieval of prior inhibitory states, it may be the case that episodic retrieval of prior excitation also contributes to performance. Future research must search for more direct evidence of episodic retrieval of prior excitatory states, for example by exploring long-term RP effects.

4.4. Proposed Model for Episodic Retrieval of Attentional States

While the original proposal of this thesis was that episodic retrieval of prior inhibitory states could mediate long-term NP and IOR effects, the outcomes of the experiments suggest that the proposal must be modified in the ways described above. Specifically, episodic retrieval of prior inhibition and excitation may both contribute to long-term NP and IOR effects, as well as explain the existence of long-term RP. Accordingly, a new network model is described to account for episodic retrieval of prior attentional states to explain long-term effects in these three paradigms. This model reveals how episodic retrieval of prior attentional states might generally mediate correct goal-directed performance over time.

4.4.1. New Neural Network Model

To clarify, it is suggested that on stimulus presentation, depending on the task, engagement of both excitatory and inhibitory processes may aid correct response, at the same time that episodes pertaining to the stimuli are stored in memory. One feature of the episodes is the transient attentional states that were associated with stimuli during encoding. In effect, the status of receiving excitatory or inhibitory processing may become a component of that item's episodic representation. If the original context is reinstated during the second presentation of the same stimulus much later in the task, this cues implicit retrieval of prior matching episodes. Then transient attentional processes associated with those stimuli may be reinstated to affect performance, by either speeding or slowing response.

Importantly, it is *not* being suggested that transient attention processes are maintained on-line for long periods and across processing of intervening items to affect performance. Rather, the physical aspects of attentional processes, such as neural suppression and excitation, will be relatively short-lasting. Instead, when the original encoding context is re-presented this may re-activate the network of attentional processes into the previous configuration to again aid correct selection and response.

Based on this framework, long-term NP and IOR effects may be a consequence of retrieving episodes pertaining to irrelevant information and associated inhibition, resulting in slowed response to that item when it is later presented as a target. Similarly, RP may be a result of retrieving an episode pertaining to a target and associated excitation, which is reinstated to speed response when that item is repeated as a target. In this way, the attentional state that is engaged during processing of a display might be reinstated on retrieval of episodic traces to aid correct behaviour over time.

The episodic retrieval of prior attentional processes proposed to mediate long-term NP, IOR, and RP effects can be understood through a modified version of Houghton and colleagues' (Houghton & Tipper, 1994; Houghton et al., 1996) neural network model of reactive inhibition. Figure 4:1 below presents a schematic of the new model. In the figure, the colour black represents processes that occur during NP, IOR, and RP tasks, blue refers to additional processing during NP tasks, green refers to processes that only occur in IOR tasks, and red indicates episodic memory processing that occurs during long-term NP, IOR, and RP tasks.

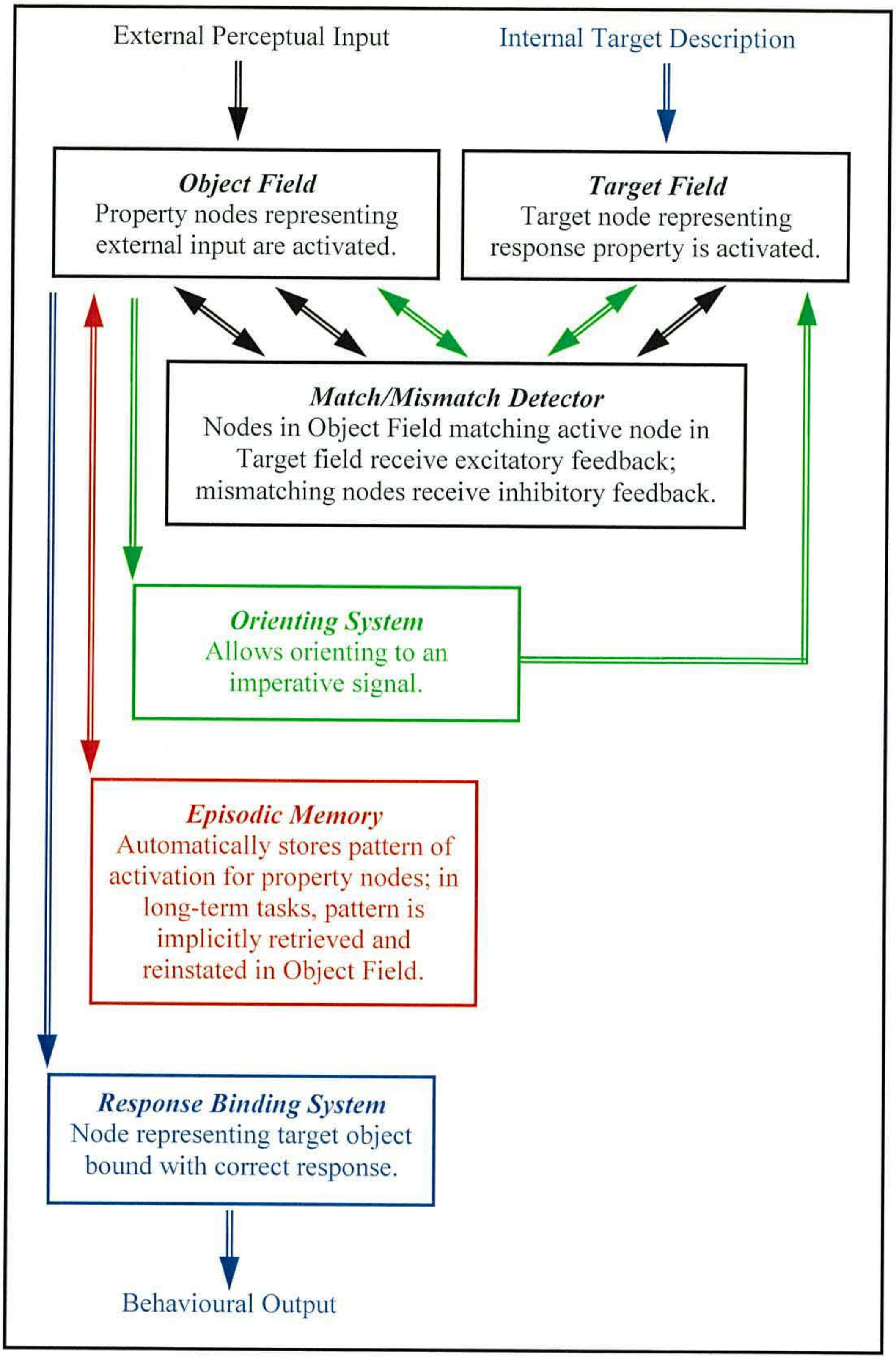

Figure 4:1. Schematic of the proposed neural network model of episodic retrieval of attentional states (based on Houghton & Tipper, 1994; Houghton et al., 1996). See text for details.

4.4.2. Modelling Long-Term NP and Repetition Priming (RP)

The new model for episodic retrieval of attention states shown above in Figure 4:1 can explain how processing might occur in the prime display of long-term NP tasks like Experiment 2. Recall that in this task, three faces were shown in a horizontal row where subjects categorised the sex of the two outer faces in the prime display, and categorised the sex of the middle face in the probe display. Additionally, this model may also explain processing in the prime display of a long-term RP task. Such a task might be very similar to NP, but subjects might have to categorise the sex of the two outer faces in both prime and probe displays.

First, external stimuli shown in the prime, for example three faces, activate property nodes representing object-based information in the Object Field. At the same time, knowledge about the task response requirements, shown in blue in Figure 4:1, activates a node representing the target property in the *Target Field.* In this example, the target node might contain information about the participant needing to categorise the sex of the two outer faces. At this point, the stimulus information represented in the property nodes is automatically compared with information stored in the Episodic Memory sub-network, displayed in red in Figure 4:1. If no matching occurs then the network only uses on-line processing to achieve correct response as described in Chapter 1.

Specifically, the property nodes are compared with the target node in the Match/Mismatch Field. Because the property nodes representing the two outer faces will match with the target node, these will receive excitatory feedback in the Object Field. However, because the property nodes representing the middle face will mismatch the target node, they will receive inhibitory feedback. Over time, the activation of property nodes associated with the target faces will increase but activation decreases for property nodes representing the middle distractor face, as shown in Figure 4:2 below. Importantly, once the activation levels of the property nodes have been resolved, a 'snapshot' of the transient pattern of activation across nodes is automatically stored in the Episodic Memory sub-network (e.g., Cohen, Braver, & O'Reilly, 1998), represented in red in Figure 4:1 above. This 'snapshot', which is represented by the red region in Figure 4:2 below, allows properties of items that match the target template (e.g., the two flanking faces) and mismatch the target template (e.g., the middle distractor face) to be stored along with the patterns of activation associated with excitatory and inhibitory feedback. Finally, patterns of activation that do not exceed response threshold decay back to resting levels. However, those that do exceed respond threshold are fed forward to a Response Binding System, displayed in blue in Figure 4:1 above, which allows the correct 'male' response to the target faces.

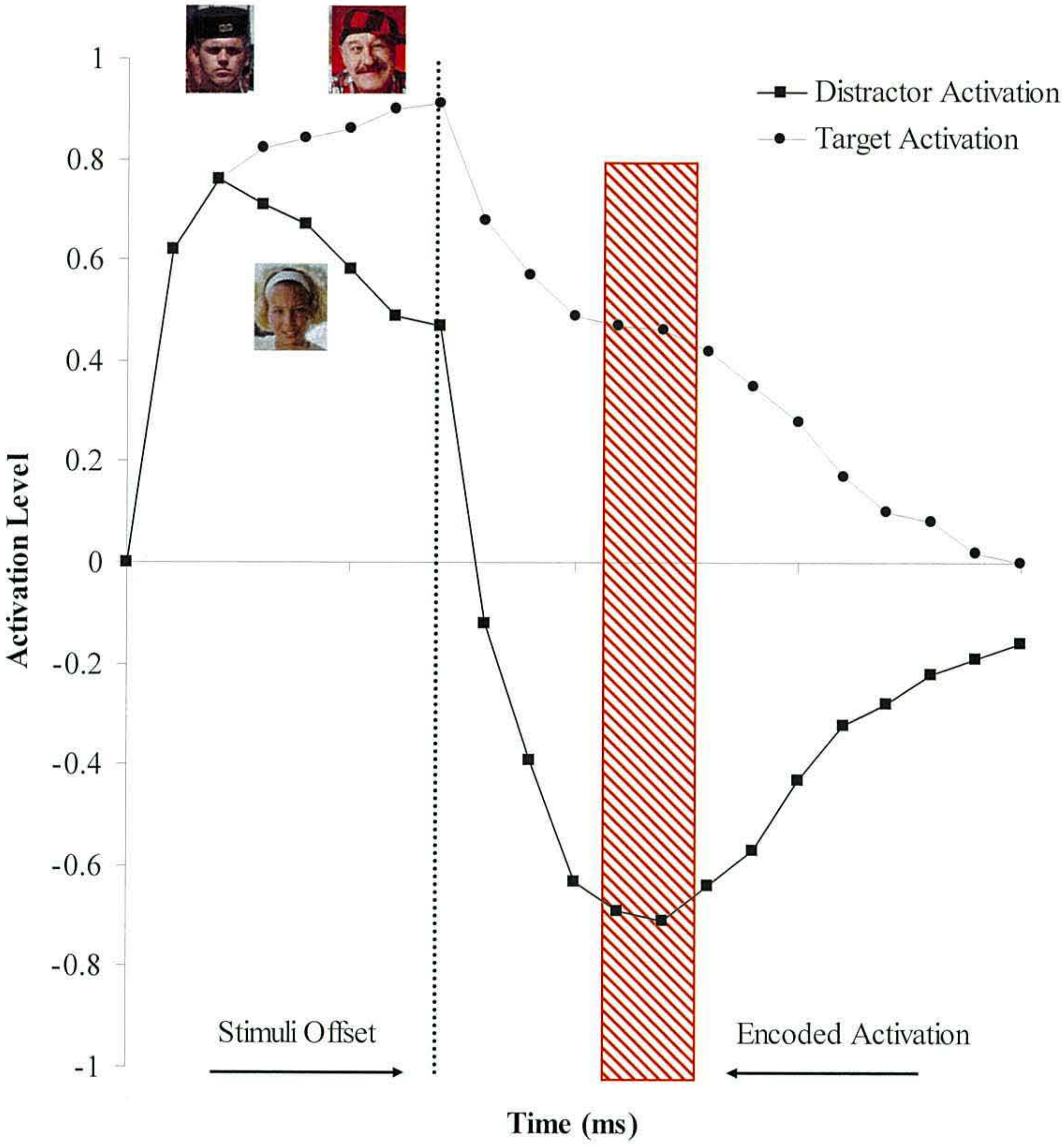

Figure 4:2. Activation levels for property nodes representing target and distractor stimuli in a prime display of a long-term NP or RP task. The red region represents the pattern of activation encoded into episodic memory. See text for details.

Importantly, this model accounts for long-term NP effects like those observed in Experiment 2, as well as the possibility of long-term RP effects, in the following way. As seen above in Figure 4:2, after the stimuli shown in the prime display offset, the patterns of activation in the property nodes representing the target faces and distractor face decay quickly, which prevents interference with on-going processing. However, if the same three faces are re-presented much later in the probe display, then because the encoding context has been reinstated, this should provide enough retrieval cues to allow the stimulus information in the property nodes to match the stored information in the Episodic Memory sub-network. This match process would activate implicit retrieval of the entire pattern of transient activation across all relevant property nodes into the Object Field, resulting in a 'reinstatement' of the prime network state shown in Figure 4:2. Importantly, after reinstatement of the prior activation pattern, this pattern must be checked against the target node in the Match/Mismatch Field for verification.

In the case of the critical attended repetition (AR+) condition of a long-term RP task, the roles of the stimuli are repeated, such that the prime target faces and distractor face remain the targets and distractor, respectively, on the probe display. Accordingly, the target node would again contain information about the participant needing to categorise the sex of the two outer faces. In this way, the property nodes representing prime target faces that are retrieved with high levels of activation will again match with the target node in the Match/Mismatch field. Similarly, property nodes representing the prime distractor face that are retrieved with low levels of activation will mismatch the target node. After the Match/Mismatch operation is performed, there is no need for additional iterations of this process to resolve excitatory and inhibitory feedback, as the pattern of activation is already stabilised across property nodes. At this point, only patterns of activation that exceed threshold, for example those for the target faces, are fed to the Response Binding System to allow a correct 'male' response. This process will result in faster response times versus in a control condition, when the external stimuli represented in property nodes must be iteratively compared with the target node in the Match/Mismatch Field before response can occur. Accordingly, long-term RP will be seen.

By contrast, recall that in the critical IR+ condition of a long-term NP task used in Experiment 2, the roles of the stimuli were reversed from the prime to the probe display, such that the prime target faces became probe distractors and the prime distractor face became the probe target. Therefore, the target node would now contain information about the participant needing to categorise the sex of the middle face. In this case, the property nodes representing the prime target faces that are retrieved with high levels of activation will *mismatch* the new target node. Similarly, the property nodes representing the prime distractor face that are retrieved with low levels of activation will *match* the target node. Importantly, to overcome the retrieved pattern of activation, many more iterations of the Match/Mismatch operation must be performed so that excitatory feedback increases activation of property nodes representing the prime distractor face and inhibitory feedback decreases activation of property nodes pertaining to the prime target faces. When these dual mechanisms finally differentiate activation levels of property nodes representing the new probe target and distractor faces, the patterns of activation that exceed threshold are fed to the Response Binding System to allow the correct 'female' response. Clearly, this process will result in slower response times than in a control condition. This is because although the Match/Mismatch process must also be iteratively performed in the control condition, there is no need to *reverse* prior levels of activation to allow correct response. For this reason, long-term NP effects will be observed.

4.4.3. Modelling Long-Term IOR

The new neural network model for episodic retrieval of attention states shown above in Figure 4:1 can also explain how processing might occur in the cue display of a long-term IOR task like Experiment 9. Recall that in this task, first one face was shown, then a semi-transparent cue signal appeared over one of the eyes, then the original face was seen again. If a red cue signal appeared, participants with held response, but if a blue signal appeared, they pressed a key to indicate that the signal appeared over the left eye or the right eye.

First, it is suggested that upon viewing the face, prior to the onset of the cue signal, the perceptual input activates property nodes in the Object Field, which represents the stimulus. The information represented in the property nodes is automatically compared with information stored in the Episodic Memory sub-network, shown in red in Figure 4:1. If no matching occurs then the network uses on-line mechanisms described in Chapter 1 to process the red cue signal, which now suddenly appears over the right eye.

The appearance of a red cue eye alters activation of the property nodes in the Object Field, updating them to reflect the new stimulus information. The cue signal is processed by the Orienting System, shown in green above in Figure 4:1, which allows orienting to occur and which sets up an internally-generated target representing the fact that the right eye was oriented. The property nodes are matched with the target node in the Match/Mismatch Field, resulting in excitatory feedback that initially increases activation of property nodes representing the cued right eye (see Figure 4:3 below). Once the activation levels of the property nodes have been resolved, a 'snapshot' of the transient pattern of activation across nodes, represented by the red region in Figure 4:3 below, is automatically stored in the Episodic Memory sub-network (e.g., Cohen et al., 1998).

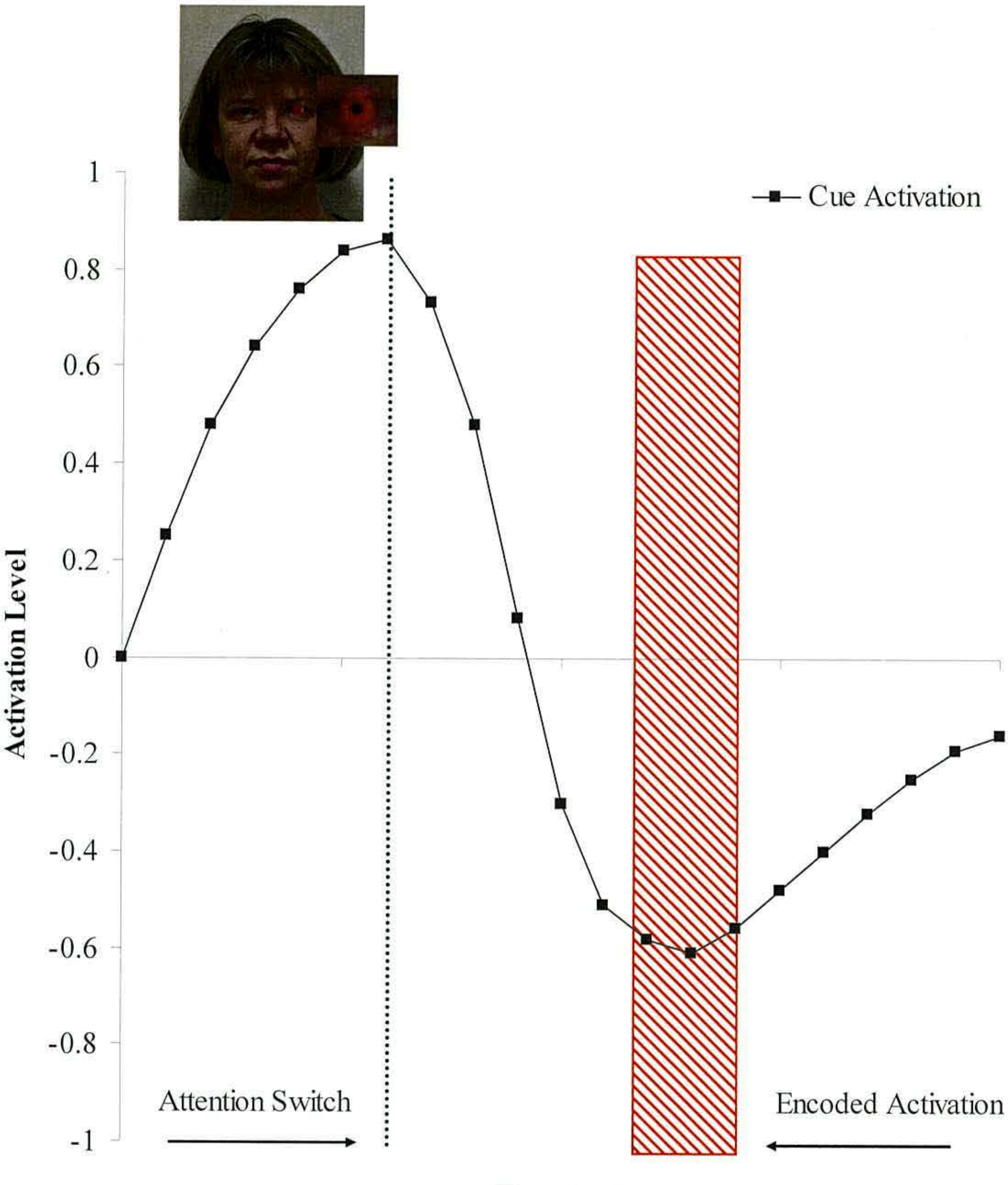

Figure 4:3. Activation level for property nodes representing a cued object shown in a long-term IOR task. An enlargement displays the cue signal for the right eye for clarity only. The red region represents the pattern of activation encoded into episodic memory. See text for details.

This updated model could account for long-term IOR effects similar like those observed in Experiment 9 in the following way. As seen above in Figure 4:3, when attention is switched from the cued right eye by the re-presentation of the original face in the final frame of the cue display, this has the effect of establishing a new target node in the Target Field. Because the new target node mismatches with the previous cue, the switch in attention results in an inhibitory rebound effect for property nodes pertaining to the cued right eye (see Figure 4:3 above). This pattern of activation in the property nodes decays quickly, thus preventing interference with continued processing. However, if the same face is re-presented much later in the target display, then reinstatement of the cue display encoding context should provide retrieval cues that allow the information to match the stored information in the Episodic Memory sub-network. This match process would result in implicit retrieval into the Object Field of the prior pattern of transient activation pertaining to this face when the right eye was cued with a red signal. The reinstatement of the cue display network state is shown above in Figure 4:3, where there is an inhibitory rebound effect for property nodes pertaining to the cued right eye. When the blue 'go' target signal appears over the right eye, the property nodes representing the cued eye will still be below resting levels. Accordingly, it will take relatively longer to reach response threshold in comparison with the length of time for the property nodes representing an uncued location to reach response threshold, thus revealing long-term IOR effects.

In sum, this new model could reveal how episodic retrieval of prior attentional states mediates performance in long-term NP, RP, and IOR tasks. However, clearly future research must focus on using converging techniques to test the predictions made by this model as well as explore the plausibility of the underlying mechanisms.

4.5. Future Research

To this point, the behavioural research described here has been successful in obtaining NP and IOR effects over the long-term, which provides indirect support for episodic retrieval of prior attentional states. In addition, these behavioural results have allowed the conceptualisation of a new neural network model of episodic retrieval of attention. However, as discussed, the use of behavioural measures alone may not fully reveal the nature of the processes that mediate performance over time in these tasks. Therefore, future research must employ converging techniques to search for evidence for episodic retrieval of attentional states. Accordingly, there are three aims of future research. The first goal is to implement the proposed model into a connectionist network and use computer simulations to further investigate the idea that episodic retrieval of attentional states underlies performance in long-term tasks. A second aim of future research is to use ERPs to search for more direct evidence of episodic retrieval of inhibitory and excitatory states in long-term NP, RP, and IOR tasks. Finally, future research will use measures of saccadic eye-movements to investigate whether episodic retrieval of prior attentional states affects overt orienting to previously cued information.

4.5.1. Simulating Performance in Long-Term Tasks

This new model of episodic retrieval of attentional states could be implemented in a neurally plausible connectionist network based on computations similar to those described by Houghton and his colleagues (Houghton & Tipper, 1994; Houghton et al., 1996) in their original model of reactive inhibition. The possible uses for this new model of long-term goal-directed behaviour are intriguing.

For example, computer simulations conducted with the network may provide converging evidence of the existence of long-term NP and IOR effects. Specifically, the model should reveal NP and IOR when many minutes and dozens of displays intervene between the first and second presentation of a stimulus. Additionally, simulations could also explore the existence of long-term RP effects. Furthermore, the outcomes of computer simulations could not only verify the existence of long-term NP, IOR, and RP, but suggest the plausibility that episodic retrieval of prior attentional states elicits these effects.

In addition, this model could also be used to better understand some of the secondary effects found in long-term NP and IOR tasks. For example, simulations might reveal why episodic retrieval of prior excitatory states affects response to object stimuli in long-term NP tasks, but not face stimuli. Recall that this effect may have been due to the automatic processing of prime target faces (e.g., Farah et al., 1998), where robust excitation wasn't necessary to allow correct response. The consequences of this processing are poor encoding the information into episodic memory so that it cannot be retrieved to affect performance later on the probe (e.g., Craik & Lockhart, 1972). By contrast, if object stimuli are more difficult to process (e.g., Garrard et al., 2001) and are not encoded automatically when they are prime targets, then greater excitation must be engaged, which leads to better encoding and more successful later retrieval, so that prior excitation affects performance. Accordingly, simulations of long-term NP tasks should reveal less excitatory feedback and lower levels of activation of property nodes representing face targets than for object targets. These different patterns of activation would also be encoded into the Episodic Memory sub-network, so that upon later retrieval, simulations might show less reinstatement of excitation in property nodes representing prime face targets than for prime object targets.

Similarly, computer simulations might also indicate the nature of the processes that allow long-term IOR to be observed when cueing object-based representations, but not with locations. For example, in cue displays, simulations might reveal inhibitory feedback that lowers activation of property nodes in the Object Field that represent either cued object- or location-based information. Furthermore, both of these patterns of activation might be stored into the Episodic Memory sub-network. Importantly, simulations might reveal that after long delays the pattern of prior low activation associated with cued objects, but not cued locations, can be retrieved from episodic memory and reinstated in the property nodes to affect performance. This outcome would support the idea that inhibition associated with stable object information can be maintained over time (e.g., Paul & Tipper, in press; Tipper et al., 2002) whereas inhibition of unstable location information cannot (e.g., Paul & Tipper, in press).

In sum, by developing a connectionist network that models episodic retrieval of prior attentional states, computer simulations could provide converging evidence of the existence of long-term NP, RP, and IOR effects. Importantly, these simulations could also provide insight into whether episodic retrieval of prior attentional states mediates performance over time as well as the specific way this mechanism functions.

4.5.2. Recording ERPs in Long-Term Tasks

A second important aim of future research is to use an on-line measure of performance that is yoked to task manipulations, such as ERPs, to provide more direct evidence of the mechanisms underlying performance in long-term tasks. ERPs are a transient series of voltage oscillations in the brain that can be recorded in response to the occurrence of a discrete event (Donchin, Ritter, & McCallum, 1978). ERPs are comprised of a number of components thought to be manifestations of underlying cognitive activity. Future research may use lateralized readiness potentials (LRP), as they are sensitive to activation of response selection processes (e.g., Eimer, 1998) and reveal parallel activation of competing responses (e.g., Coles, 1989). Therefore, LRPs can show inhibition of an inappropriate response (e.g., De Jong, Coles, Logan, & Gratton, 1990).

Accordingly, to investigate whether inhibition is retrieved with episodic memories, long-term NP effects could be examined in one of the new paradigms, for example Experiment 2. This task could also be altered to investigate long-term RP effects, which might reveal whether excitation is also retrieved from episodic memory to aid long-term performance. In the RP experiment, an AR+ condition would be used, where the prime targets are also the targets on the probe display and the prime distractor remains the probe distractor. At the same time as participants performed these NP or RP tasks, LRPs could be recorded from central scalp sites located over the motor cortices of the two cerebral hemispheres.

In the long-term NP task, evidence that memory processes contribute to response would be obtained if NP occurs over three minutes and 56 displays, where responses are once again slower to the IR+ versus the control condition. Evidence that inhibition also aids performance in IR+ probe displays would be obtained if initial activation of the incorrect response to the target face, shown by negative-going LRPs, is followed by activation of the correct response, shown by positive-going LRPs (see Figure 4:4 below). Additionally, evidence of inhibitory processing would also be obtained if either the latency of LRPs was slower and/or the peak amplitude was less in the IR+ versus the control condition.

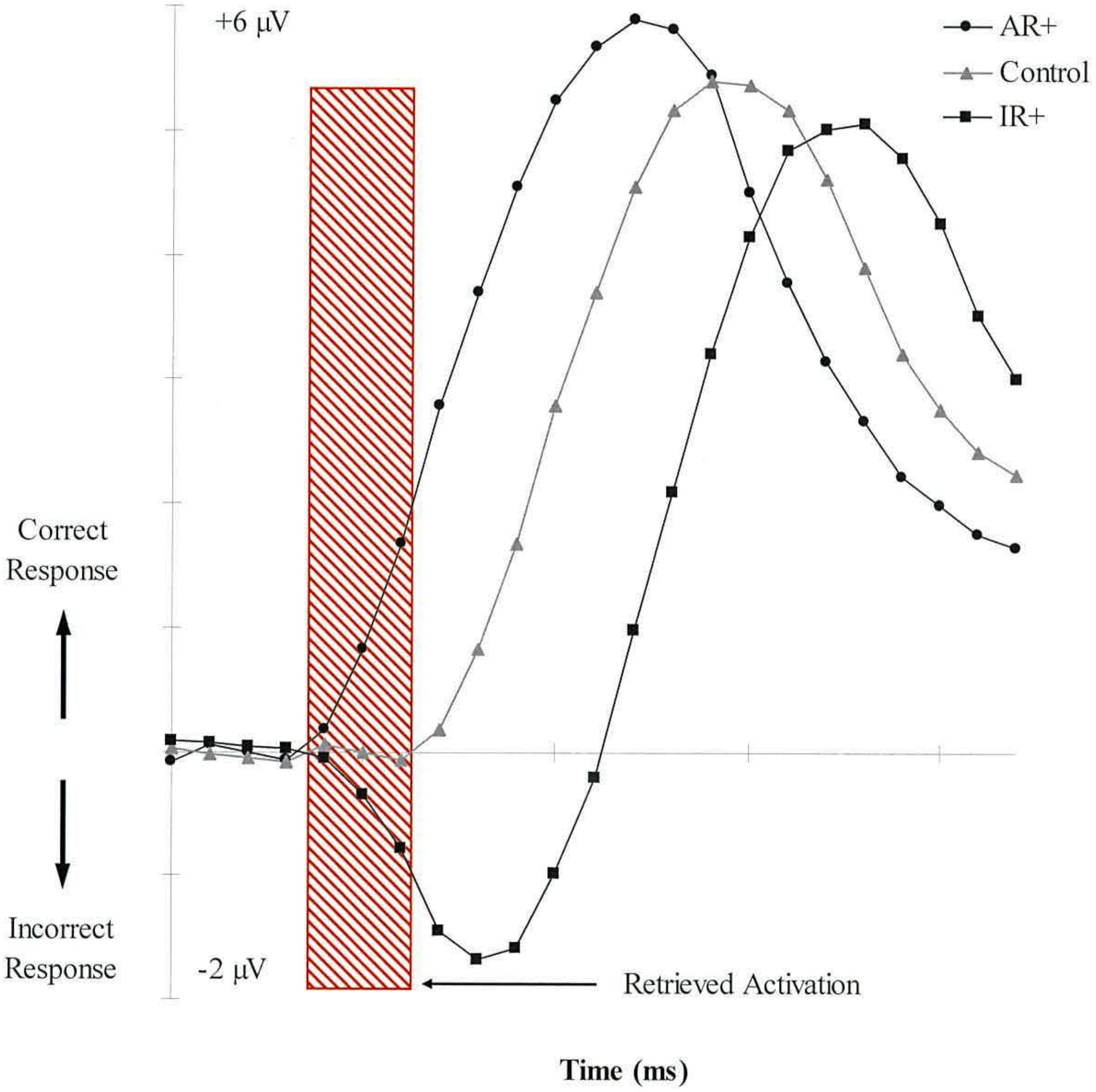

Figure 4:4. LRP waveforms revealing activation of correct responses in the AR+ and control conditions of a long-term RP task and in the IR+ and control conditions of a long-term NP task. The red region represents the pattern of activation retrieved episodic memory. See text for details.

In the RP experiment, if RP occurs over three minutes and 56 displays, where RTs to the target faces are faster in the AR+ versus control condition, then this will suggest that memory processes contributed to response. Evidence that excitatory processing also aids performance in AR+ probe displays would be found if there was only activation of the correct response to the target face, shown by positive-going LRPs (see Figure 4:4 above). Additionally, evidence of excitatory processing would also be obtained if either the latency of LRPs was faster and/or the peak amplitude was greater in the AR+ than the control condition.

Similarly, the LRP component of the ERP can also reveal the presence of inhibitory and excitatory processing in long-term IOR tasks (see Eimer & Schlaghecken, 1998). Accordingly, one of the new long-term IOR paradigms, for example Experiment 9, could be used to search for behavioural long-term IOR effects while again recording LRPs. Given the data obtained in Experiment 9, it is plausible to expect to find evidence that memory contributes to response in target displays if long-term IOR effects are observed over 18 minutes and 96 displays when the left eye is cued, but facilitation is obtained when the right eye is cued. Similarly, evidence that inhibition aids response may be found for cued targets appearing in the left eye, if initial activation of the incorrect response to the target, shown by negative-going LRPs, is followed by activation of the correct response, shown by positive-going LRPs (see Figure 4:5 below). Additional evidence of inhibitory processing for the cued left eye would be obtained if either the latency of LRPs were slower and/or the peak amplitude were less in the cued than the uncued condition. By contrast, evidence that excitation aids response may be found for cued targets appearing in the right eye, if there is only activation of the correct response to the target, shown by positive-going LRPs (see Figure 4:5 below). Additional support for excitatory processing of the cued right eye would also be found if either the latency of LRPs was faster and/or the peak amplitude was greater in the cued versus uncued condition.

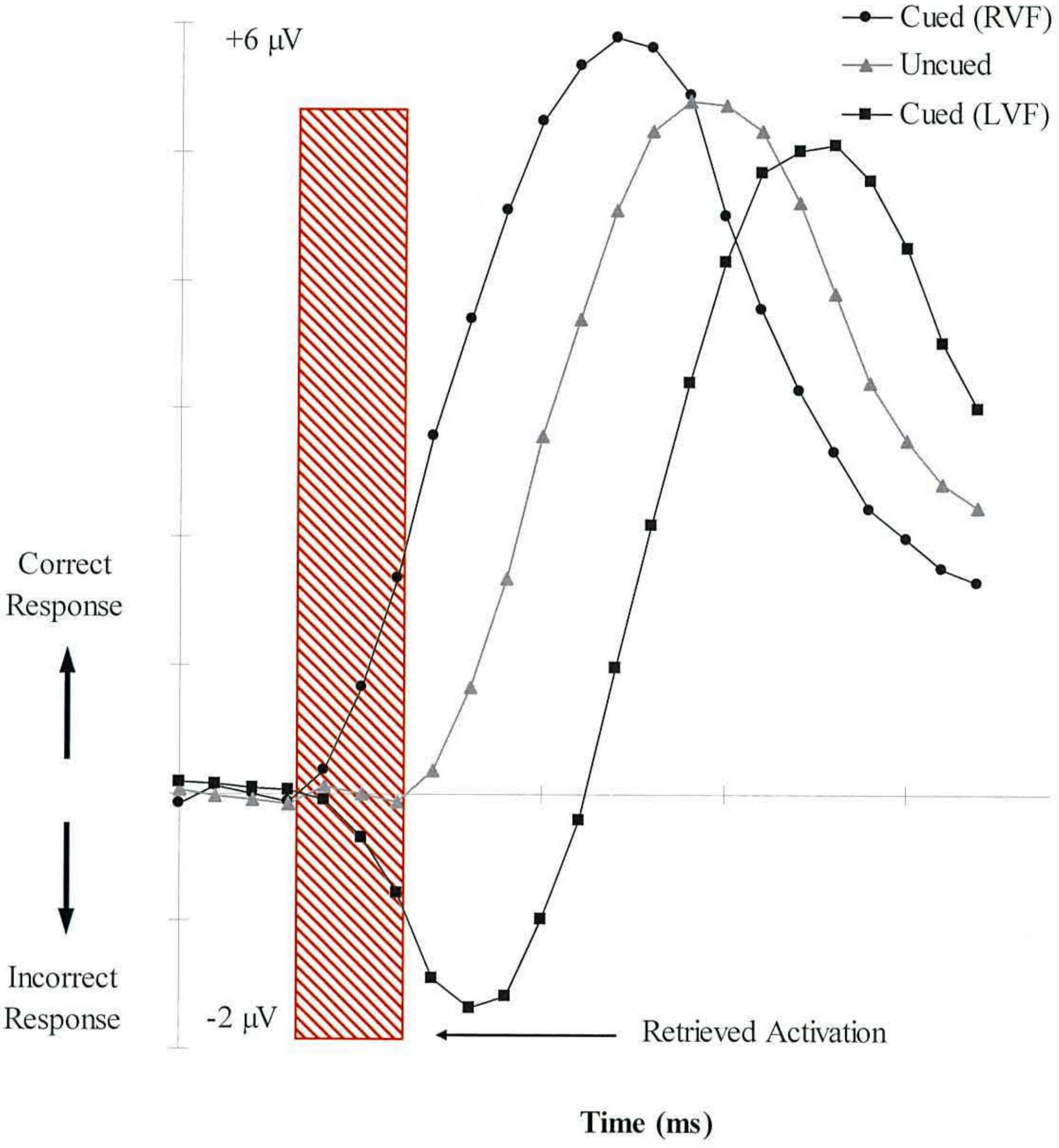

Figure 4:5. LRP waveforms revealing activation of correct responses in the Cued (RVF), Uncued, and Cued (LVF) control conditions of a long-term IOR task. The red region represents the pattern of activation retrieved episodic memory. See text for details.

In sum, the LRP component of the ERP may provide converging evidence of the existence of long-term NP, RP, and IOR effects. Importantly, these experiments could also reveal more direct evidence of reinstatement of prior excitatory and inhibitory states to mediate performance in these tasks.

4.5.3. Measuring Eye-Movements in Long-Term Tasks

A final aim of future research is to use measures of eye-movements to examine whether episodic retrieval of prior attentional states affects overt orienting to previously cued information in long-term IOR tasks. Therefore, a modified version of one of the new long-term IOR tasks, such as Experiment 9, could be used to search for long-term IOR effects while recording measures of saccadic eye-movements to the cue and target signals. Interestingly, evidence that memory and inhibition both contribute to performance in long-term IOR effects might be observed if saccades are made more slowly to a left eye that was previously cued over 18 minutes and 96 displays earlier, in comparison with an uncued left eye. Similarly, support for memory and excitatory mechanisms in this same task would be obtained if saccades are made more quickly to a previously cued versus uncued right eye.

Together, the results from these future computer simulations, ERP experiments, and measures of eye-movements might reveal additional support for the existence of long-term NP, RP, and IOR, as well as provide converging evidence episodic retrieval of prior attentional states may explain these effects. Although the studies outlined here could significantly increase understanding of the mechanisms that mediate correct goal-directed behaviour over time, additional research must utilize converging measures of on-line processing that have good spatial and temporal resolution, such as Event-Related Optical Signals (EROS) (e.g., Gratton, Fabiani, Goodman-Wood, & Desoto, 1998), to search for complementary evidence of the neural mechanisms engaged during episodic retrieval of attentional states in long-term tasks.

4.6. Conclusions

In sum, the research conducted in this thesis has laid the foundation for a new model of goal-directed behaviour that describes how episodic retrieval of inhibitory and excitatory states can mediate long-term performance. Clearly, the work described here can increase understanding of how humans correctly respond to information over time. However, it will remain for future research to explore the relationship between dual excitatory and inhibitory mechanisms of attention, especially in relation to episodic retrieval of these states, in mediating both long-term and transient behaviour. The ultimate goal is therefore to develop the first model of dual attentional processes, where flexible attention and memory processes function differently across task contexts to allow correct behaviour in our complex visual world.

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Appendix

Figures of Experimental Conditions

Figure 1. Experimental conditions for faces in Experiment 1.

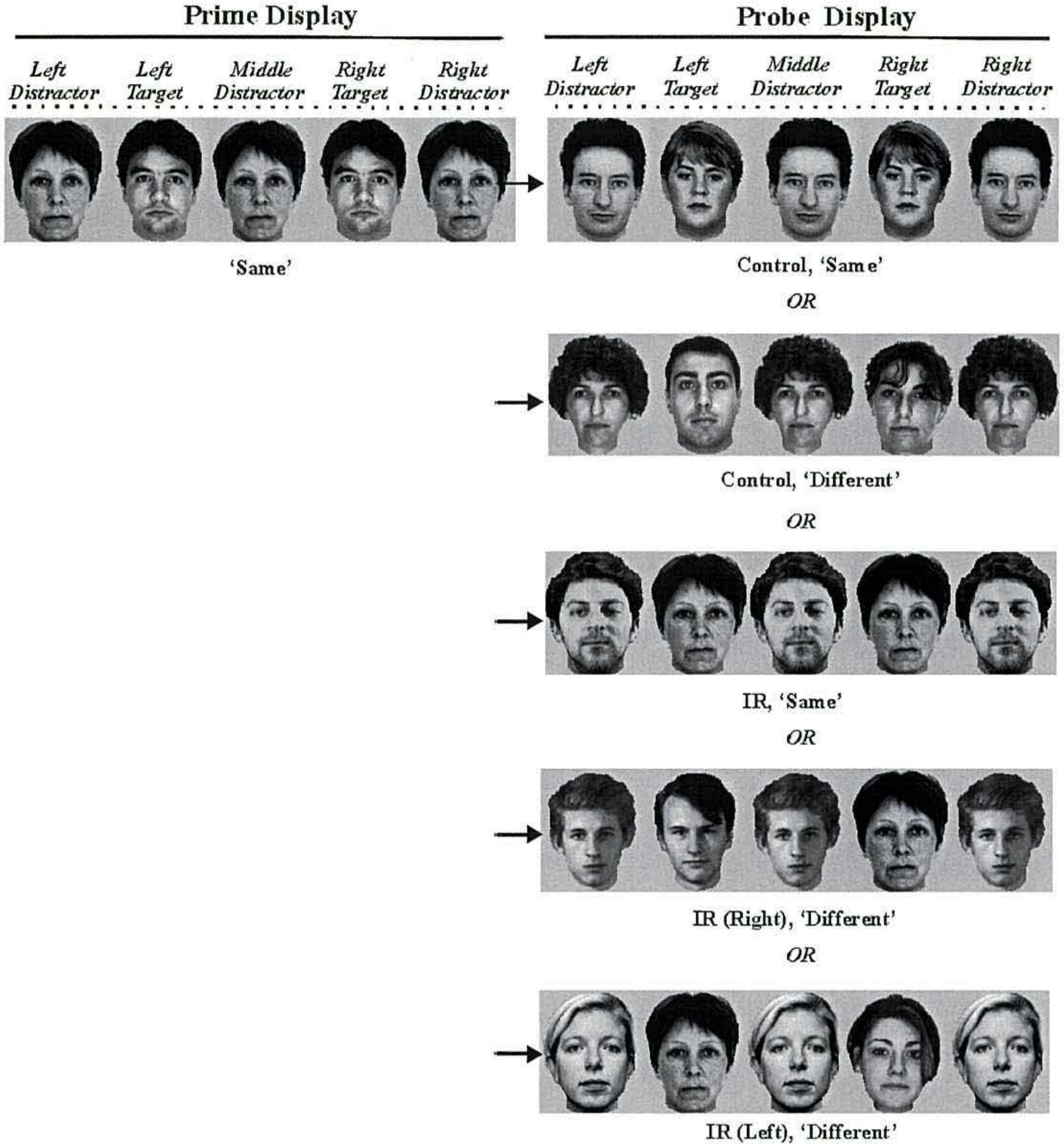

Figure 1 (continued).

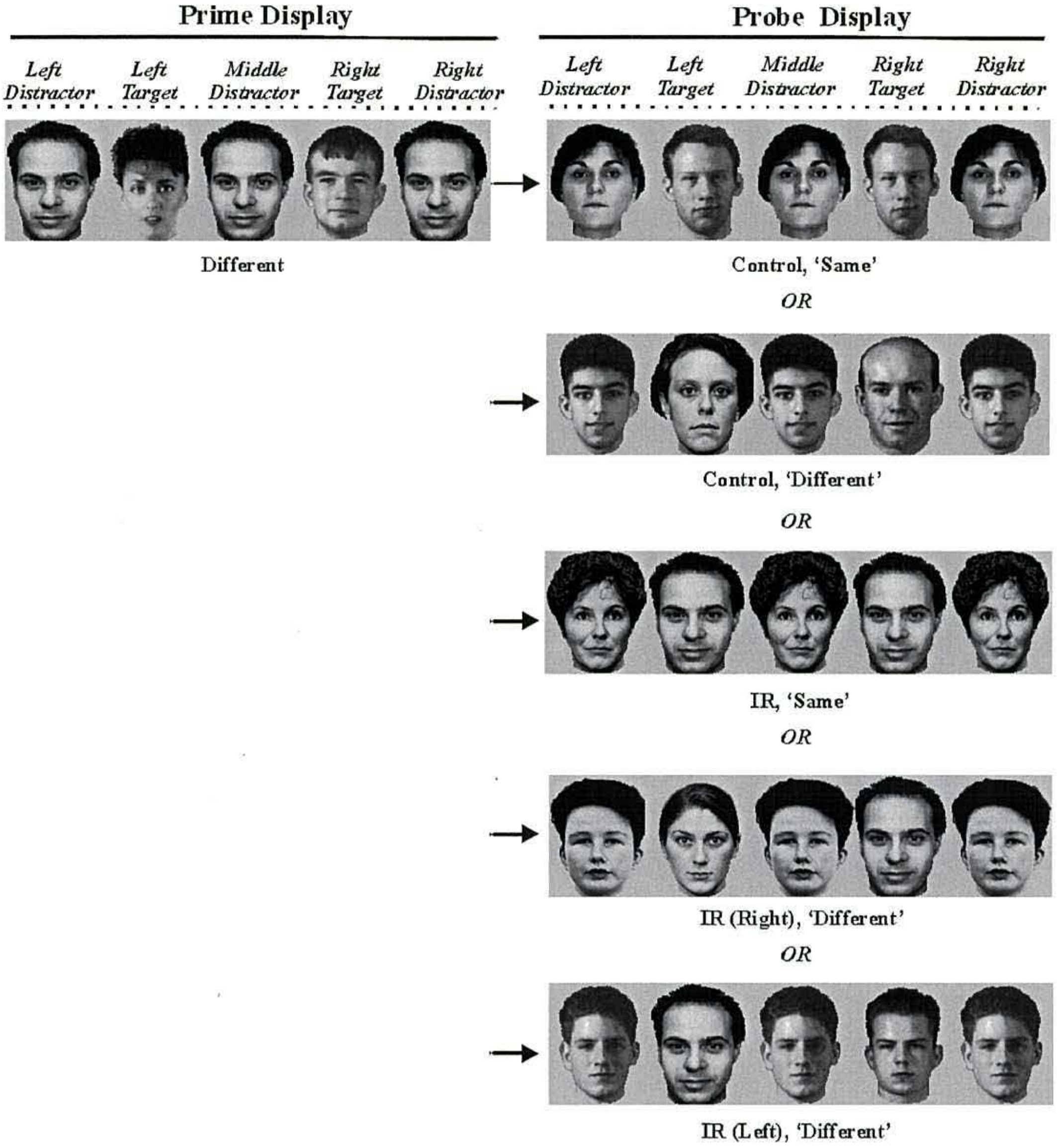

Figure 2. Experimental conditions for faces and objects in Experiment 2.

Figure 2. (continued)

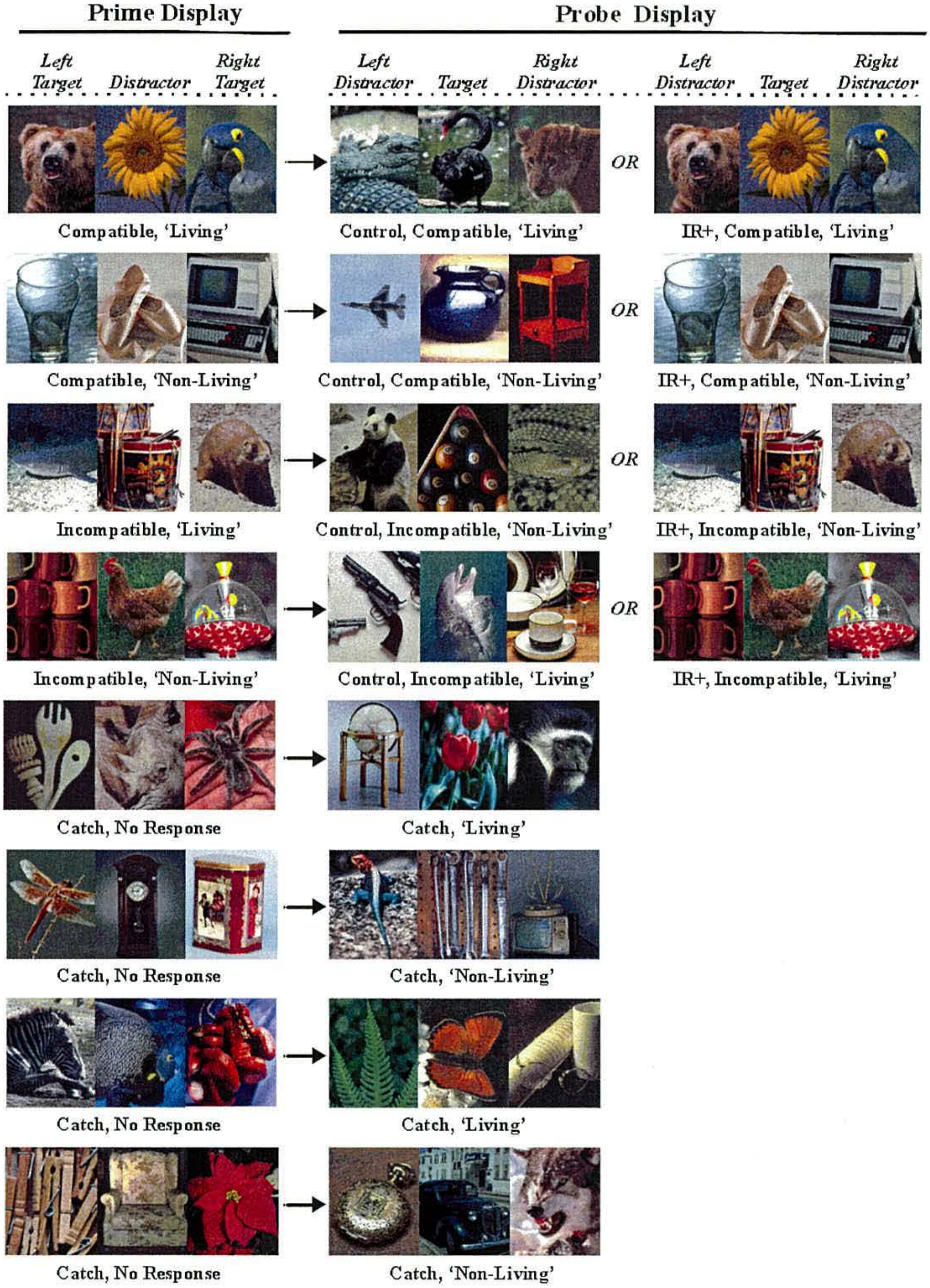

Figure 3. Experimental conditions for faces and scenes in Experiments 5 to 7.

Figure 3 (continued).

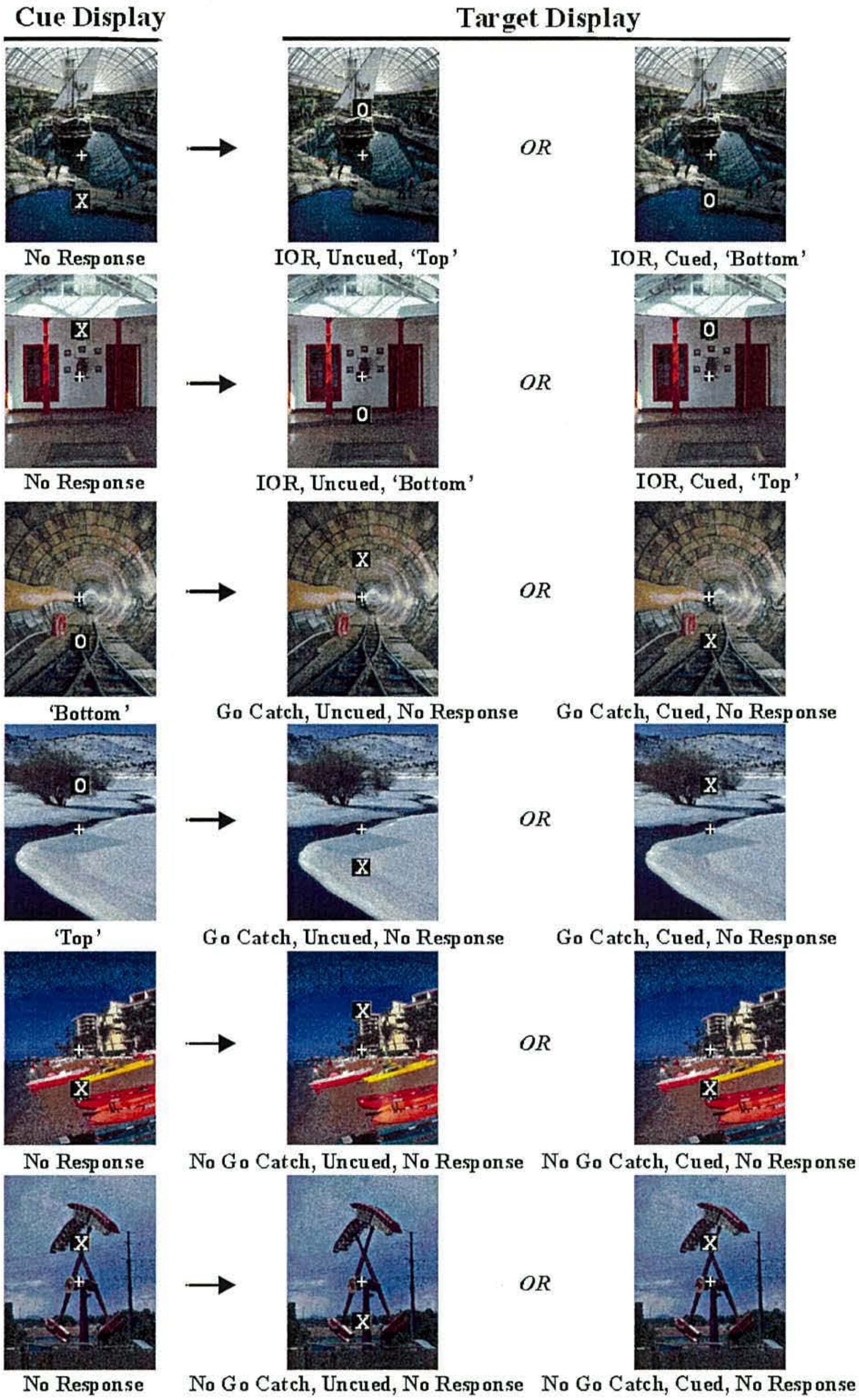

Figure 4. Experimental conditions for faces and scenes in Experiments 8 and 9.

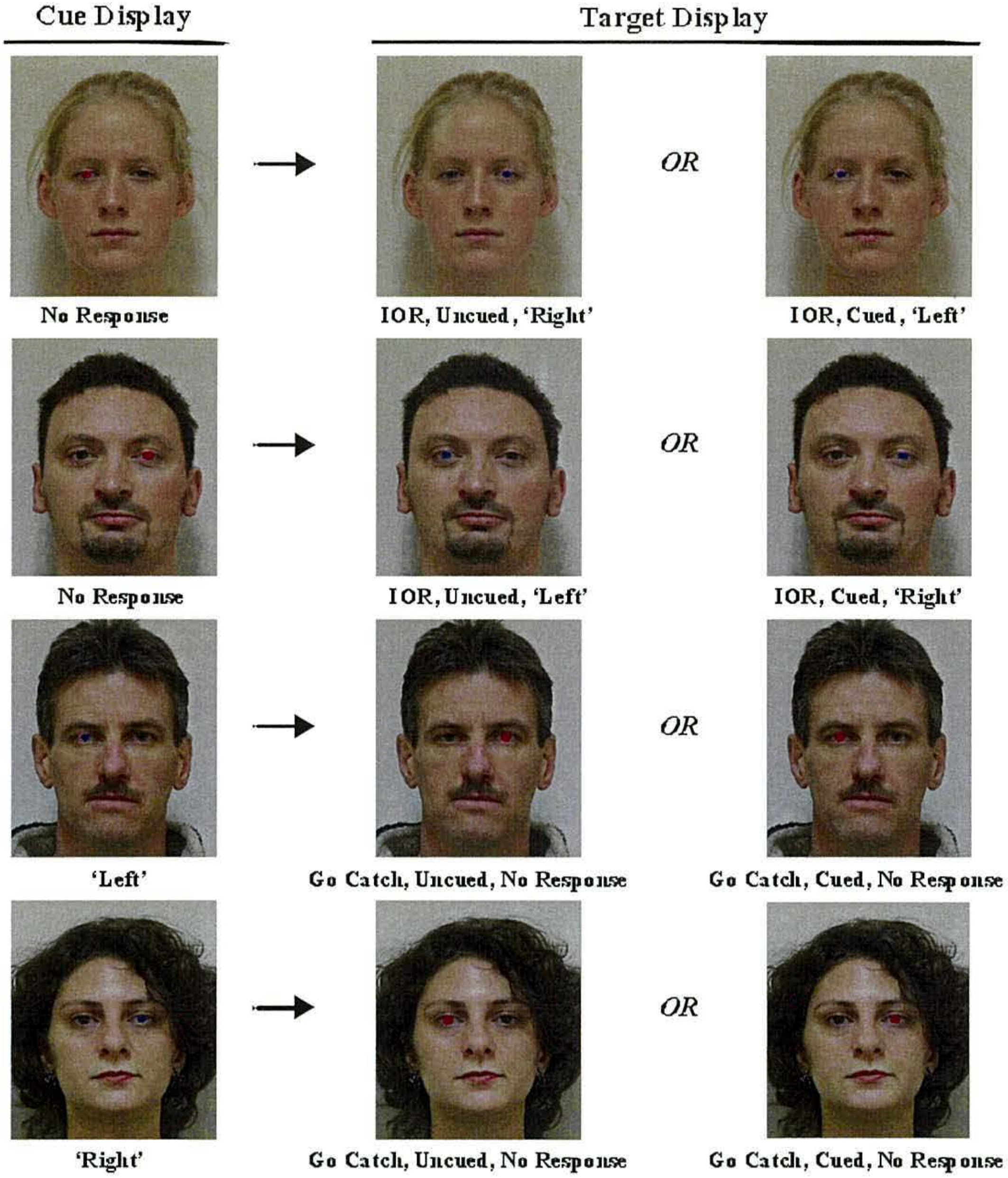

Figure 4 (continued).