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Attentional facilitation for faces in dynamic spatial cueing tasks

Robert Ben Swalwell

Abstract

This thesis explored whether faces produce inhibition of return (IOR) in dynamic displays. As previous literature exclusively used static displays, it is not possible to discern whether the IOR observed is attributable directly to the face or simply reflects location-based IOR. Whether faces produce object-based IOR is suggested as a way to distinguish two contemporary theories of IOR: the habituation hypothesis and detection cost theory. In the habituation hypothesis, IOR reflects a weaker response to previously attended objects due to habituation, whereas detection cost theory proposes IOR as an attentional cost incurred when there is a similarity between the cue and target. As highly salient objects may not be habituated to, the habituation hypothesis would predict that certain objects would not show IOR, whereas detection cost theory would predict IOR for all objects provided the relationship between cue and target remains the same. Thus, whether faces produce object-based IOR may distinguish between these accounts. Nine experiments were conducted comparing face stimuli to other objects in spatial cueing tasks. In the eight experiments that used dynamic displays, faces did not produce object-based IOR. In fact, cueing effects for faces were consistently in the direction of facilitation, rather than inhibition. This was the case for schematic and photographic faces and for both manual and saccadic responses. A secondary finding was that other schematic objects also did not produce object-based IOR, while shapes and photographic objects did produce object-based IOR. The present data are most consistent with the habituation hypothesis, although this only specifically explains the lack of IOR for faces rather than the presence of facilitation. This cueing effect may be explained by the maintenance of attention at cued faces and/or the interaction of different perceptual representations and their subsequent attentional effects.

Attentional Facilitation for Faces in Dynamic Spatial Cueing Tasks

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effects. The values for Experiment 1 and Experiment 2 are derived only from blocks that were completed first as condition order significantly interacted with these cueing effects. The values for Experiment 5 are derived from two of three SOAs, as the 900ms SOA produced significantly different responses in both conditions. Experiments 7 and 9 reflect the cueing effects from the short SOA only, as the long SOA did not produce significant cueing effects. Experiment 8 used a static design which prevented distinguishing between object and location-based cueing effects: thus, the values for this experiment are the general cueing effects and are identical to those presented in Figure 5.2. All other values are collapsed across SOA and condition order where applicable.

Figure 6.1: Summary of object-based cueing effects obtained in previous work using dynamic displays. Negative values indicate an inhibitory effect, while positive values indicate a facilitatory effect. E indicates the experiment number within the cited study (e.g. E2 = Experiment 2), with the following number in brackets representing the SOA in milliseconds. As many of these studies did not provide the standard deviations necessary to calculate effect sizes and confidence intervals, where necessary standard deviations were estimated based on the standard deviations obtained in Vivas, Humphreys & Fuentes (2008), adjusted for differences in the means (i.e. if the mean reaction time was 90% of the equivalent Vivas et al. 2008 condition, the standard deviation value used was 90% of the Vivas et al. (2008) standard deviation). While this estimate will obviously contain error, it is considered sufficient to illustrate that these cueing effects are comparable to those in the thesis experiments.

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Chapter 1: Cueing Effects for Objects and Faces in Static and Dynamic Displays

1.1 General Introduction

The attention system is necessary for us to select and process subsets of information from our environment. In some situations, the information we choose to attend is driven primarily by our own expectations and goals, which is referred to as endogenous or active attention. However, there are also cases where a stimulus captures our attention regardless of our current task, such as a bright flash of light or a loud noise. This is referred to as exogenous or passive attention. How attention is distributed also differs in our day-to-day lives. In many situations, it is necessary to focus on a single stimulus or task even when there are a range of stimuli or tasks to attend. This is typically referred to as selective attention. In contrast, divided attention refers to any situation where there are at least two stimuli or tasks that an individual must attend to simultaneously. The present thesis is an investigation into exogenous selective attention.

In a seminal work by Posner and Cohen (1984), a time course for the effect of a salient stimulus on attentional allocation was identified. It was found that a peripheral cue speeded up responses to a target at the same location relative to targets at a different location, provided the target was presented within 300ms of the cue. However, this effect was reversed for targets presented after 300ms, which participants responded to more slowly compared to targets at an uncued location. This latter effect was later given the name inhibition of return (IOR; Posner, Rafal, Choate, & Vaughan, 1985). Although IOR was originally described as a location-based effect, later research demonstrated that IOR could be found in a non-spatial frame of reference. For example, Tipper, Driver and Weaver (1991) found IOR remained intact for squares after they had moved to a new location. This effect is termed object-based IOR.

Traditionally, IOR was believed to be tied directly to orienting. That is, speeded responses occurred when the target appeared while the cue was being oriented to, while slowed responses occurred once attention had been withdrawn. However, IOR can be observed in the absence of attentional orienting (e.g. Smith, Rorden, & Jackson, 2004). In light of these and other results, it has been proposed that IOR is more appropriately conceived of as being a form of habituation (Dukewich, 2009) or a detection cost (Lupiáñez, 2010). However, although these theories have been supported in the context of location-based IOR, neither has been directly tested in the context of object-based IOR.

If IOR can be attributed to habituation, then it would be expected that a particularly salient object would not show IOR. Human faces seem a strong candidate for this, given they capture attention rapidly to the point of interfering with the detection of other objects (e.g. Crouzet, Kirchner, & Thorpe, 2010). This claim has not been supported as studies that used faces typically find IOR (Rutherford & Raymond, 2010; Silvert & Funes, 2016; Taylor & Therrien, 2005, 2008). However, these studies used static displays, where the locations of the stimuli are fixed in each trial. This is important because IOR can be found for both locations and objects. Thus, from this research the extent to which the IOR observed is attributable to the faces rather than their locations is unclear.

This thesis aims to examine whether faces and other complex objects produce object-based IOR in dynamic displays and how this is best accounted for theoretically. By using displays with moving objects, location-based and object-based IOR for faces can be studied separately. This will be explored using a variety of schematic and real objects and faces primarily in a behavioural paradigm similar to Weaver, Lupiáñez and Watson (1998). The introduction to the thesis will provide a background to IOR by discussing defining characteristics of IOR, including the perceptual and motoric forms of IOR. Next, key studies will be reviewed demonstrating the location-based and object-based forms of IOR and their respective qualities. Studies regarding the neural substrates of IOR will then be discussed. Theories of IOR will be presented along with discussions as to how these theories account for previous studies. This will be followed by a focus on studies examining IOR specifically in faces. In both sections, emphasis will be placed on the relative lack of study received by object-based IOR and how distinguishing location-based and object-based IOR can improve our understanding of IOR.

1.2 Forms of IOR

1.2.1 Posner Cueing Task

The IOR effect was first demonstrated concurrently in work by Berlucchi, di Stefano, Marzi, Morelli and Tassinari (1981) and Cohen (1981). However, most influential was Posner and Cohen (1984), which used what is now considered the canonical task for studying IOR, a task referred to as either the Posner cueing task or the spatial cueing task (e.g. Reppa et al., 2012). In this task, two boxes are located either side of a central point. In Posner and Cohen (1984) the central point was a third box, although later work often uses a small point or cross instead (e.g. Lupiáñez, Milan, Tornay, Madrid, & Pudela, 1997; Maylor & Hockey, 1985). This is commonly referred to as the fixation point as participants are normally instructed to maintain fixation at this point. Firstly, a stimulus is presented in or around one of the two boxes. In Posner and Cohen (1984), this was a brightening of the outline of one of the boxes. This brightening was displayed for 150ms before disappearing. This is known as the cue. The second component of the trial was the appearance of a target: in Posner and Cohen (1984), the target was a black box which appeared in the middle of one of the three boxes. In subsequent experiments based on this task, the target typically only appears in one of the two boxes either side of the fixation point. The target could appear at one of six possible times, which corresponded to 150, 200, 250, 350, 450 or 650ms after the cue appeared. The time period between the appearance of the cue and the appearance of the target is known as the stimulus-onset asynchrony (SOA). In 60% of trials, the target appeared in the central box. In 10% of trials, the target appeared in the left box. Similarly, the target appeared in the right box in 10% of trials. Finally, in 20% of trials, no target appeared. When the target appeared, participants had to indicate they detected its presence by pressing a button as soon as the change was identified. The reaction times of these responses were analysed. For the purposes of analysis, a distinction was made not in terms of the absolute position of the target but its position relative to the cue. Thus, if the target appeared in the same box as the cue, this was referred to as a cued trial. When the target appeared in the box opposite the cue, this was referred to as an uncued trial. When comparing the reaction times of cued trials and uncued trials, a pattern of results linked closely to the time of the target presentation was identified. Participants showed faster reaction times for cued trials compared to uncued trials when the target appeared at 150, 200 or 250ms after the cue. When it occurred 350ms after the cue, participants responded at a comparable speed for both cued and uncued trials. However, if the target appeared 450 or 650ms after the cue, it was found that reaction times were faster for uncued trials compared to cued trials. When cued trials are faster than uncued trials, this is referred to as facilitation or a facilitatory cueing effect. When uncued trials are faster than cued trials, this is referred to as IOR or an inhibitory cueing effect.

1.2.2 IOR in Different Tasks

The observation of IOR is affected by the demands of the task employed. Traditionally, IOR was measured with what is now termed a detection task: that is, a task where participants simply have to respond upon detection of a target. In detection tasks, IOR appears robust and is consistently observed at SOAs above 300ms (see Chica, Martín-Arévalo, Botta, & Lupiáñez, 2014 for a review). However, this is not the case in more complex task types. The most common example is the discrimination task. In this task, at least two different targets are used, with each target being associated with a unique response. Thus, rather than a simple button press once a target appears, this task requires participants to give the correct response to a given target. It was originally believed that IOR was not present in discrimination tasks, as early studies did not find the effect (e.g. Klein & Pontefract, 1994). However, it has subsequently been established that IOR can be found in discrimination tasks, but occurs later than in detection tasks: for example, Lupiáñez et al. (1997) found that in a letter discrimination task, IOR did not emerge until 700ms after the appearance of the cue. However, IOR may not be generated in discrimination tasks if the discrimination is difficult. Lupiáñez, Milliken, Solano, Weaver, and Tipper (2001) did not find IOR at any of four SOAs (100ms, 400ms, 700ms, 1000ms) for a task that required identifying whether a letter presented for 100ms was an M or an N, while IOR was found at SOAs of 700ms and 1000ms if the task required instead identifying whether the letter was an X or an O. The latter task is an easier discrimination as these letters differ primarily on a single feature rather than a conjunction of features. The majority of studies have focused on shape discrimination, although the time course of IOR emerging at approximately 700ms after the cue onset seems consistent for colour discrimination tasks (Hu & Samuel, 2011; but see Chica, Lupiáñez, & Bartolomeo, 2006, where IOR was seen at 400ms after cue onset). Another task type of note is the localisation task, where participants have to identify the location of the target (typically either to the left or the right of the fixation point). Unlike discrimination tasks, localisation tasks show results comparable to detection tasks, with IOR found for SOAs of 300ms and greater (Gabay, Chica, Charras, Funes, & Henik, 2012; Maylor, 1985). IOR has also been investigated using a target-target paradigm. In this task, no cue is present. Instead, IOR is measured based on the location of the target in the previous trial: when the target appears at the same location as the target on the previous trial, this is a valid trial, while invalid trials consist of successive targets at different locations. Target-target paradigms generally produce results similar to the traditional cue-target design, although IOR is not observed in discrimination tasks using a target-target paradigm when consecutive targets are identical (Taylor & Donnelly, 2002). IOR has also been investigated using visual search tasks. In a visual search task, a probe is presented following a search task which participants must respond to. The probe can appear at either an empty location (equivalent to an uncued location in a spatial cueing paradigm) or at a location occupied by a distractor (equivalent to a cued location). In a task of this nature, IOR (that is, slower response to probes at distractor locations compared to empty locations) is typically observed provided the search is difficult enough to require the serial deployment of attention (Klein, 1988). IOR appears to be robust in tasks of this kind provided the display is maintained throughout the trial: if the display disappears between the search task and the probe presentation, IOR is not found (Müller & von Mühlenen, 2000; Takeda & Yagi, 2000). Unless specified otherwise, experiments investigating IOR discussed during this chapter employed detection tasks.

1.2.3 Perceptual and Motoric IOR

Posner and Cohen (1984) discussed IOR primarily as a perceptual effect. The cause suggested was the presence of a visual stimulus which had the consequence of delaying detection of subsequent targets. However, Posner et al. (1985) subsequently identified that IOR appeared to be linked to the oculomotor system. In this study, patients with progressive supranuclear palsy (PSP) were tested for IOR. PSP is a neurodegenerative disorder that includes among its primary characteristics an abnormality in orienting behaviour, which includes a reduced ability to make saccades in a vertical direction compared to a horizontal direction. Posner et al. (1985) found that when the cue and target appeared in a vertical arrangement, individuals with PSP did not show IOR, while IOR remained when the cue and target were in a horizontal arrangement. Taylor and Klein (2000) provided a comprehensive investigation using a total of 24 conditions. At the beginning of each trial, a central arrow or a peripheral luminance change was presented. This is referred to as signal 1 (S1). Depending on the condition, participants either had to provide no response, provide a manual response or a saccadic response to the location indicated. Next, a second signal was presented (S2). The possible conditions were identical to S1 excluding the no response condition. This study found a clear distinction between conditions requiring a saccadic response and those that did not. Specifically, if either S1 or S2 was responded to with a saccade, IOR was found for both central and peripheral S2s. In the remaining conditions, where no saccades were made, IOR was found exclusively for peripheral S2s, with no inhibition observed for central S2s. These studies provided the first evidence that rather than IOR being either a perceptual or motoric effect, that these forms are distinct and dissociable but not mutually exclusive effects. The saccadic form of IOR is also referred to as output IOR, while perceptual IOR is accordingly input IOR. Sumner, Nachev, Vora, Husain and Kennard (2004) provided clear evidence for a dissociation by taking advantage of constraints in the retinotectal pathway: specifically, short-wave sensitive cones (S cones), which contribute to colour perception, make no projections to the superior colliculus. As the superior colliculus is necessary for eye movements, using a colour change detectable only by S cones as a cue should not lead to any form of IOR that requires eye movements. Sumner et al. (2004) found that for saccadic responses, no IOR was generated in response to S cone cues. However, perceptual IOR remained intact as IOR was found for manual responses. This dissociation has further been supported by several lines of argument. For example, Smith et al. (2004, 2009) found the presence of perceptual IOR in an individual who was incapable of making eye movements, thus preventing oculomotor IOR. Hilchey et al. (2014) presented an experiment where participants had to respond to either peripheral or central targets. In one experiment, saccadic responses were made to all targets and both targets were equally likely. In a second experiment, saccadic responses were made only to central targets, which were significantly less frequent than peripheral targets (20% versus 80%). In the first experiment, IOR was indistinguishable between the two target types, while in the second experiment, IOR was found only for peripheral targets. Thus, even when the oculomotor system was active but in a reduced state of activation, only perceptual and not motoric IOR was observed

The distinction between perceptual and motoric IOR has also been supported at the neural level. Vivas, Humphreys and Fuentes (2003) found that individuals with parietal lesions showed perceptual IOR only for targets on the contralesional side. Bourgeois, Chica, Migliaccio, de Schotten and Bartolomeo (2012) expanded on the findings of Vivas et al. (2003) by considering whether individuals with neglect due to right parietal damage show impaired IOR in the saccadic domain as well. This study found that IOR was only impaired when manual responses were used, while saccadic responses led to IOR. Bourgeois, Chica, Valero-Cabré and Bartolomeo (2013a) subsequently explored the effect of TMS on the intraparietal sulcus (IPS) and temporoparietal junction (TPJ) in both saccadic and manual IOR. This study found that TMS for either site abolished perceptual but not saccadic IOR for right-sided targets. For left-sided targets, TMS on the TPJ did not affect either form of IOR, while TMS on the IPS affected both manual and saccadic IOR. Additionally, only when TMS was applied to the right IPS or TPJ was IOR affected, with both saccadic and manual IOR remaining intact if the left IPS or TPJ was stimulated (Bourgeois et al., 2013b).

To conclude this section, IOR can be considered to be either perceptual (input-based) or motoric (output-based). This was first demonstrated by a dissociation made by Taylor and Klein (2000), which found that central cues only produced IOR following a prior saccade. Subsequently, it was established that IOR could be found in the absence of an intact oculomotor system and conversely, could be found using cues undetectable to the eye movement system. Later behavioural evidence indicated even in circumstances when the eye movement system was not entirely suppressed, motoric IOR was prevented. Indeed, Hilchey et al. (2014) have recently argued that to avoid confusion, the term IOR should be used only to describe inhibitory effects that are generated by or observed in saccadic eye-movements to peripheral locations, and that the term "inhibitory cueing effect" (ICE) should be used to describe inhibitory effects generated by cueing paradigms in which eye-movements are not permitted. This convention will be adopted for the remainder of the thesis, with ICEs being the main focus of the present thesis. Where necessary to group IOR and ICEs together, the term "attentional inhibition" will be used. A distinction of greater importance to this thesis is that of location-based attentional inhibition and object-based attentional inhibition. These will now be discussed in turn.

1.2.4 Location-based Attentional Inhibition

Posner and Cohen (1984) proposed that attentional inhibition was a mechanism of spatial attention that reflected a bias from attending to the spatial position of a peripheral stimulus. Beyond simply identifying the effect, Posner and Cohen (1984) reported additional experiments which further characterised location-based attentional inhibition. When longer SOAs of 600ms and 1450ms were used, ICEs were found at both SOAs. When a total of five locations were used for the target (one central and two either side of the central location, all equally distant from the central location), ICEs were found only to the cued location and not nearby locations on either the same or different side. Secondly, when the original experiment was replicated with an additional double-cueing condition (i.e. both non-central boxes were cued), the 500ms SOA showed slowed reaction times compared to an uncued trial in a single-cue condition, suggesting ICEs persisted in this condition, although facilitation was not observed at the short SOAs. Posner and Cohen (1984) also experimented with modifications of the cue. When the cue was a dimming rather than a brightening, an ICE was still found. However, when the cue was changed from a peripheral one (a change in the state of a box either side of the central point) to a central cue (an arrow appearing at the central location pointing at one of the two peripheral boxes), ICEs were not found at any of three SOAs (450ms, 950ms, 1250ms), although facilitation was present at the 450ms SOA. ICEs also persisted if a brightening at the central box was inserted between the appearance of the cue and the target. Finally, it was considered whether IOR existed in retinal or spatial coordinates. Five locations were used, one central and two either side of the central location, with one location on both sides below the central location and the other location in line with the central location. Firstly, a digit appeared in one of the lower locations, to which participants made an eye movement. Then, a second digit appeared in the location directly above this and participants made a second eye movement to this location. The central location was then illuminated and a third eye movement was made to this point. A target then appeared in one of the three upper locations. If IOR was strictly retinotopic, IOR would not be observed at the location of the second digit as it appeared only at the spatial location and not the retinal location. However, Posner and Cohen (1984) found IOR remained in this task, supporting the idea that IOR is encoded in spatiotopic coordinates. Based on these experiments, Posner and Cohen (1984) concluded that the facilitation and inhibition effects were distinct. It was proposed that the facilitatory effect was tied to orienting and served to improve the efficiency of detecting targets, while the inhibitory effect was in response to a peripheral stimulus and existed to maximise sampling of the environment by favouring unexamined areas.

Attentional inhibition has been further characterised in subsequent work. With regard to the time course, it has been found that ICEs persist beyond the 1450ms limit suggested by Posner and Cohen (1984). Samuel and Kat (2003) present three experiments that examined ICEs at SOAs ranging from 600ms to 4200ms in a detection task. In experiments 1 and 2, significant ICEs were found consistently until an SOA of 3200ms, which produced an ICE of 14ms which was not statistically significant (the only other exception was that no ICE was found at the 2000ms SOA in experiment 2). However, these experiments used a display of considerably greater complexity than a traditional spatial cueing task, using a total of eight locations (grey circles). Experiment 3 addressed this potential confound by using two locations either side of a fixation cross. In this experiment, ICEs were significant at the 1700ms SOA, but ceased being statistically significant at SOAs of 2200ms and beyond. This suggests that the duration of ICEs has an upper limit of approximately 3 seconds, with it appearing reliably for the first 2 seconds in typical spatial cueing tasks.

The exact location of the space inhibited has also been explored. Maylor and Hockey (1985) expanded on Posner and Cohen (1984) by using seven LEDs located on each side of a fixation LED for a total of 14 target positions. However, only two of these 14 positions were used as a cue (the central LED on the left side and the right side respectively). All target responses on the same side as the cue were significantly slower than all target responses on the opposite side of the cue. Additionally, the slowest response was when the target and cue occupied the same location, with responses speeding up as the distance between the cue and target increased in a mostly linear relationship. This was the first demonstration that ICEs are not restricted to the exact location of the cue. Subsequent work has proposed that ICEs follow a spatial gradient. For example, Bennett and Pratt (2001) used a 21 x 21 grid (although this was not visible to the participants) to make their displays. Cues appeared at one of four locations (the centre of each visual field quadrant), but targets could appear in any of the 441 squares on the grid. They found responses were slowest for targets in the cued quadrant, with ICEs being found in the remaining uncued quadrants and largest in the diagonally opposite quadrant. Klein, Christie and Morris (2005) investigated the effect of multiple cues at differing locations and found the magnitude of the ICE increased based on the target's distance from the net vector of the cues (i.e. the average cue position).

ICEs are also affected by the predictive power of the cue: that is, the probability of a target appearing at the same location as the cue. If the cue indicates an increased chance of the target appearing at that location, ICEs are not observed (Berger, Henik, & Rafal, 2005; Chica et al., 2006; Remington & Pierce, 1984). Thus, the use of a non-predictive cue appears to be a prerequisite of ICEs with one exception: if the cue is counter-predictive (that is, the target is more likely to appear at the opposite location to the cue), then ICEs are found in detection, localisation and discrimination tasks (Chica & Lupiáñez, 2009; Chica et al., 2006). Indeed, Posner and Cohen (1984) inadvertently supported this as when they used an arrow cue instead of a peripheral cue they also manipulated the predictive power of the cue, changing it from being correct 10% of the time to 60% of the time. Thus, it is unclear whether it was this manipulation, rather than the different cue employed, that led to the lack of ICEs in this experiment.

Another manipulation of the spatial cueing paradigm is in the presence or absence of a cue-back. A cue-back is an event that occurs between the cue and the target with the intent of “returning” a participant’s attention to the fixation point. Typically the cue-back used is of the same format as the cue (such as a brightening). Martín-Arévalo et al. (2013) specifically investigated the effect of a cue-back and found it to have relatively little effect on ICEs in detection tasks. The primary effect found was an interaction with target duration: the cue-back did not affect ICEs for short target durations (50ms), but the magnitude of the ICEs did increase with the presence of a cue-back for long target durations (in this case, when the target was displayed until the end of the trial). Martín-Arévalo et al. (2013) did find cue-backs to have a dramatic effect for discrimination tasks: when a cue-back was present, significant ICEs were found at SOAs of 300ms and 700ms, while significant facilitation was found when the cue-back was absent.

In summary, location-based ICEs have been explored extensively across a variety of tasks since first reported by Berlucchi et al. (1981) and Cohen (1981). Important characteristics of location-based ICEs have been delineated, including its time course and its spatial gradient. Additionally, conditions for generating ICEs have been explored, which suggest that ICEs need a non-predictive cue to be produced, but with this exception, location-based ICEs appear robust to a variety of manipulations.

1.2.5 Object-based Attentional Inhibition

Traditionally, attentional inhibition was considered principally in the context of spatial attention. In the spatial cueing paradigm, emphasis is placed on the location that is being responded to rather than the stimulus in question. This appears supported by the finding that IOR exists in spatiotopic coordinates (Posner & Cohen, 1984). However, if attentional inhibition is represented in a purely environmental way, it is not clear how it would be of functional use in displays that contain moving objects. For example, an object of interest could move to an inhibited location and so delay its detection, or an examined object could move to an uncued location and be inappropriately re-examined. Tipper et al. (1991) used a moving variant of the spatial cueing paradigm to investigate whether ICEs could be encoded in terms of object coordinates. Two filled squares were presented either side of a fixation square as in the spatial cueing paradigm. One of the squares was cued by having a larger open square appear around it before disappearing. At this point, the peripheral squares began to move clockwise. Once movement had completed, the squares ceased moving and a target in the form of an empty square replaced one of the filled squares. Participants had to detect this target with a keypress. The total SOA was either 430ms or 695ms. The final location of the squares was contingent on the SOA: at the shorter SOA, the final locations of the squares were directly above and below the fixation point (90° in polar coordinates). At the longer SOA, the final location of the square was at the starting location of the opposite square (180° in polar coordinates). If ICEs exist only spatially, then ICEs would only be expected at the longer SOA and with a reversal of the traditional relationship (as the cued square would now be at the uncued location and vice-versa, participants would show speeded responses to the cued square and slowed responses to the uncued square). However, Tipper et al. (1991) instead found evidence for object-based ICEs. At both SOAs, participants were significantly faster to respond to a target replacing the uncued square compared to the cued square. A follow-up experiment that replaced the 430ms SOA with an SOA of 959ms (equating to 270° of motion in polar coordinates) again found significant object-based ICEs at both SOAs. This finding suggests not only that ICEs can apply to objects, but also that ICEs may not always operate spatially: if ICEs operated simultaneously at the location and object level, then at the longer SOA it would be expected for the two ICEs to oppose each other, leading to comparable responses to the cued and uncued squares.

As with location-based attentional inhibition, subsequent work has aimed to expand on Tipper et al.'s (1991) findings to characterise object-based attentional inhibition. Jordan and Tipper (1999) used a design that comprised two rectangles surrounding a central cross. The rectangles were presented at an orientation of 45° from vertical so that one end of each rectangle was directly above or below the fixation cross, while the opposite end was directly to the left or right of the fixation cross. A key aspect of the design was that rather than cueing one of the rectangles, the cue (a white square) appeared at one of two possible locations in each rectangle, for a total of four cue positions: the end located above/below the fixation point and the end located left/right of the fixation point. Similarly, the target (a black square) could appear at any of these four positions in each trial. Reaction times were significantly slower to targets that appeared not only at the same location, but also for targets within the same rectangle as the cue, compared to targets appearing in the uncued rectangle. This is despite the fact that half of the targets in the uncued rectangle were equidistant from targets at the uncued part of a cued triangle: given that ICEs appear to follow a spatial gradient (Maylor & Hockey, 1985), a purely spatial conception of ICEs would expect comparable inhibition for these locations. Thus, when part of an object is cued, the rest of the object is inhibited, but inhibition does not appear to spread beyond the boundaries of the cued object. Leek, Reppa and Tipper (2003) expanded on this finding by using objects with two parts: a smaller rectangle attached to a larger rectangle demarcated by a line. In this case, the effect of the cue and target being at the same location, a different location on the same part and a different location on a different part of the object could be compared. Although significant ICEs were present for all three conditions, the cueing effect was significantly greater when the target appeared in a different part of the same object as the cue compared to the same part of the object. If the two object parts were not separated by a boundary, the effect was the same for both parts. Reppa and Leek (2006) investigated different types of boundaries separating parts of objects. In one condition, the boundaries were contained wholly within the rectangles (internally segmented). In another condition, the boundary was represented by superimposing a second rectangle on top of the first rectangle (externally segmented). In addition to replicating Leek et al.'s (2003) finding in the internally segmented condition that ICEs were greater for targets in a different part compared to the same part, no significant difference in the magnitude of ICEs was found for same and different parts in the externally segmented condition. This study establishes the importance of representations of distinct objects in object-based ICEs. Additionally, this suggests that object-based ICEs can spread across partially occluded objects.

In addition to the internal structure of objects, the contours and forms of objects also appears to influence object-based IOR. In addition to identifying the spread of object-based IOR across the surface of a rectangle, Jordan and Tipper (1999) also compared the magnitude of object-based ICEs for three types of rectangles. In addition to rectangles defined simply by outline, Jordan and Tipper (1999) also presented illusory rectangles in the form of a Kanizsa figure: in this case, the rectangle has no outline and is defined relative to two incomplete black circles. Due to the empty space of part of the circles, they appear to be occluded by a white rectangle despite the fact the "rectangle" is in fact empty space. A third condition combined these elements by adding an outline to the rectangle of the Kanizsa figure. For a rectangle defined solely as a Kanizsa figure, object-based ICEs were not significantly observed, in contrast to the outline and combined conditions which did produce significant object-based ICEs.

The generation of object-based ICEs appears to be dependent on the spatiotemporal continuity of the objects. For example, Tipper, Weaver, Jerreat and Burak (1994) used a display with four squares, two of which remained in place throughout a trial and two of which moved. In one condition, the static squares were smaller than the moving squares, while in another condition the moving squares were larger. At the start of each trial, the moving squares would move to the location of the static squares. Once they shared a location, one of the two locations the squares occupied was cued. Due to the difference in the size of the squares, the moving square could be totally occluded or partially occluded by the static square at the time of cueing. ICEs were only generated for moving squares if the moving square could be partially seen during the cueing phase. Tas, Dodd and Hollingworth (2012) examined the effect of changing an object during motion to investigate if object-based ICEs were still present. Specifically, they employed two differently coloured circles located above and below a fixation point. In a trial, the circles would move rotationally until they were located to the left and right of the fixation point. However, just before the motion ended, the circles would change colour. If the objects changed to new colours, then object-based ICEs were unaffected. However, if the circles swapped colours, no object-based ICEs was found. Additionally, if the circles disappeared and then reappeared at the new locations instead of being seen to move there, no object-based ICEs were present. Visual search tasks also provide evidence for the necessity of object continuity in generating object-based ICEs. Takeda and Yagi (2000) found ICEs were only observed if the search array remained on the display during the probe task, with no cueing effect if the search array was removed. Taking these findings together, it is clear that object-based ICEs require object continuity and unambiguous cueing to be generated.

In contrast to location-based ICEs, the presence of a cue-back appears to be important to generate object-based ICEs. Ro and Rafal (1999) conducted six experiments investigating cueing effects for objects. In both experiments when a cue-back was absent, object-based ICEs were not found, with object-based facilitation being present instead. Object-based ICEs were also absent when the cue-back coincided with the beginning of the objects moving. Ro and Rafal (1999) speculate that participants track moving objects and stay oriented to them unless another stimulus leads to a shift in attention. This benefit of orienting may be sufficient to mask object-based ICEs.

Reviewing these findings, it is clear that ICEs can apply specifically to objects independently of spatial locations. In objects that move, ICEs can be found at the new location of the object even in the absence of location-based ICEs. In static displays, the presence of objects affects the spatial gradient of ICEs, with cueing effects restricted to the boundaries relative to the cue. For example, ICEs are not found for spatial locations outside the cued object, including for locations that appear to be part of distinct objects. Similarly, for objects with multiple parts, ICEs are weaker for uncued parts of cued objects compared to cued parts. The generation of object-based ICEs appears contingent on spatiotemporal continuity of objects, as it is not found for objects hidden in a cued location, for objects that change or disappear and reappear or on the removal of objects. Additionally, cue-backs also appear necessary for the generation of object-based ICEs.

1.2.6 Social IOR

Another type of IOR that has been found is a delay in responses to locations that have been previously responded to by a different person. This effect has been termed social IOR (Skarratt, Cole, & Kingstone, 2010). Social IOR was first demonstrated by Welsh et al. (2005). The paradigm employed consisted of two participants sat opposite to each other, with each participant having two response boxes, positioned on their left and right respectively. The stimulus to be detected by participants was the brightening of a light on one of the response boxes, which was to be responded to by pressing a button on the respective response box. The target was first displayed to one participant and following their response, the target was then displayed to the other participant. Thus, this paradigm resembles a target-target paradigm in the measurement of traditional IOR. Importantly, the different positions of the possible responses meant that the second responder knew which location the first participant responded to. An IOR effect emerged in that participants were significantly slower to respond to the location responded to by the other participant compared to the unresponded location. However, participants could also see the target that the other participant responded to: thus, it is possible that this served as a cue and was the actual source of the IOR rather than the observed response. Thus, a second experiment required participants to wear goggles which could become opaque. On half of the trials, the goggles became opaque during the presentation of the target to the other participant, and then returned to transparent so that they could see where the participant responded. On the remaining half of trials, the goggles did not change, replicating the first experiment. This factor had no effect on the IOR observed. Thus, even in the absence of a peripheral target, seeing a participant respond in a particular direction led to IOR for subsequent responses.

More recent research has further characterised the social IOR effect. Welsh et al. (2007) further reduced the information available to participants in a series of experiments. In Experiment 1, a condition where participants could only see the end of the other participant's response, rather than the motion leading to that response was used. Significant IOR remained in this experiment. In Experiment 2A, participants could only see the beginning of the response, which provided likely information as to the direction of response but no event that could potentially capture attention at the location was present. In spite of this absence, social IOR remained intact. Experiment 2B examined the social component of social IOR by using the projection of a white box rather than a second person: this white box indicated the likely direction of response by moving slightly towards the response location (comparable to Experiment 2A). In this condition, IOR was observed for participant's own responses, but was not for the white box responses. Thus, social IOR could be observed even based on the prediction of a person's response rather than directly seeing the response. However, an alternative representation in the absence of an actual second participant did not generate the same effect. Skarratt et al. (2010) supported the necessity of a second person in the generation of IOR by using an animated projection of a person taking part in the task alongside an actual participant. IOR, but not social IOR, was observed in this experiment. Skarratt et al. (2010) also found that even if a second responder only saw the eye gaze of the first participant rather than their response, this was still sufficient to generate social IOR. Furthermore, social IOR can be found even when the two participants carry out different actions: Cole, Skarratt, & Billing (2012) used a variant of the social IOR task but additionally, participants responded in one of two ways, with either a pointing motion or a gripping motion. Regardless of whether the action the second responder matched or did not match the action of the first responder, significant social IOR was found. However, the differing responses in this experiment were similar, as both consisted of a reaching motion to a specific object. Manzone, Cole, Skarratt and Welsh (2016) heightened the distinction by separating participants into aimers (who had to reach and press one of two buttons located on the left and right sides of their desk) and key pressers (who used a simple keyboard and pressed Z for left targets and 3 on the number pad for right targets). As in previous experiments, a partial vision condition was present in addition to a full vision condition, with the former being distinguished by having aimers only seeing the end of the key press made by key pressers and key pressers only seeing the beginning of the aimer's reaching motion. Social IOR was found regardless of whether the responses matched or not, with the exception of the partial vision condition, which led to an observation of social IOR only for matching responses.

In summary, social IOR is another manifestation of IOR whereby a previous response by one actor leads to delayed responses to that same location by a second individual. This effect remains even in the absence of direct visual information confirming the location of the first response and when actions between the responders differ (unless both visual information is reduced and the response types differ considerably; Manzone et al., 2016). The next section will consider what neural substrates have been implicated in the generation of IOR, with reference to the specific types of IOR discussed.

1.3 Neural Substrates of Attentional Inhibition

The midbrain was implicated as being important for the generation of attentional inhibition in the earliest work to address the subject. For example, Posner et al. (1985) examined ICEs in patients with PSP, which causes degeneration of the midbrain leading to a slowing of vertical saccades among other effects. This study found that ICEs were not present in a vertical form of the spatial cueing task, while it remained present for the standard horizontal version. Subsequent work has identified the superior colliculus in particular as mediating attentional inhibition. This has been supported by several lines of evidence. As there are an unequal number of pathways from the retina to the superior colliculus, the superior colliculus receives more input from the temporal hemifield than the nasal hemifield. If the superior colliculus mediates attentional inhibition, this asymmetry would predict that attentional inhibition differences can be found for these different hemifields. Rafal, Calabresi, Brennan and Sciolto (1989) found this exact pattern when using a spatial cueing task presented monocularly: IOR for targets presented to the temporal hemifield was significantly greater than for targets presented nasally. However, it is unclear whether this difference would exist for ICEs which presumably are less reliant on the oculomotor system.

Visual processing is conducted primarily through the geniculostriate visual pathway. However, some processing occurs along the retinotectal pathway, which includes the superior colliculus. Thus, an observation of IOR in the absence of geniculate visual processing would give credence to the superior colliculus as the source of IOR. Danziger, Fendrich and Rafal (1997) examined two hemianopic patients to determine if a cue displayed to a patient's blind hemifield would still lead to the generation of ICEs. It was necessary to modify the traditional spatial cueing paradigm for this experiment: participants fixated on the centre of the screen, with two vertical variants of a spatial cueing display either side of this central point. That is, on both the left and right of the screen were displays consisting of two placeholder squares located above and below respectively a fixation point. One of the four squares was cued with the onset of a smaller square within the placeholder square. An arrow then appeared at the centre of the screen which instructed participants to shift their gaze to the fixation point of one of the two displays. Once this was done, the target (a white square) appeared in one of the two placeholder squares of the display being looked at. This manipulation was necessary so that the cue could appear in either the sighted or unsighted hemifield while having the target appear consistently in the participant's sighted hemifield. It was found that one of the two patients showed ICEs both for cues that appeared in their blind and sighted hemifield, while the other participant only showed ICEs for cues in their sighted hemifield. While it is unclear why these participants performed differently, this experiment nonetheless demonstrated that ICEs could be generated in the absence of the geniculate visual pathway. This argument was also supported in healthy subjects by Simion, Valenza, Umiltà and Dalla Barba (1995). In this study, IOR was examined in newborns, who see primarily using retinotectal processing compared to the geniculostriate pathway in adult vision (Johnson, 1994). Simion et al. (1995) found significant IOR in newborns, supporting the notion that IOR can exist without geniculostriate processing. However, as reaction times were not measured, IOR was measured in terms of the number of times a target in a cued location was oriented to compared to an uncued location, a measure considerably different from a typical IOR study.

Sapir, Soroker, Berger and Henik (1999) provide direct evidence by testing for ICEs in a patient with a unilateral lesion specifically affecting the right superior colliculus. This allows a comparison between the intact left superior colliculus (which receives signals from the nasal hemifield of the left eye and temporal hemifield of the right eye) and the damaged right superior colliculus (corresponding to the nasal hemifield of the right eye and temporal hemifield of the left eye). By using a spatial cueing task that was viewed monocularly, a clear dissociation was found, where ICEs were only present for cues presented to the regions linked to the intact superior colliculus.

The research discussed above suggests that the superior colliculus is a key mediator and is possibly necessary to generate location-based attentional inhibition. However, other neural substrates have also been implicated in the generation of location-based attentional inhibition. Dorris, Klein, Everling and Munoz (2002) recorded neural activity in rhesus macaques during an IOR task. Despite the observation of IOR in these macaques, the measured neurons in the superior colliculus were more active following presentation to the cued location compared to an uncued location. Similarly, direct electrical stimulation of these neurons led to speeded responses to cued locations relative to uncued locations. Based on these results, Dorris et al. (2002) propose that the superior colliculus is not the site of inhibition, but that this occurs "upstream" in a region of the posterior parietal cortex. This is consistent with Robinson, Bowman and Kertzman (1995), a study that found some neurons in parietal cortex showed weaker responses to targets that appeared at a cued location compared to an uncued location. This pattern of results was found despite the fact that the task used by Robinson et al. (1995) did not demonstrate IOR, which is likely attributable to the fact the cue was valid for 80% of trials (and therefore highly predictive of the target location). Neuroimaging data with human adults supported the superior colliculus' role as being a key mediator, but not the origin of inhibitory signals (Anderson & Rees, 2011).

Support for the role of parietal areas in ICEs has also been found from studies of neglect patients. Bartolomeo, Chokron and Siéroff (1999) found that patients who exhibited left neglect following right hemisphere damage showed significant facilitation instead of ICEs for targets on the right side, while ICEs was observed for targets on the left side. This was observed both in a target-target paradigm and a cue-target paradigm (Bartolomeo, Siéroff, Decaix, & Chokron, 2001). However, a distinct group of patients with right hemisphere damage (including lesions in the parietal lobe) who did not show neglect did show ICEs for both ipsilesional and contralesional targets, suggesting that these results may be a specific sequela of neglect rather than related to the function of the parietal cortex. This was challenged by a study from Vivas et al. (2003) who investigated ICEs in four patients with inferior parietal lesions. As with the neglect patients in Bartolomeo et al. (1999), IOR was only found for contralesional targets in these individuals. Thus, damage to parietal cortex can lead to a lack of ICEs for the same visual field as the lesion even in the absence of neglect. Chica, Bartolomeo and Valero-Cabré (2011) supported this in healthy participants using transcranial magnetic stimulation (TMS). When a pulse was applied to either the right intraparietal sulcus (IPS) or the right temporoparietal junction (TPJ), facilitation instead of ICEs was observed for contralateral cues. However, no effect was observed on ipsilateral cues.

Areas of the frontal lobe have also been associated with attentional inhibition. Lepsien and Pollmann (2002) found in an fMRI study that ICEs were associated with activation in both the right frontal eye field (FEF) and right supplementary eye field (SEF) regions. Further support for the role of the FEF comes from Ro, Farnè and Chang (2003). In this study, applying TMS to the FEF 600ms after the presentation of the cue (and 150ms before the target) led to an abolition of ICEs for ipsilateral targets. Ro et al. (2003) suggest that the mechanism that leads to ICEs is a saccade program in the opposite direction of the cue generated by the FEF, a mechanism disrupted by TMS in their study.

The studies reviewed so far have focused on the neural substrates of space-based attentional inhibition. However, it is also important to consider the distinction between space-based and object-based attentional inhibition. In particular, the neural basis for object-based attentional inhibition has been proposed to differ compared to location-based attentional inhibition. Tipper et al. (1997) presented specific evidence for this by examining ICEs in two individuals who had undergone a corpus callosotomy. This procedure severs the corpus callosum, the function of which is to link comparable regions of the two cortical hemispheres. A paradigm comparable to that of Tipper et al. (1991) was employed with the use of two moving squares. Importantly, a distinction was made between trials where both squares remained in the same hemifield and trials where the squares crossed hemifields. This was achieved by having the starting position of each object occur at 45° (in polar coordinates) either above or below the fixation point. This allowed a separation where depending on the movement being clockwise or anticlockwise, the squares could move 90° (polar coordinates) and then be located in either the same or different hemifields after movement. The hemifield separation is key as once the object moves to a different hemifield, it is inaccessible for cortical processing without a functioning corpus callosum. In contrast, subcortical areas such as the superior colliculus are unaffected by the presence or absence of the corpus callosum. Tipper et al. (1997) found that in those with corpus callosotomy, ICEs disappeared once objects changed hemifields. This indicates that cortical involvement is necessary for object-based ICEs. It also appears to be the case that object-based IOR declines with age while location-based ICEs appears resistant. McCrae and Abrams (2001) found that older adults (mean age = 74 years) showed location-based ICEs in a static display, but did not show object-based ICEs when a dynamic display was used, while the young adult group (mean age = 19 years) showed both location-based ICEs in static displays and object-based ICEs in dynamic displays. The basal ganglia have also been indicated in relation to location-based IOR but not object-based IOR. Possin, Filoteo, Song and Salmon (2009) investigated ICEs in individuals with Parkinson's disease, a disorder which primarily affects the basal ganglia. It was found that location-based ICEs was not present in these participants, while object-based ICEs remained intact. Vivas, Humphreys and Fuentes (2008) investigated whether individuals with parietal damage (specifically, the inferior parietal lobule) also showed reduced object-based ICEs, following on from Vivas et al.'s (2003) observation that location-based ICEs were affected in these individuals. In the four patients with parietal lesions studied, Vivas et al. (2008) found significant object-based ICEs, although only when objects moved from the contralesional hemifield to the ipsilesional hemifield, with no IOR found when this movement was reversed. Object-based ICEs have also been found in DF, an individual with apperceptive visual agnosia due to damage to the lateral occipital gyrus (Smith, Ball, Swalwell, & Schenk, 2016). It seems difficult to reconcile the presence of object-based ICEs in an individual that cannot perceive objects. This may suggest that object-based ICEs are generated mostly by the spatiotemporal continuity of objects rather than their precise identity. In summary, although it is unclear which regions precisely are necessary for object-based ICEs, research broadly supports the notion that cortical processing is necessary due to its absence in those with corpus callosotomies and its decline with aging. More specifically, it appears that parietal regions are required, consistent with Vivas et al.’s (2008) observation that parietal lesions prevent object-based ICEs for objects cued in the ipsilesional hemifield. In contrast, the lateral occipital gyrus is not necessary to generate object-based ICEs (Smith et al., 2016).

Seidel Malkinson and Bartolomeo (2017) propose a model that aims to account for the differing results in ICEs (perceptual) and IOR (saccadic). According to their model, the right IPS is the source of a priority map which is necessary for the generation of attentional inhibition: the left IPS is only activated for right-sided targets and due to hemispheric asymmetry produces weaker output than the right IPS. Accordingly, TMS applied to the right but not the left IPS disrupts attentional inhibition. To explain the disruption of ICEs but not IOR due to TMS at the right IPS, a similar asymmetry is proposed for manual and saccadic responses, with the IPS mediating saccadic responses through the FEFs and manual responses through the premotor and motor cortices. Specifically, the FEFs are linked directly to the regions responsible for saccades, while the connections between the IPS and motor regions are more indirect. The fact this connection is more indirect means that activation along this pathway must be sustained for longer for attentional inhibition to occur, thus ICEs are easier to disrupt than IOR. Additionally, the right TPJ (and not the left) is specifically indicated to act as a hub that connects visual and attentional areas relevant to attentional inhibition. Thus, TMS stimulation to this area can interfere with attentional inhibition, as the TPJ is linked to the FEFs which process stimulus saliency. However, this is not sufficient to abolish ICEs because the FEFs also produce a priority map of visual information based on its direct connection to primary visual cortex. This allows most forms of attentional inhibition to remain intact. However, for right-sided targets, only the left FEF is activated. As interhemispheric transfer is weaker when travelling from the left hemisphere to the right hemisphere (Koch et al., 2011; Marzi, 2010), this activation alone without the TPJ is a weak signal. This is sufficient to disrupt ICEs (perceptual) but not IOR (saccadic).

Although this model accounts for the results of studies such as Ro et al. (2003) and Bourgeois et al. (2013a, 2013b) and provides predictions on the relative importance of left and right-sided regions such as the IPS, FEFs and TPJ in attentional inhibition, the model has not been specifically tested by any study to date. It is also unclear whether the frontoparietal network proposed in this model can activate the object and motion representations that appear necessary for object-based attentional inhibition. On first viewing, the model appears broadly consistent with the findings of Vivas et al. (2008), which found that damage to the inferior parietal lobule led to no object-based ICEs for contralesional targets, with object-based ICEs remaining for ipsilesional targets. Given that the majority of patients had their lesion in the left hemisphere, this corresponds to ICEs being abolished specifically for right-sided targets, consistent with Seidel Malkinson and Bartolomeo's (2017) model. This interpretation is complicated by two observations. Firstly, the patients studied by Vivas et al. (2008) varied in the location of their lesion, with the lesion being in the left hemisphere for three participants and the right hemisphere for the remaining participant. This is important not only because Seidel Malkinson and Bartolomeo (2017) place great significance on regions in specific hemispheres, but also because Vivas et al. (2008) discuss their findings based on the target's relative and not absolute location: unfortunately, no indication is provided whether the individual with the right hemisphere lesion differed in performance from those with left hemisphere lesions or to what extent the results would differ without their inclusion. Secondly, the lesions as described do not correspond exactly to the regions implicated by Seidel Malkinson and Bartolomeo (2017), although they likely correspond to the TPJ and possibly the IPS discussed by the model. Nonetheless, it is clear that these patients only had unilateral lesions and specifically left parietal lesions in three of the four patients. Given that Seidel Malkinson and Bartolomeo (2017) argue that only a lesion or TMS stimulation in the right IPS and/or TPJ would disrupt ICEs, the fact that these patients showed abolished object-based ICEs suggests that at the least this model in its current form does not account for object-based ICEs.

In contrast, the neural basis of social IOR has received little empirical study. Welsh et al. (2005; 2007) argued that the mirror neuron system may generate social IOR based on evidence that the observation of a motor response activates similar cortical mechanisms as when a motor response is performed. Although there is no direct empirical evidence for mirror neurons generating social IOR, it is consistent with the observation that actions that are very different do not lead to social IOR in limited viewing conditions (Manzone et al., 2016). However, a specific investigation of the neural substrates of social IOR has not been published to date.

In summary, a variety of regions have been implicated in the production of attentional inhibition. The superior colliculus appears to be an essential mediator due to the fact that attentional inhibition can be observed in the absence of geniculostriate visual processing. However, the true source of attentional inhibition has been more recently implicated in frontoparietal areas, with Seidel Malkinson and Bartolomeo (2017) most recently presenting a specific neurological account of attentional inhibition. Although this model can explain differences in ICEs (perceptual) and IOR (saccadic), its current form does not appear to account for object-based ICEs as it is absent in individuals with parietal damage that would be expected to show ICEs (Vivas et al., 2008). It is possible that an addition to this model could allow for object-based attentional inhibition to be explained. However, while Vivas et al. (2008) suggests that the inferior parietal lobule is necessary for consistent object-based ICEs, it is otherwise unknown what cortical structures are required for object-based ICEs. Finally, the mirror neuron system has been proposed to account for social IOR (Welsh et al., 2005; 2007), but this has yet to be investigated empirically.

1.4 Theories of IOR

1.4.1 Reorienting Hypothesis

Posner et al. (1985) presented what is considered the traditional or canonical account for attentional inhibition; an account subsequently termed the reorienting hypothesis (Berlucchi, 2006; Lupiáñez, Klein, & Bartolomeo, 2006). The principal idea of this account is that cueing effects, both facilitatory and inhibitory, are a direct consequence of orienting. According to this account, the presence of a peripheral cue causes orienting to the cue's location for several hundred milliseconds. If a target appears at this location within this time, it is detected more quickly than a target at a different location because attention is located there. This is why the initial presence of a cue leads to facilitation. However, after this initial period where attention is oriented to the cue, attention is subsequently withdrawn. In addition to the withdrawal of attention, it is proposed that an inhibitory mechanism is applied to the previously oriented location. This mechanism makes it more difficult to attend to the previous location. In accordance with this notion, Posner et al. (1985) defined the latter effect as IOR.

Early research into attentional inhibition appeared consistent with the reorienting hypothesis. Maylor (1985) found that a peripheral cue did not lead to IOR if participants were required to make a saccade that competed with orienting to the cue. Similarly, no ICEs were found if two locations were cued simultaneously, with Maylor (1985) suggesting that this was because the locations competed so that neither could be oriented to (but see Posner & Cohen, 1984, for a contrary result). Posner and Cohen (1984) found that ICEs were not present if the cue was predictive of the target location. This appears consistent with the reorienting hypothesis as it seems likely that attention would be maintained at this location due to its predictive nature.

However, despite the appealing simplicity of the reorienting hypothesis, a wide range of experimental evidence has accumulated which are inconsistent with this theory. In the reorienting hypothesis, facilitation and inhibition are necessarily coupled, as they are a consequence of orienting to and then withdrawing attention from a location. Thus, the reorienting hypothesis would predict that ICEs would only be found in the presence of a preceding facilitatory effect. However, the effects have been dissociated. In fact, this was first shown by Posner and Cohen (1984): in their double-cueing experiment, ICEs were present in the absence of facilitation. The finding of ICEs without facilitation has been replicated by a variety of studies (e.g. Lambert & Hockey, 1991; Smith et al., 2004; Tassinari, Aglioti, Chelazzi, Peru, & Berlucchi, 1994) and indeed, despite what is often assumed, initial facilitation is often not observed in detection tasks despite the robustness of ICEs (see Chica et al., 2014 for a review).

A second line of evidence comes from the fact that ICEs can be observed even in the absence of exogenous orienting. In an individual that cannot make eye movements, Smith et al. (2004; 2009) found the presence of both location-based and object-based ICEs despite there being no exogenous attentional orienting, an effect replicated by Gabay, Henik and Gradstein (2010) in patients with

Duane Syndrome. Similarly, the use of eye abduction (having participants fixate a point near the limit of their oculomotor range, which prevents making eye movements beyond this range) has been used to show a similar pattern of results in healthy participants (Smith, Rorden, & Schenk, 2012). This manipulation prevented exogenous orienting at locations that could not be the goal of a saccadic eye-movement and accordingly, no facilitation was observed. However, ICEs remained intact. Additionally, ICEs can be observed even when characteristics of the cue are such that exogenous orienting could not have taken place. This includes Danziger et al.'s (1997) observation of ICEs in a hemianope for cues in their blinded hemifield, as well as studies that found ICEs despite the use of subliminal or near-invisible cues (Ivanoff & Klein, 2003; Mele, Savazzi, Marzi, & Berlucchi, 2008; Mulckhuyse et al., 2007; Smith & Schenk, 2010). Finally, ICEs can be observed for central targets even when this region is continuously fixated, a further indication that the movement of attention is unnecessary for ICEs (Possamai, 1986).

Just as exogenous orienting is seen as necessary for ICEs in the reorienting hypothesis, this explanation suggests that endogenous orienting should prevent the generation of IOR. However, ICEs can be found at endogenously attended locations. Berger et al. (2005) used a spatial cueing design that included both a central (arrow) and peripheral (thickening of the border representing a potential target location) cue in each trial. Additionally, the central cue was predictive of target location while the peripheral cue was not. These cues exhibited the typical effects expected of them and did not interact with the other cue type: the predictive central cue led to facilitation at its location regardless of the peripheral cue, while the slowed response to the previously peripherally cued location compared to the uncued location characteristic of ICEs was observed even if that location was attended endogenously.

While the reorienting hypothesis appears unsuited to explain all cases of attentional inhibition, the reorienting hypothesis can accommodate a range of findings relating specifically to facilitation. A common finding is that facilitation is found when predictive cues are used, consistent with the notion that orienting leads to facilitation (Berger et al., 2005; Chica et al., 2006; Remington & Pierce, 1984). The ability of a cue-back to manipulate orienting has also provided evidence for facilitation being linked to orienting. Martin-Arevalo et al. (2013) found in a discrimination task that facilitation was observed at 300ms and 700ms SOAs, but only if there was no cue-back, with no cueing effects observed when a cue-back was employed. This suggests that the facilitation observed was due to attention being oriented to the cued location, as presumably the cue-back moved attention from this location. Similarly, facilitation is not typically observed in the absence of orienting (Smith et al., 2004; 2012). However, some contrary findings exist. While some studies have not found facilitation to occur in the absence of orienting in both neuropsychological patients (Smith et al., 2004) and control groups where ability to make eye movements was prevented (Smith et al., 2012), facilitation has been observed for subliminal cues (Ivanoff & Klein, 2003; McCormick, 1997). As participants were not aware of the cues, it seems improbable that orienting took place and so it is unclear how the reorienting hypothesis would account for the observed cueing effect. Lupianez et al. (2013, Experiment 3) also showed the presence of facilitation at unexpected locations by comparing performance on a discrimination task in two blocks, one where the cue was predictive of the target location 75% of the time and one where the cue only predicted the target location 25% of the time. Facilitation was observed in both blocks, even though participants would necessarily have to have oriented away from the cued location for counterpredictive trials. Thus, the reorienting hypothesis cannot explain the entirety of the attentional facilitation literature.

It is clear that the reorienting hypothesis cannot account for all findings pertaining to either attentional inhibition or facilitation. In spite of findings contrary to the reorienting hypothesis being demonstrated consistently following its proposal, general belief in the reorienting hypothesis persisted for more than 20 years after its suggestion (see Berlucchi, 2006; Lupiáñez et al., 2006, for discussions on this subject). However, two recent conceptions of attentional inhibition have supplanted the reorienting hypothesis: the habituation hypothesis (Dukewich, 2009) and the detection cost theory (Lupiáñez, 2010). These will be discussed in turn.

1.4.2 Habituation

Dukewich (2009) proposes that attentional inhibition can be conceived of as a form of habituation. Habituation is typically defined as a reduction in the magnitude of a response following repeated presentation of a stimulus. In this account, a target at the cued location receives a response of less magnitude than one at an uncued location because the cued location has been stimulated twice relative to the uncued location.

Many of the characteristics of habituation appear consistent with that of attentional inhibition. Habituation is a form of nonassociative learning as the stimulus does not correspond to another stimulus or event. For attentional inhibition to be generated, the cue must be non-predictive, a circumstance comparable to that needed to produce habituation. Although on a trial-by-trial basis any particular location in a spatial cueing task may have been stimulated a different amount of times compared to its opposite location, the balanced designs employed mean that on average the accumulated habituation will be equal between the two possible cue and target locations. Habituation can apply at all levels of processing and so can apply to the orienting response, the target response etc., which explains how attentional inhibition can be found both as ICEs (perceptually) and as IOR (a motor effect). Similarly, habituation applies not only to a single stimulus but also to comparable stimuli. Thus, it is not exclusively a stimulated location that is habituated but similar locations, consistent with the spatial gradient of attentional inhibition.

Findings inconsistent with the reorienting hypothesis can be explained with the habituation hypothesis. The habituation hypothesis does not necessitate that facilitation and inhibition are coupled, but argues that facilitation is likely if the cue and target occur closely in time due to a summation of orienting responses. Similarly, although habituation of the orienting response may contribute to attentional inhibition in some respects, attentional inhibition without orienting can be accounted for by habituation at a different level of processing. Finally, social IOR could be accounted for in terms of habituation of mirror neurons, the neural substrate primarily implicated in social IOR.

Experimental evidence has supported the habituation account. Dukewich and Boehnke (2008) found that when a location was cued several times in a trial, a greater ICE was found compared to the use of a single cue. Hu, Samuel and Chan (2011) also provided support for the habituation account in a series of experiments that made use of a complex display comprising eight locations (grey circles). Half of the circles contained two small shapes, which could be a square or circle with a red or blue colour while the remaining circles were empty. Empty circles alternated with shape-containing circles around the display. After being presented this display, a cue (a red or blue circle or square) would appear in one of the empty circles. Finally, a target (also a red or blue circle or square) would appear in either the same circle as the cue, a circle located 90° (polar coordinates) clockwise or anticlockwise from the cue or a circle located 180° from the cue. Unlike a traditional spatial cueing task, the cue and target could be the same or different. In addition to traditional space-based ICEs, an additional inhibitory effect was found when the cues and targets matched on their colour or shape. However, this effect was only found when the cue and target occupied the same location. As with other results reported, an increase in inhibition due to cue and target similarity cannot be explained by the reorienting hypothesis, but is consistent with a habituation account.

Additionally, neurophysiological investigations appear consistent with a habituation account of attentional inhibition. Müller and Kleinschmidt (2007) applied fMRI in the study of attentional inhibition and found that facilitation was associated with increased activation in visual areas, while ICEs were associated with subsequent suppressed activation in the same areas. Smith, Ball and Ellison (2012) also provide support using TMS-induced phosphenes. When TMS is applied to V5, the typical effect is that participants see phosphenes (Cowey & Walsh, 2000). Smith, Ball and Ellison (2012) investigated whether phosphenes were perceived equally at both cued and uncued locations in a spatial cueing paradigm. It was found that phosphenes were significantly less likely to be detected at cued locations compared to both neutral (the fixation point) and uncued locations. This suggests that ICEs directly affects the strength of visual signals in extrastriate visual cortex and that specifically, ICEs are a suppression of visual signal, consistent with the habituation hypothesis.

However, the habituation account has some limitations. Although Dukewich (2009) mentions that habituation can occur at many levels of processing, her account mostly refers to habituation of the orienting response. If only the orienting response was habituated, then this account cannot be reconciled with findings that attentional inhibition is independent of orienting or the finding of object-based attentional inhibition in general. Of course, habituation operating at a different level (such as for features of the stimulus) is a simple addition to the model and would render it immune from this criticism. However, there are other findings that are not explained as easily by the habituation account. Hu and Samuel (2011) used a paradigm comparable to Hu et al. (2011) but participants were now required to make a discrimination between stimuli instead of simple detection. Although space-based ICEs were observed regardless of the similarity between the cue and target, two key differences pertaining to this similarity were found in their results compared to Hu et al. (2011). Firstly, participants responded faster to targets presented within 350ms of the cue when the cue and the target matched on either colour (Experiment 1) or shape (Experiment 2) compared to when they did not match (a feature-matching benefit). For targets occurring later than 350ms after the cue, the similarity between the cue and the target did not affect reaction times (equal ICEs for matching and non-matching cues/targets). Both of these findings pose a problem for the habituation hypothesis. When the cue and target match, greater habituation (and therefore greater ICEs) would be expected than when the cue and target do not match, whereas Hu and Samuel (2011) found cue-target similarity to have the opposite effect at short SOAs and no effect at longer SOAs. While the first effect could be explained in the same way as the habituation hypothesis explains facilitation (i.e. the cue and target occur closely in time which leads to a summation of the orienting response), this does not extend to longer SOAs. Additionally, it is difficult to imagine why this cue-target similarity did not lead to a reaction time benefit for this same display in a detection task as found by Hu et al. (2011). Martín-Arévalo, Chica and Lupiáñez (2016) also suggested that habituation cannot account for attentional inhibition based on their review of visual evoked potentials associated with attentional inhibition. It is asserted that the P1 component is important in attentional inhibition as it has been found by a majority of studies to show reduced activation for cued compared to uncued locations. Similarly, it is proposed that the habituation hypothesis, which attributes cueing effects to a single mechanism, would expect enhanced P1 activation to consistently lead to facilitation and a reduced P1 activation to lead to attentional inhibition. Contrary to this proposal, Martín-Arévalo et al. (2016) observe that P1 can show a similar pattern of activation regardless of whether the behavioural result is inhibitory or facilitatory. This appears inconsistent with habituation by itself accounting for attentional inhibition. However, it is necessary to note that the P1 component is unlikely to account entirely for attentional inhibition, as attentional inhibition has been dissociated from the P1 component (e.g. Hopfinger & Mangum, 2001; see also Tian, Klein, Satel, Xu and Yao, 2011) and there is no single electrophysiological component consistently related to attentional inhibition. Thus, as measured by EEG, the precise neural basis for attentional inhibition remains unknown. Furthermore, other neurophysiological evidence has supported the habituation hypothesis (Müller & Kleinschmidt, 2007; Smith, Ball, & Ellison, 2012). Accordingly, it seems premature to rule out the habituation hypothesis on these grounds.

1.4.3 Detection Cost Theory

Another recent account is detection cost theory, proposed by Lupiáñez (2010; Lupiáñez, Martín-Arévalo & Chica, 2013). This framework was designed specifically to explain facilitatory cueing effects and attentional inhibition and incorporates three components, which are termed spatial orienting, spatial selection and detection cost. These three components contribute differentially to performance in spatial cueing tasks and relate to interactions between the cue and the target, with spatial orienting and spatial selection speeding up reaction times and the detection cost slowing reaction times respectively at cued locations. Spatial orienting refers to the directing of attention in response to a cue. This leads to an improvement in target detection for targets at the oriented location compared to those at a different location, resulting in faster reaction times for cued compared to uncued targets. The remaining components are considered in the context of object files theory (Kahneman, Treisman, & Gibbs, 1992). Specifically, when a target occurs in spatial and/or temporal proximity to the cue, the target is more likely to be integrated into the existing representation (object file) for the cue rather than a new representation being created. Thus, the target is selected in advance which speeds up the processing of the target (spatial selection). However, this integration can also delay processing of the target: if the target is very similar to the cue, it is more difficult to detect than if it is different, particularly if it occupies the same object file. This is referred to as the detection cost. As spatial orienting and spatial selection both improve performance at cued locations, attentional inhibition is only observed when the detection cost is present and exceeds the facilitatory contributions of both spatial orienting and spatial selection. It is argued that cueing effects manifest differently over time because of the differing time courses of the three components: the spatial orienting benefit peaks shortly after cue presentation but then declines to zero; the spatial selection benefit is strongest immediately after cue presentation and then falls (but some benefit persists); finally, the detection cost is strongest in magnitude immediately after cue presentation, declines rapidly after several hundred milliseconds, then levels off (but does not reach zero). It is argued that these time courses are of particular import in assessing differences in detection and discrimination tasks, with Lupiáñez (2010) arguing that the cueing effects seen in detection tasks are largely due to the detection cost, while cueing effects for discrimination tasks are tied mostly closely to the spatial selection benefit. Additionally, Lupiáñez et al. (2013) state that the detection cost will be of less magnitude in more complex designs, where other processes will contribute more to performance.

Lupiáñez's (2010) detection cost theory can account for the majority of the attentional inhibition findings in the literature. Although detection cost theory includes orienting as a component, attentional inhibition could be observed without orienting as the detection cost component is solely responsible for attentional inhibition in this model. It has also been supported by several subsequent studies. Hu et al. (2011)'s finding of an increase in ICEs when a cue and target matched in terms of their colour and shape is consistent with detection cost theory, as this similarity would lead to an increased detection cost. Lupiáñez et al. (2013) present two experiments using discrimination tasks in support of the detection cost theory. In the first experiment, it was found that a discrimination task with an SOA of 500ms led to significant facilitation for cued targets without a cue-back, but led to ICEs with a cue-back. To rule out the reorienting hypothesis, experiment 2 added central targets, with 50% of targets occurring at the centre compared to 25% at the cued and uncued locations, as well as instructions to maintain fixation at all times. This led to the same pattern of results, with facilitation for cued targets without a cue-back and ICEs with a cue-back. It is argued that the sudden onset of the cue-back disrupts the creation of an object file for the peripheral cue, which necessitates a new object file (and thus an increased detection cost) for the target. Without the cue-back, the peripheral cue can be successfully incorporated into an object file and the space indicated by the cue is selected, which leads to a reduced detection cost and an increased facilitatory effect at this location, leading to facilitation. However, one limitation of the detection cost theory is it offers no explanation for social IOR. Given Lupiáñez (2010) considers the detection of a cue and target (and therefore their detection cost) necessary for attentional inhibition, it does not seem possible that this could explain the generation of social IOR when there is no cue and only a predicted response from another individual as a "target" (such as in Welsh et al., 2007). It is presumed that this account would attribute social IOR to other processes. Alternatively, this theory may be more suited to explain ICEs rather than IOR, with social IOR being characterised as the latter in this account. However, Lupiáñez (2010; Lupiáñez et al., 2013) do not note the input/output distinction in their theoretical account.

Klein, Wang, Dukewich, He and Hu (2015) used a paradigm comparable to that of Hu et al. (2011) with the intent of comparing the detection cost theory and the habituation hypothesis. Klein et al. (2015) argue that the results of Hu and Samuel (2011) were affected by the fact that the cue and targets were identical. It is proposed that when a feature to be discriminated is presented in a stimulus additional to the target, the required response is "primed" and that this affects performance on the task (e.g. Pashler & Baylis, 1991). This phenomenon is referred to as cue-elicited automatic response activation. Accordingly, Klein et al. (2015) attribute the finding of Hu and Samuel (2011) of a feature-matching benefit to this effect as opposed to a cueing effect. Klein et al. (2015) conducted a replication of both Hu et al. (2011) (Experiment 1) and Hu and Samuel (2011) (Experiment 2), as well as a third experiment that took cue-elicited automatic response activation into consideration by having the discrimination required (shape) be unrelated to the cue-target matching characteristic (colour). With this modification, Klein et al. (2015) failed to find a feature-matching benefit on the task. Furthermore, ICEs were reduced for cues/targets that did not match compared to those that did, while Hu and Samuel (2011) found this to have no effect on IOR. In contrast, Klein et al.'s (2015) replications produced comparable results to Hu et al. (2011) and Hu and Samuel (2011). Klein et al. (2015) argued that detection cost theory could not account for the pattern of results identified. Firstly, Klein et al. (2015) found comparable ICEs in their detection (Experiment 1) and discrimination (Experiment 3) experiments, contrary to the notion that the detection cost is of a smaller magnitude in discrimination tasks. Secondly, when the cue and target did not match, detection cost theory would propose that this reduced detection cost would lead to reduced ICEs. This is inconsistent with the finding of Experiment 2, where ICEs did not differ based on the similarity between cues and targets. Taking this into account, Klein et al. (2015) propose that the habituation hypothesis is a more appropriate explanation for their data, although it is important to note that the second observation is similarly unexplained by the habituation hypothesis.

1.4.4 Accounting Theoretically for Object-based Attentional Inhibition

Although the reorienting hypothesis is no longer adequate in accounting for attentional inhibition, the habituation hypothesis of Dukewich (2009) and the detection cost theory of Lupiáñez (2010) appear consistent with the majority of research regarding attentional inhibition. However, it is apparent that these theories do not account for all experimental findings. In particular, it is of great significance to note that these theories do not specifically account for object-based attentional inhibition. This is a problem as it is widely believed that location-based selection and object-based selection are distinct, both in attentional selection generally (Chen, 2012) and specifically in the context of cueing effects such as IOR (Reppa et al., 2012). The distinction between object-based and location-based attentional selection has been supported in attentional selection in neuropsychological patients (e.g. de-Wit, Kentridge, & Milner, 2009; Smith et al., 2016), neuroimaging studies (e.g. Müller & Kleinschmidt, 2003) and behavioural studies (e.g. Hollingworth, Maxcey-Richard, & Vecera, 2012). This extends similarly to attentional inhibition, with location-based and object-based attentional inhibition dissociated in a variety of studies (Jordan & Tipper, 1998, 1999; Leek et al., 2003; McCrae & Abrams, 2001; Reppa & Leek, 2006; Possin et al., 2009; Tipper et al., 1991, 1997; Tipper, Jordan, & Weaver, 1999; Vivas et al., 2008).

Although not addressed specifically by this account, the reorienting hypothesis can be used to explain object-based attentional inhibition. According to this account, object-based attentional inhibition will be found when participants orient away from a cued object. As attentional inhibition is a byproduct of orienting, it makes no distinction between the effects obtained between cued locations and cued objects. To date, no evidence exists that object-based attentional inhibition can be found without orienting. Thus, the reorienting hypothesis can account for object-based attentional inhibition.

Can the habituation hypothesis and detection cost theory be updated to account for object-based attentional inhibition? While simple habituation of the orienting response would be insufficient to explain object-based attentional inhibition (as in moving object displays the cued target would now be at a novel location), habituation to the cued stimulus could adequately account for object-based attentional inhibition effects. Even if the two objects in the display were the same (e.g. Tipper et al., 1991), the unique spatiotemporal identity of the cued object would allow for habituation to differentiate responses between cued and uncued objects. Consistent with this is that object-based attentional inhibition is not generated if this spatiotemporal continuity is not preserved (Tipper et al., 1994). Similarly, it is consistent with attentional inhibition being stronger for cued parts of objects compared to uncued parts. Thus, the habituation hypothesis accounts for the majority of object-based attentional inhibition effects.

As with Dukewich (2009), Lupiáñez's (2010) detection cost theory does not specifically account for object-based attentional inhibition. Due to its basis in object files theory (Kahneman et al., 1992), it seems reasonable that object-based attentional inhibition could be explained by detection cost theory. The main assumption for this to be the case is that cues and targets can be integrated into an object file (and so there be an associated detection cost) on the strength of stimulus features rather than their locations. This amendment appears to explain object-based attentional inhibition. However, it provides no such explanation for object-based facilitation, as the two components in detection cost theory responsible for facilitatory cueing effects (spatial orienting and spatial selection) are tied exclusively to the location of the cue. Thus, it cannot explain the results of studies that have found object-based facilitation (e.g. Lamy & Tsal, 2000; Soto & Blanco, 2004). In contrast, Dukewich (2009) can dissociate facilitation and inhibition with the fact that habituation (and therefore attentional inhibition) is only observed in the absence of associative learning. This accounts for object-based facilitation as it has only been observed with predictive cues. Outside of a moving object paradigm, Dukewich (2009) proposes that facilitation is observed as a summation of orienting responses.

Although all three accounts can explain object-based attentional inhibition following slight amendments, the habituation hypothesis is favoured at present due to a combination of parsimony and it appearing to best account for the greatest range of evidence. However, none of the accounts have been specifically tested in the context of object-based attentional inhibition. An interesting possibility to distinguish between these two theories would be to examine the effect of object salience on object-based attentional inhibition. The strength of a stimulus can have a significant effect on habituation, with strong stimuli not necessarily producing habituation (Rankin et al., 2009). Additionally, the reorienting hypothesis would predict different cueing effects for strong cues, provided such cues are either oriented to more quickly or take longer to orient away from. In contrast, the detection cost theory makes no specific prediction on this issue. One stimulus that is believed to hold a particularly privileged status is the human face. For example, Crouzet et al. (2010) found that in a forced saccadic response task, participants could saccade to an image of a face rather than a distractor within 110ms of presentation, with an average saccadic reaction time of between 138ms and 147ms while maintaining an accuracy of no less than 89% (based on three experiments). In contrast, the average reaction times to other stimuli ranged from 165ms to 184ms with accuracy between 65% and 82%. Studies have also emphasised the strength with which faces capture attention. Cerf, Frady and Koch (2009) found participants to examine faces when free viewing a scene 16 times more frequently than comparable regions. Langton et al. (2008) found in displays of six objects which could either contain one or no faces that participants were significantly slower to detect the presence of a butterfly in the display in face-present displays compared to face-absent displays. This effect was not present for inverted faces. This supports the notion that faces may be a preferential subject of orienting and/or attentional selection and subsequently influence the manifestation of IOR. To examine this claim, studies that have used face stimuli to assess IOR will now be reviewed.

1.5 Attentional Inhibition for Faces

1.5.1 Faces as Cues

Fox, Russo and Dutton (2002) used schematic faces as cues in a spatial cueing task over three experiments. Three face stimuli were employed in experiments 1 and 2: a face with a neutral expression, a happy expression and an angry expression. In experiment 3, a scrambled face was used instead of the happy face, the scrambled face being composed of parts of the angry face. Two boxes were present on either side of a fixation cross throughout each trial. In one of the boxes a schematic face appeared and disappeared, serving as the cue. After the cue presentation, a target (a square or circle) appeared in one of the boxes. In experiment 1, participants had to identify which box the target appeared in with a button press (a localisation task). In experiments 2 and 3, participants simply pressed a button as soon as they detected the target (a detection task). In experiment 1, no ICEs were found for any of the faces. In experiment 2, a significant ICE was found for happy (19ms) and neutral faces (14ms), but not for the angry face (2ms). In experiment 3, an interaction between trait anxiety, cue validity and the faces employed was found: for those with low trait anxiety, all three face types (neutral, angry, scrambled) produced ICEs, while only neutral faces produced ICEs for those with high trait anxiety. This study was the first examination of face stimuli in a spatial cueing task and provided an indication that faces may not generate ICEs, particularly angry faces. However, the inconsistent results between experiment 2 and 3 in participants with low trait anxiety calls into question the replicability of this finding.

Stoyanova et al. (2007) conducted a similar study using three cue types: faces with a neutral expression, fearful faces and a scrambled version of the fearful face. After the cue, participants had to detect a square and indicate whether the square appeared on the left or the right of the fixation cross. Significant ICEs were found for all three cue types at a 900ms SOA. In a follow-up experiment that examined three SOAs (500ms, 1000ms, 1500ms), significant ICEs were again found for the fearful face and the scrambled face as cues (the neutral face cue was not used in this experiment). There was no interaction between SOA and target location.

Lange et al. (2008) also used photographic stimuli as cues, comparing angry faces, neutral faces and smiling faces in two experiments. Comparable to other experiments, the target was a circle, which participants had to detect with a button press. Three SOAs were employed (150ms, 250ms, and 550ms). Significant ICEs were found for all three faces in both experiments, including a sample of participants with social anxiety. An additional two experiments examined the effect of using drawings of spiders, butterflies and crosses as cues: again, significant ICEs were found for all cues, including a sample of participants with a fear of spiders.

Verkuil, Brosschot, Putman and Thayer (2009) used schematic neutral, happy and angry faces as cues. The target was a dot which participants had to localise and press one of two keys to indicate which side of the fixation cross it appeared on. Trait anxiety and trait worry were also assessed using the State Trait Anxiety Inventory-Trait (STAI-T) and Penn State Worry Questionnaire (PSWQ) respectively. A main effect of cue validity was found, with ICEs found across all face types. However, a variety of significant interactions were present, including Trait Worry x Valence (happy vs neutral vs angry faces as cues) x Cue Validity and Trait Worry x Trait Anxiety x Valence x Cue Validity. To explore these interactions, two variables were created: the angry-modulated cue validity (CV) index and the happy-modulated CV index. Specifically, the angry-modulated CV index was the ICE for neutral faces subtracted from the ICE for angry faces, while the happy-modulated CV index was the ICE for neutral faces subtracted from the ICE for happy faces. Partial correlations on these indices revealed a significant association between the angry-modulated CV index and the interaction between trait worry and trait anxiety ($r = .23$), but no significant association between these variables separately. This suggests that the ICE was reduced for angry faces for participants who scored highly both on trait worry and trait anxiety. For happy faces, partial correlations found a positive association with trait worry ($r = .31$) and a negative association with trait anxiety ($r = -.29$).

This suggests that participants who scored highly on trait worry showed reduced ICEs for happy faces, while participants who scored highly on trait anxiety showed increased ICEs for happy faces. Finally, partial correlations on the cueing effect for neutral faces found the inverse pattern compared to happy faces: a negative association between ICEs and trait worry ($r = -.21$) and a positive association between ICEs and trait anxiety ($r = .24$). However, these correlations were only significant at $p < .06$. Nonetheless, these results provide a suggestion that opposite to happy faces, participants with high trait worry showed increased ICEs to neutral faces, while participants with high trait anxiety showed reduced ICEs to neutral faces.

Park, Van Bavel, Vasey and Thayer (2012) used photographic stimuli in a similar task, where neutral faces and fearful faces were used as cues. These two faces were also manipulated for spatial frequency, which could be a normal broad spatial frequency (i.e. unchanged), low spatial frequency and high spatial frequency. The low spatial frequency faces appeared blurry but were recognisable as faces, while high spatial frequency faces appear as a collection of lines in a face-like arrangement. Heart rate variability (HRV) was also measured: this has been proposed as a measure of emotional self-regulation (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012) and has been found consistently to be lower in those with anxiety disorders compared to controls (Chalmers, Quintana, Abbott, & Kemp, 2014). Participants were split into low and high HRV groups. The task aim was to localise the target (a black dot) by indicating whether it appeared in the left box or the right box. A significant ICE of 14ms was found. However, there was an interaction between HRV level, cue validity and cue emotion. Follow-up analyses found an ICE for participants with high HRV (i.e. better emotional regulation) regardless of cue emotion. However, low HRV participants only showed significant ICEs to neutral faces, with no ICEs for angry faces. No effect of spatial frequency was identified.

Hu et al. (2014) used a detection task using fearful faces and scrambled faces as cues at four SOAs (380ms, 580ms, 880ms and 1280ms). Significant ICEs were found for both cues at all SOAs in control participants, although no ICEs were found for schizophrenic patients.

Based on the above research, it appears that when faces are used as cues in a spatial cueing task, they typically produce ICEs. The principal exceptions are for schizophrenic participants (Hu et al., 2014) and for participants with high trait anxiety, trait worry or poorer emotional regulation (Fox et al., 2002; Park et al., 2012; Verkuil et al., 2009). However, manipulating the salience of the cue may not be the most appropriate measure to investigate the presence of attentional inhibition for particular objects. It is important to note that exogenous cues rapidly capture attention regardless of the nature of the cue (Egeth & Yantis, 1997; Theeuwes, 2010). Thus, it is likely that there is a ceiling effect whereby attention is captured by these cues to a similar extent regardless of the stimulus presented, making this manipulation a poor test of the effect of cues on subsequent reaction times. Thus, it is necessary to examine whether IOR is still present when faces are used as the target, rather than as a cue. These studies will now be reviewed.

1.5.2 Faces as Targets

Taylor and Therrien (2005) present three experiments examining ICEs for faces. The stimulus used in their cues was based on a photograph of a face but with a high-pass filter applied. This led to a grayscale image consisting of a pair of eyes, a nose and a mouth. This object was used in both a face-like arrangement and in a random arrangement. Their first experiment was comparable to Fox et al. (2002), using these stimuli as cues and a circle as the target, with the aim of the task to identify where the target appeared. Significant ICEs were found for both types of cue. In their second experiment, the cue and target were reversed. That is, the cue was a circle, while the target was either a face-like arrangement or random arrangement of a set of eyes, nose and mouth. As before, both targets produced significant ICEs, although the ICE was smaller for the face-like arrangement than the scrambled face arrangement. A third experiment combined the previous experiments by using these stimuli as both the cues and the targets. Additionally, a second control stimulus in the form of a random arrangement of pixels was added in addition to the face-like and random arrangements of the face features. A main effect of cue validity was found, indicating an overall ICE across the combinations of stimuli. No interactions were identified. Taylor and Therrien (2008) replicated their second experiment using a discrimination task: either a face or scrambled face was used as a target and participants had to identify whether the target was a face or a scrambled face. An overall main effect of cue validity revealed ICEs across both target types. An interaction between cue validity and face configuration revealed that ICEs for faces were significantly larger than ICEs for scrambled faces.

Baijal and Srinivasan (2011) used emotional schematic faces as targets. As in other spatial cueing paradigms, two squares were presented on either side of a fixation point (a circle). A peripheral cue was presented (a black square onset) in one of the squares, followed by a cue-back (the circle increased in size briefly). Following this, the target, either a happy face or a sad face, appeared. In this case, participants simply had to detect when the target appeared. Significant ICEs were found for both happy and sad faces. However, the ICE was modulated for sad faces based on which side of the visual field was viewed: ICEs were significantly smaller for sad faces viewed in the left visual field compared to sad faces viewed in the right visual field. No significant difference in ICEs were present across the visual fields for happy faces.

Rutherford and Raymond (2010) present three experiments examining real faces as targets. Participants were presented a screen with only a fixation cross present. On either side of the cross a cue in the form of a circle appeared. After the cue offset, a face appeared as the target, with the aim of the participants being to localise which side the target appeared on. In the first experiment, angry and neutral expressions were employed and the total SOA was 1000ms. These expressions were used in two blocks: that is, participants completed one block of trials using only angry faces as targets and a second block that used only neutral faces. This produced significant ICEs for both faces, although the ICE for angry faces was significantly smaller than for neutral faces. In a second experiment, the blocked design was replaced with a randomised design. Additionally, happy expressions and fearful expressions were added. In this experiment, a significant ICE was found, with no interaction between cue validity and the expression of the targets. A third experiment hybridised the blocked and randomised designs by using mini-blocks: 4, 8 or 12 trials where all targets were a single facial expression. Only neutral and angry expressions were used in this experiment. Again, significant ICEs were present across all trials and did not appear to be modulated by facial expression. However, a further analysis was conducted using only what Rutherford and Raymond (2010) refer to as the "switch trials": these were the first trials of a new mini-block. This led to an interaction between cue validity and facial expression, with angry faces producing significantly greater ICEs than neutral faces. That is, ICEs were smaller after sustained exposure to angry faces compared to neutral faces. Given that this finding was likely affected by the effect of the current trial and/or the expectation of the expression changing, the average ICE at the midpoint of each mini-block was also examined. This revealed that ICEs were only significant for neutral faces and not for angry faces. This study suggests that ICEs can be affected by emotional faces, although the mere presence of emotional faces was not sufficient. Rather, the repeated exposure to emotional faces produces a particular affective context which is capable of attenuating ICEs.

Perez-Duenas, Acosta and Lupiáñez (2014) compared participants with high and low-trait anxiety with a spatial cueing task using faces with three emotional expressions (happy, neutral and angry faces) as targets. The task was that of emotional categorisation, with participants having to identify whether the face was neutral or emotional. SOAs of 100ms and 1000ms were employed. As is typical in cueing tasks using short and long SOAs, an interaction was observed between cue validity and SOA, with a significant facilitator cueing effect at the short SOA and significant ICEs at the longer SOA. A three-way interaction between SOA, cue validity and target emotional valence was also identified. Further examination revealed that while target valence did not affect ICEs at the short SOA, it had an effect at the long SOA: specifically, significant ICEs were observed for both neutral faces and happy faces, while ICEs were non-significant for angry faces. Of note is that there was no effect of trait anxiety, indicating that this apparent lack of ICEs for angry faces was found in both low-anxiety and high-anxiety participants. A second experiment examined the effect of state anxiety instead of trait anxiety by adding a presentation designed for either anxiety or positive mood induction before the experiment, but otherwise replicated the first experiment. As in experiment 1, an interaction between target valence and cue validity was present at the long SOA, with significant ICEs for neutral and happy faces and no significant ICEs for angry faces. Again, no interaction was found between the anxiety group and the cueing effects observed. These experiments also support the idea that ICEs can be overridden using emotional stimuli. In this case, the fact that the task required identifying the emotions of the stimuli may have increased their salience and so reduced the magnitude of the ICEs.

Silvert and Funes (2016) examined ICEs for faces across four experiments. The cue was a circle appearing in one of the two placeholder boxes which was followed by a cue-back. Three SOAs were employed of 500ms, 750ms and 1000ms respectively. The three categories of stimuli employed were neutral faces, fearful faces and non-face stimuli (blurred ovals consisting of white noise of different spatial frequencies), of which sixty faces of each emotion and ten distinct non-face stimuli were employed. In each experiment a different task was required, with localisation, face discrimination (identifying face versus non-face), emotion discrimination and gender discrimination. In the emotion and gender discrimination tasks, the non-face stimuli were not used. For the localisation and face discrimination tasks, ICEs were robust, with significant ICEs at all SOAs for all types of stimuli. However, this pattern of results was found to differ in the other types of discrimination tasks. In both the emotion and gender discrimination tasks, ICEs were not found for neutral faces at the 1000ms SOA. For fearful faces, ICEs were not found at the 500ms and 1000ms SOAs.

Similarly to when faces are used as cues, research appears to consistently demonstrate ICEs for faces as targets. In detection and localisation tasks, ICEs were found regardless of the emotional expression with only one exception: Rutherford and Raymond (2010) found angry faces did not show significant ICEs in “switch” trials (i.e. for trials specifically in the middle of blocks where the same emotional expression was shown). Given that ICEs were found for angry faces for all other measurements in their task, it is unclear if this finding is replicable. However, for discrimination tasks, ICEs were found to be attenuated for face stimuli, with Perez-Duenas et al. (2014) finding this effect to apply specifically to angry faces in emotion discrimination tasks and Silvert and Funes (2016) finding no significant ICEs for both neutral and fearful faces at long SOAs in both emotion and gender discrimination tasks (but see Taylor and Therrien, 2008 for a demonstration of ICEs for faces in a discrimination task). The finding that ICEs can be attenuated in discrimination tasks for faces appears consistent with a habituation account: specifically, as faces were task-relevant, participants would learn to respond in a way that benefitted their performance rather than showing habituation (and thus ICEs). However, the fact that faces did not change performance in detection tasks is less amenable to the habituation hypothesis: given their special status in processing, it would be expected that they would produce less habituation and thus a significantly reduced (or absent) ICE. In turn, the detection cost theory could account for both of these results: as the detection cost is reduced in discrimination tasks compared to detection tasks, this would explain a lack of ICEs in discrimination tasks. Furthermore, no difference in ICEs is predicted in relation to the salience of the cue or target, only their similarity, consistent with the findings of the literature to date.

1.6 Object-based or Location-based Attentional Inhibition for Faces

The review of attentional inhibition for faces revealed that excluding specific participant characteristics (Fox et al., 2002; Hu et al., 2014; Park et al., 2012; Verkuil et al., 2009) or discrimination tasks (Perez-Duenas et al., 2014; Silvert & Funes, 2016), faces appear to generate ICEs robustly. This appears to be a problem for the reorienting hypothesis and habituation hypothesis, while the detection cost theory appears to more adequately accommodate these findings. However, just as with theories of attentional inhibition in general, the literature of attentional inhibition for faces has neglected the role of object-based attentional inhibition. At the time of writing, every study of attentional inhibition for faces has used a static design comparable to a traditional spatial cueing task. This is important as it indicates that these studies cannot specify whether the attentional inhibition observed was of a location-based or object-based nature, effects that have been clearly dissociated (Jordan & Tipper, 1998, 1999; Leek et al., 2003; McCrae & Abrams, 2001; Reppa & Leek, 2006; Possin et al., 2009; Tipper et al., 1991, 1997, 1999; Vivas et al., 2008). This has implications with regard to interpreting the results of these studies with relation to their support for theories of attentional inhibition. For example, it is possible that the habituation hypothesis is correct in its assumption that a strong stimulus such as a face does not produce habituation, but that this effect is being masked by habituation of the orienting response to the location of the cue, leading to an observation of attentional inhibition. Thus, the literature regarding attentional inhibition for faces has yet to demonstrate that the attentional inhibition observed is actually attributable to the face stimuli independent of their locations. Indeed, the majority of these studies were conducted using designs that are unsuited to the generation of object-based ICEs, due to a lack of spatiotemporal continuity over the course of a trial: in a typical spatial cueing paradigm, elements of the display (e.g. the cue and target) appear and disappear without continuity. In some cases (e.g. Grison, Paul, Kessler, & Tipper, 2005), the entire display was removed between cue and target presentation. Without spatiotemporal continuity, object-based attentional inhibition is not observed (Reppa et al., 2012). Taking this design consideration into account, it seems likely that the attentional inhibition observed in the majority of previous studies of IOR for faces was location-based, not object-based. Of course, this must be qualified with the observation that the use of a static design makes it impossible to precisely specify the relative contributions of location-based and object-based attentional inhibition to the cueing effect observed. Nonetheless, despite what appears to be a large body of evidence supporting attentional inhibition for faces, without a separation of location-based and object-based attentional inhibition, it remains an open question whether faces produce attentional inhibition.

1.7 Conclusions

In conclusion, attentional inhibition has been studied extensively following its discovery by Berlucchi et al. (1981) and Cohen (1981), with the subsequent work of Posner and Cohen (1984) leading to the prominence of the spatial cueing task. Attentional inhibition has been found to exist in both location-based coordinates and object-based coordinates, with differing characteristics of these forms delineated. More recently, a similar distinction has been made for ICEs and IOR which similarly have unique characteristics. The neural basis for attentional inhibition has also been explored, with areas such as the superior colliculus and frontoparietal regions in general appearing to be important for the generation of attentional inhibition in its varying forms.

With regard to theoretical accounts, attentional inhibition was traditionally believed to be closely tied to orienting, with facilitation and attentional inhibition a simple consequence of the cue's effect of orienting, with this explanation termed the reorienting hypothesis. Subsequent research has shown that attentional inhibition can be dissociated from orienting, leading to the development of other theoretical accounts. Accordingly, attentional inhibition is now generally conceived of as either a form of habituation (Dukewich, 2009) or a detection cost related to perceptual integration of the cue and target (Lupiáñez, 2010). Although these theories explain many attentional inhibition findings, the three accounts (including the reorienting hypothesis) do not specifically account for object-based attentional inhibition. This can be addressed with minor modifications of the theoretical accounts. However, even taking this into account, no study has compared the accounts in the specific context of object-based attentional inhibition. One promising avenue suggested to investigate these theories is the use of highly salient stimuli as the theories offer differing predictions for stimuli that are not subject to habituation. The human face is offered as a highly salient and privileged stimulus with regard to attentional and perceptual processing, which therefore should not show attentional inhibition according to the habituation hypothesis and the reorienting hypothesis. However, this prediction has not been supported by the literature, which, with the exception of certain participant characteristics and discrimination tasks, has produced an almost unanimous observation of attentional inhibition for faces. This interpretation has been complicated by the fact that these studies have not considered the relative contributions of location-based and object-based attentional inhibition in the generation of these effects. Thus, despite the apparent comprehensive demonstration of attentional inhibition for faces, the question remains whether faces actually produce attentional inhibition independent of their locations.

The most direct way to address this question would be to use a dynamic display, which allows a separation of objects and locations by moving objects away from their locations over the course of a trial. In principle, this could also be studied by using a static display and comparing object-absent to object-present conditions. In this design, the assumption is that the object-absent condition represents location-based attentional inhibition, while the object-present condition represents location-based and object-based attentional inhibition. While this may also be a fruitful line of enquiry, a dynamic display is favoured due to evidence that object features can interact with what are traditionally considered to be location-based effects. For example, the location and magnitude of attentional inhibition is altered by object boundaries and features in static displays (Leek et al., 2003; Jordan & Tipper, 1998, 1999; Reppa & Leek, 2003, 2006). These effects are not purely object-based because differences can be observed when different parts of an object (i.e. locations within an object) are cued (e.g. Reppa & Leek, 2006). From this data alone, it cannot be determined if the cueing effect differs due to an object part or due to a change in location within an object, leading potentially to different location-based effects as a consequence of object properties. If the size of location-based attentional inhibition differs between object-absent and object-present conditions, then subtracting these conditions will not produce a precise object-based cueing effect. In contrast, the effect of object features on attentional inhibition is equivalent across cueing conditions in a dynamic display.

Weaver et al. (1998) used a three-box paradigm based on that of Tipper et al. (1991) which allows a distinction between location-based and object-based attentional inhibition. By cueing one of three objects and then moving the objects rotationally to a location previously occupied by another object, the target can then appear at three locations: on the same object as the cue (now at a different location), at the same location as the cue (now a different object) or at the location of the third object, which shares neither location nor object in common with the cue. Object-based attentional inhibition refers to a slowed response to a target that appears on the cued object compared to the third object, while location-based attentional inhibition refers to a slowed response to a target that appears at the cued location relative to the third object. This paradigm meets the requirements necessary to generate object-based attentional inhibition as the objects in the display maintain spatiotemporal continuity and a cue-back is inserted between the cue phase and the motion of the objects. Chapter 2 assesses this paradigm's suitability to investigate location-based and object-based cueing effects across two experiments, with Experiment 1 looking specifically at shapes and Experiment 2 comparing faces and shapes in separate blocks. The aims of these experiments were to replicate Weaver et al.'s (1998) finding of both object-based and location-based ICEs for shapes and to investigate whether the use of faces instead of shapes leads to object-based and location-based ICEs.

Chapter 2: Using a Dynamic Display in the Study of Attentional Inhibition for Shapes

2.1 Introduction

In Chapter 1, it was identified that theories of attentional inhibition do not specifically explain object-based attentional inhibition. Although object-based attentional inhibition can be accommodated by the three theories discussed, they have not been tested in relation to object-based attentional inhibition. In a similar vein, the study of attentional inhibition for faces has ignored the distinction between location-based and object-based attentional inhibition by using exclusively designs which cannot distinguish these effects. This is important because these effects are likely to be driven by different cognitive mechanisms. This renders a true interpretation of the source of the attentional inhibition impossible. Additionally, without this distinction, it is difficult to interpret these results in the context of competing theories of attentional inhibition. Thus, although the finding of attentional inhibition for faces is unanimous in static displays for neutral faces, it is not evident whether the attentional inhibition is location-based or object-based and therefore, how this effect is best explained theoretically. It is proposed that the use of a dynamic display to study attentional inhibition for faces, a display type which has not been employed previously, can elucidate the nature of the attentional inhibition observed in previous experiments.

However, before conducting an experiment using faces in a dynamic display, it was judged necessary to confirm that the paradigm used was capable of generating location-based and object-based ICEs. In this chapter, an experiment is presented based on Weaver et al. (1998). In this paradigm, three objects are presented in a triangular arrangement surrounding a fixation cross. One of the objects is cued with a luminance change. Following this, a cue-back is applied with the onset and offset of a square around the fixation cross. Next, the three objects move clockwise rotationally to the nearest location occupied by a different object. At this point, a target in the form of a grey circle appears on one of the three objects, which participants respond to with a manual response when the circle is detected. In addition to replicating Weaver et al. (1998), an additional condition was added in which the objects change shape during motion. Although spatiotemporal continuity appears necessary to generate object-based attentional inhibition, it is important to note that this is based primarily on studies that used ambiguous cueing (i.e. it is not possible to be certain what object was cued as it was occluded at the time of cueing; Tipper et al., 1994) or studies where objects either disappear or transform into other objects in the display (Tas et al., 2012). In these studies, it is impossible to track the original cued object, either because participants do not know with certainty if the object was cued or because the object has disappeared. The only exception was Tas et al. (2012; Experiment 2), where object-based ICEs were found to remain for objects that changed colour. However, it is unknown if object-based ICEs can be generated for changes in other characteristics for objects that otherwise maintain spatiotemporal continuity.

2.2 Experiment 1

2.2.1 Method

2.2.1.1 Participants

Thirty-one participants were recruited by volunteer sampling. Twenty-six of the participants were female. The range of ages of the participants was from 18 to 59 years (M = 23 years). Four of the participants were left-handed. All participants had normal or corrected-to-normal vision. Participants were naive to the purpose of the experiment. Previous research has found object-based ICE effect sizes to vary between d = 0.1 and d = 0.3 (see figure 6.1 for a summary of previous effect sizes). Assuming an effect size of d = 0.2, power analysis using Gpower determined that 28 participants were necessary to attain a power of .8 as recommended by Cohen (1988). Participants were recruited until 28 had been tested and then all remaining recruited participants were tested, giving an actual power of .87. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the British Psychological Society's (BPS) guidelines for ethical research.

2.2.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. In the object same condition, the shapes presented in the visual display did not change during trials. In the object change condition, the shapes presented changed to a different shape during the motion phase of each trial. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. A valid cue is one where the target overlaps with the cue. In the case of a valid location cue, this means that the target to be detected appeared at the same spatial location as the cue. For a valid object cue, the target appeared in the same object as the cue. As the objects move between the presentation of the cue and presentation of the target, these cues can be distinguished: in particular, in valid location trials the target appears at the same location as the cue but on a different object, while in valid object trials the target appears on the same object as the cue but in a different location. For an invalid cue, the target appears at a part of the display which is neither the same location nor the same object as the cue. The second independent variable was the condition (object same or object change). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

2.2.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix A). The experiment was created in E-Prime version 1 and presented on a 17" LED colour monitor with a refresh rate of 100Hz. Responses were collected using a serial response box.

2.2.1.4 Stimuli

Four black geometric shapes were used in the present experiment (a cross, hexagon, octagon and square). Each object subtended 1.2° of visual angle at their widest points. A fixation cross (5mm, approximately 0.4° of visual angle) was present in the centre of the monitor, with each object located 3.5° of visual angle from this cross. Each object was 120° away (polar coordinates) from any other object. These objects were cued with a black outline 2 pixels in width filled with white replacing the original object. The target was a grey spot of diameter 0.35° of visual angle appearing on the target object.

2.2.1.5 Procedure

The experimental protocol is displayed in figure 2.1. The experiment was carried out in a dark room. Participants made use of a chinrest positioned 45cm from the display for the experiment's duration. At the onset of each trial, a square, hexagon and octagon were displayed in a triangular arrangement, with a fixation cross in the centre. The location of the three objects was counterbalanced across trials. Once these were displayed for 1500ms, a peripheral cue appeared in the place of one of the objects for 100ms. The cue then disappeared and the scene was as before for 100ms. Then, the fixation cross was cued with a black square for 100ms. After a 50ms delay, the objects moved in a straight line to the location of another one of the objects. This motion was fixed across trials and determined by the original location of the object: the top object moved to the location previously occupied by the lower right object, the lower right object moved to the location previously occupied by the lower left object and the lower left object moved to the location previously occupied by the top object respectively. This movement lasted for 112ms and the objects moved at a speed of 63°/s. In the object change condition, the three shapes became crosses after moving for 56ms. Once this was complete, 200ms passed before the probe appeared. This target remained in place until participants responded or 1500ms had passed. Including motion, the total

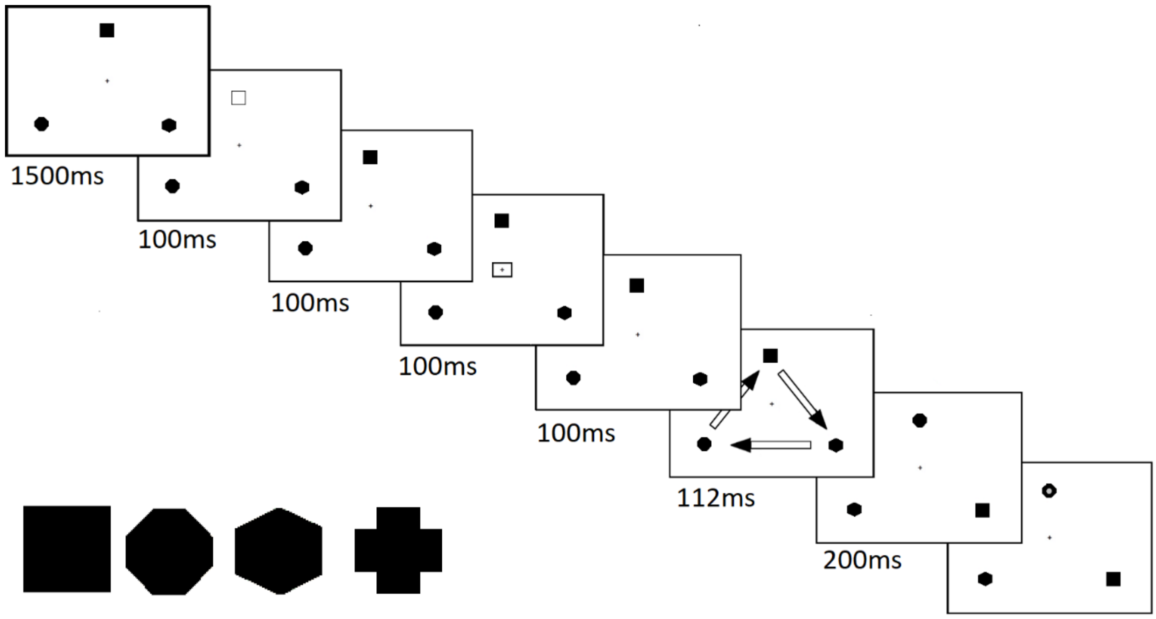


Figure 2.1: *A graphic representation of the procedure in Experiment 1. This represents a valid location trial in the object same condition. The depicted arrows are for illustrative purposes. The four objects used in the experiment (including the cross which all objects changed into in the object change condition not depicted) are presented in closer detail in the bottom-left.*

SOA between cue and probe was 662ms. In 25% of trials, the probe appeared at the original location of the cued object (valid location trials). In 25% of trials, the probe appeared at the new location of the cued object (valid object trials). In 25% of trials, the probe appeared at the remaining object, which was neither the same location nor the same object as the cue (invalid trials). The remaining 25% of trials were catch trials; a cue was presented but no probe followed. For these trials, participants were instructed to withhold a response. In total, 12 practice trials, 72 object same trials and 72 object change trials were completed, with these trials presented in blocks. The order of the blocks of object same and object change trials were counterbalanced across participants, although due to the odd number of participants, one more participant received the object change block first. Participants were asked to fixate on the fixation cross throughout the experiment and to respond as quickly as possible when they detected the target. On catch trials, participants were instructed to withhold a response.

2.2.2 Results

Reaction times below 100ms (N=1) were removed before analysis, as were incorrect responses, which included catch trials that were responded to (N = 36, ~3% of catch trials) and misses on target trials (N=94, ~3% of target trials).

Median reaction times were analysed using a 2 (Condition: Object Same versus Object Change) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) x 2 (Condition Order: Object-same Condition First versus Object-change Condition First) mixed-model ANOVA. The median reaction times for each condition are presented in table 2.1. The main effect of Condition was significant ($F (1, 29) = 6.593$, $p = .016$, $\eta^2 = .185$). It was found that participants' reaction times were significantly faster in the object-same condition (M = 417ms) than the object-change condition (M = 443ms). The effect of Cue Validity was not significant ($F (2, 58) = 2.332$, $p = .106$, $\eta^2 = .074$). The interaction of Condition and Cue Validity was also not significant ($F (2, 58) = 0.464$, $p = .631$, $\eta^2 = .016$). Condition Order did not significantly interact with either Condition (F (1, 29 = 0.315, $p = .579$, $\eta^2 = .011$) or Cue Validity ($F (2, 58) = 1.919$, $p = .156$, $\eta^2 = .062$). Finally, no significant interaction between Condition, Cue Validity and Condition Order was observed ($F (2, 58) = 0.01$, $p = .99$, $\eta^2 < .001$).

Based on this pattern of results, it appears that this paradigm did not generate cueing effects. However, this may be attributable to the disruptive nature of the object change condition: that is, it may be that objects changing mid-trial may have disrupted spatiotemporal continuity in the object same condition. Thus, a second repeated-measures ANOVA analysis was conducted on the participants who completed the object-same condition first (N = 15). The object-change condition was not considered, with cue validity the only factor of the ANOVA. This allowed a direct comparison with the original experiment using this paradigm (Weaver et al., 1998). This analysis found a significant effect of cue validity ($F (2, 28) = 4.796$, $p = .016$, $\eta^2 = .255$). The size of the cueing effects was calculated by subtracting the median valid location/object reaction time from the

Table 2.1
Experiment 1 reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) for each cue validity within each stimulus type for each condition order.

		Condition			
		Same		Change	
Condition Order	Validity	RTs	Errors	RTs	Errors
Same-Change	Location	446 (115)	0.4	474 (130)	2.4
	Object	442 (99)	3.3	470 (132)	3.1
	Invalid	418 (108)	3.0	458 (119)	2.4
	Location CE	-27*		-16	
	Object CE	-24*		-12	
Change-Same	Location	407 (93)	3.7	422 (101)	2.8
	Object	393 (81)	3.0	411 (86)	2.4
	Invalid	395 (78)	4.1	423 (106)	2.4
	Location CE	-12		1	
	Object CE	2		12	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* $p < .05$

median invalid reaction time: thus, a negative value indicates an ICE, while a positive value indicates a facilitatory cueing effect. Using a paired t-test to compare invalid responses to valid location responses revealed a significant location-based ICE ($M = -27$ms, $p = .014$, $d = -0.24$). When invalid responses to valid object responses were compared, a significant object-based ICE was found ($M = -24$ms, $p = .042$, $d = -0.23$). In comparison, the ICEs observed by Weaver et al. (1998) were -15ms (location) and -23ms (object) respectively, which appear similar to the -27ms and -24ms observed here. However, care should be taken as Weaver et al. (1998) did not provide standard deviations, which makes an effect size calculation impossible: without standardising these effects, it is unclear how comparable the cueing effects observed are. An ad-hoc analysis estimated the standard deviations of Weaver et al. (1998) to produce an estimate of the effect size: this was done by taking the standard deviations of the conditions in the present experiment and adjusting it by the difference in means between this experiment and Weaver et al. (1998) (i.e. if the invalid mean in Weaver et al. was 10% smaller than the invalid mean in this experiment, the standard deviation used was made 10% smaller). This suggested that the effect sizes of Weaver et al. (1998) were approximately $d = -0.15$ for the location-based ICE and -0.26 for the object-based ICE.

Although the repeated-measures ANOVA did not reveal any significant main effects related to cue validity or interactions, given the significant ICEs found in one condition, the cueing effects for each other combination of condition and task were calculated. When the object change condition was completed after the object same condition, a location-based ICE (-17ms, d = -0.13) and object-based ICE (-12ms, -d = 0.1) were present. When the object change condition was completed first, no location-based (1ms, d = 0.01) ICE was present and an object-based facilitatory cueing effect was present (12ms, d = 0.13) in this condition. In the subsequent object same condition, a location-based ICE (-12ms, d = -0.14) was found, but no object-based ICE (2ms, d = 0.02). None of these effects were statistically significant ($p > 0.05$). The interaction is represented graphically in figure 2.2.

The same repeated-measures ANOVA was also conducted on the error data (misses on probe trials). No significant effects were identified (all Fs < 1.3, all ps > .3), suggesting that the results were not influenced either by a speed-accuracy trade off or by certain trials being more difficult than others.

2.2.3 Discussion

In Experiment 1, a replication of Weaver et al. (1998) was conducted to confirm that object-based and location-based ICEs could be generated for shapes as found in previous studies. In addition, a condition where the object changed shape during motion was added to investigate if ICEs were still present. Examining the data as a whole, no significant ICEs were found in either the object same or object change conditions. However, examining specifically the object same condition by participants who completed this condition first did find significant location-based and object-based ICEs. Both effects (location-based IOR = -27ms, d = -0.24; object-based IOR = -24ms, d = -0.23) were found to be comparable in size to Weaver et al. (1998) (location-based ICE = -15ms, estimated d = -0.15; object-based ICE = -23ms, estimated d = -0.26). This supports the notion that this design is capable of generating both location-based and object-based ICEs.

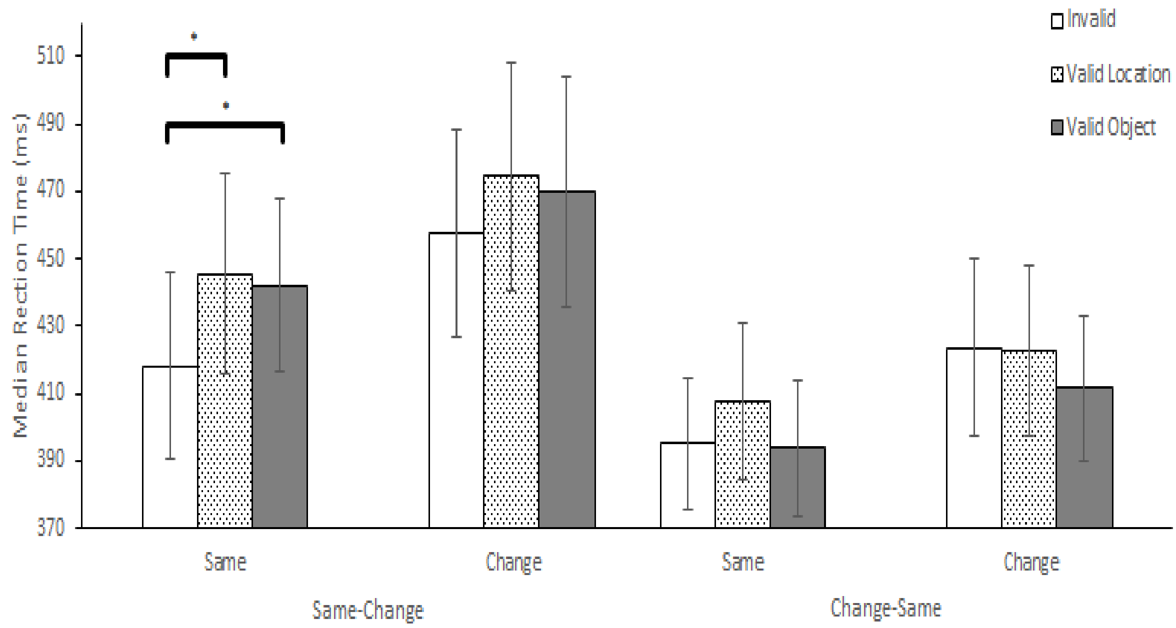


Figure 2.2: *Reaction times (ms) for each cue validity for objects that stayed the same during a trial and objects that changed during a trial for participants that completed the same condition first and participants that completed the change condition first. Error bars represent +/- 1 SEM.*
* p < .05

This experiment found no object-based ICE in the object change condition. Thus, consistent with work such as Tas et al. (2012), it was found that changing a fundamental characteristic of an object during a display led to a lack of inhibition for the object. As found by previous research, it appears that the continuity of the object is strictly necessary for the generation of object-based ICEs (Reppa et al., 2012). This manipulation appeared to be particularly disruptive, as location-based ICEs were also not found in this condition. In fact, for participants who completed the object-same condition following the object-change condition, this disruption appeared to extend to the second display, as neither location-based nor object-based ICE was present in the object same condition for these participants. However, a closer examination revealed that, although these effects were not statistically significant, the location-based ICEs observed were comparable to that of Weaver et al. (1998) in all combinations of condition and condition order excluding the change condition in the change-same order. Thus, the results of this experiment support the notion that this paradigm can generate both object-based and location-based ICEs.

These findings can be broadly accounted for by the three theories of attentional inhibition. According to the habituation hypothesis, location-based ICEs were generated because of the habituation of the orienting response. When the cue and target shared the same location, participants oriented to the same location twice, while at other target positions each location was oriented to once. This habituation led to reduced activation of the orienting response and therefore, slowed responses. Object-based ICEs were found because when the cue and target were the same object, this stimulus was responded to twice, whereas for other target objects, each object was responded to once. However, in the object-change condition, the object being responded to could be perceived as a new object regardless of which object was cued. Accordingly, no habituation was present, leading to no object-based ICE. In the case of the reorienting hypothesis, it is suggested that object-based and location-based ICEs were observed in the object same condition due to participants orienting away from these stimuli following cueing. However, in the object-change condition, participants would orient equally to any of the new three objects following cueing and therefore would not show cueing effects. Finally, the detection cost theory can account for these findings. Location-based ICEs were present because there was a detection cost associated with detecting a target at the location attended to, which had to be integrated into the event-file associated with the cued object which shared that location. In contrast, targets at other locations could be associated with a separate event-file, which reduces the cost necessary to detect them. In turn, object-based ICEs were due to a detection cost based on the stimulus similarity, with the cue and target being the same object. When the cue and target were different objects, the detection cost is reduced. This also manifested in the absence of object-based ICEs in the object-change condition. One finding less easily explained by the accounts is the fact that for participants that completed the object-same condition after the object-change condition, object-based ICEs were not found in the object-same condition. That is, despite using displays where objects did not change and thus participants would be expected to habituate/orient to the same object or show the detection cost of integrating a target into an old event-file, participants did not show these effects seemingly because of a previous display. One speculation from a habituation perspective is that participants learned from the object-change condition that the objects would change and therefore the object-same condition did not lead to an ICE because the habituation response did not generalise to a stimulus without this property. It is not clear how the reorienting hypothesis or detection cost theory would account for this effect.

In this experiment, the use of a moving object display with three objects allowed for the separate generation of location-based and object-based ICEs. The experimental findings are broadly consistent with the three accounts of attentional inhibition. However, the question of whether the ICEs observed in experiments using face stimuli is of a location-based or object-based nature has not been investigated. It is also worth noting that this experiment did not conclusively demonstrate ICEs as ICEs were not consistently present depending on both the condition and the condition order. While it is possible that this is simply due to the disruptive nature of the object change condition, it may also be that ICEs in dynamic displays are not as prevalent as previously thought. In Chapter 3, five experiments are presented which examine whether faces produce location-based and object-based ICEs in dynamic displays. ICEs for other objects are also examined to determine the extent to which the results of Experiment 1 were affected by the object change condition. Experiment 2 compared ellipses with schematic faces. Experiment 3 compared schematic faces and scrambled faces. Experiment 4 compared schematic faces and schematic cars. Experiment 5 replicated Experiment 2 but used squares instead of ellipses, as well as introducing several changes in the experimental design including the introduction of multiple SOAs. Finally, Experiment 6 compared schematic faces and schematic houses using two SOAs.

Chapter 3: The Predominance of Facilitatory Object-based Cueing Effects for Faces and Complex Objects in Dynamic Displays

3.1 Introduction

Experiment 1 supported the notion that the dynamic display paradigm used generated location-based and object-based ICEs. It was also found that objects that changed shape during a trial did not produce object-based ICEs, which was attributed to the lack of spatiotemporal continuity that this change generated. However, the interpretation that this experiment produced ICEs is complicated by the fact they were not displayed consistently across conditions and condition order, with notable examples including location-based ICEs not being found consistently during the object change condition, as well as object-based ICEs being absent when the object same condition was completed second. This raises the possibility that this paradigm may not consistently generate ICEs. However, it may be the case that the object change condition was sufficiently disruptive that it affected location and object-based ICEs as well as different tasks following this condition. Additionally, the issue raised in Chapter 1 regarding whether ICEs observed for faces in static displays are of a location-based or object-based nature has yet to be investigated.

To further investigate cueing effects in dynamic displays for faces and other objects, this chapter presents five experiments. In each experiment, faces are presented in the dynamic display in one block, while objects (shapes or schematic objects) are presented in a second block. Although the nature of the cueing effects for faces is the principal subject of investigation of the thesis, examining cueing effects for other objects is also important to determine that this paradigm produces results comparable to previous work in the literature. Additionally, if faces do produce different cueing effects to other objects, comparisons between the cueing effects obtained for faces and other classes of objects may provide insight with regard to understanding these cueing effects. In Experiment 2, ellipses and schematic faces were compared to examine the cueing effects observed for faces in dynamic displays. The findings of this experiment are developed in Experiments 3-6, with Experiment 3 comparing scrambled faces and schematic faces, Experiment 4 comparing schematic cars and schematic faces, Experiment 5 comparing squares and schematic faces with additional methodological changes (most notably the introduction of multiple SOAs) and Experiment 6 comparing schematic houses and schematic faces.

3.2 Experiment 2

3.2.1 Method

3.2.1.1 Participants

Thirty-eight participants volunteered for this experiment. Twenty-seven of the participants were female. Participant age ranged from 18 to 61 years (M = 24). All participants had normal or corrected-to-normal vision. Based on an effect size of d = 0.24 (the average obtained in Experiment 1's object same condition), power analysis using Gpower determined that 26 participants were necessary to attain a power of .8 . As recruitment was faster than anticipated, this was increased to 38 participants to achieve a power of .95. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

3.2.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting schematic faces and one condition presenting ovals, which were equivalent to the outline of the face with the internal details removed. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or squares). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

3.2.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix B). A 21” CRT colour monitor with a refresh rate of 100Hz was used for the display of stimuli in this experiment. With this exception, the apparatus was as described in Experiment 1.

3.2.1.3 Stimuli

The present study employed two types of objects, which were displayed on a white background. One was a schematic face while the other was an ellipse based on the schematic face. This schematic face was originally used by Fox et al. (2002), defined by them as a "neutral" face. The ellipse was created by removing internal features from this schematic face. The neutral face was chosen and was the only face used, as it was the only face that generated an inhibitory effect across all three experiments in Fox et al. (2002). Participants viewed the display using a chinrest placed 45cm from the monitor. At this distance, each object subtended 3.2° x 2.8° of visual angle at their widest and highest points respectively. A fixation cross (7mm, 0.6° of visual angle) was present in the centre of the monitor and each object was located 16.7° away from this cross. Each object was 120° (polar coordinates) distant from each other object. All objects used in each trial were present at the beginning of the trial. The cue used was the border of a black square appearing around the object, with a line width of three pixels. The probe to be identified was a grey-filled variant of the original object.

3.2.1.4 Procedure

The paradigm was modelled on that of Experiment 1 with some modifications. Each trial began with the onset of three identical objects for 1000ms, either ellipses in the ellipse condition or faces in the face condition, as well as the fixation cross. This was followed by a peripheral cue, which was displayed for 100ms, comprising a black square around one of the three objects. After this cue, there was a 100ms delay and then the fixation cross was similarly cued for 100ms. One further delay of 100ms was present and then the three objects moved in a clockwise direction at a speed of 128°/s for 200ms. Another 300ms elapsed after the objects had moved. At this point, one of the three objects was replaced with the probe object. The probe object remained on the screen until participants responded or 2500ms had elapsed. Combining these elements, the total SOA from cue onset to target onset was 900ms. In 32% of the trials, the probe object replaced the object that occupied the same original location as the cued object (valid location trials). In 32% of the trials, the probe object replaced the cued object at its new location (valid object trials). In 32% of the trials, the probe object replaced the third object, which was neither the same cued object nor at the location of the cued object (invalid trials). In the remaining 4% of trials, no probe object appeared (catch trials); for these trials, participants were instructed to respond with a different button press. In total, participants completed 9 practice trials, one block of 75 trials in the object condition and one block of 75 trials in the face condition. The order of the two conditions was counterbalanced across participants. An example trial of the face condition demonstrating this procedure is presented in figure 3.1. With regard to differences between Experiment 1 and Experiment 2, the number of catch trials was reduced from 25% to 4% as a larger number of catch trials is believed to reduce the magnitude of ICEs (Tipper & Kingstone, 2005). Fixation offset was increased from 50ms to 100ms to ensure consistency with other frames which lasted for 100ms. The motion animation in Experiment 1 consisted of 4 frames which were displayed for 28ms each. To create a smoother animation, for Experiment 2 this was changed into an animation which consisted of 20 frames, each displayed for 10ms. This led to an SOA of 900ms compared to a 662ms SOA in Experiment 1.

3.2.2 Results

Before analysis, data were filtered to exclude all reaction times below 100ms from analysis (N=61, 1% of trials) and misses on target trials (N=55, 1% of trials). Catch trials were not analysed. Median reaction times were analysed using a 2 (Condition: Ellipse versus Face) x 3 (Cue Validity: Valid

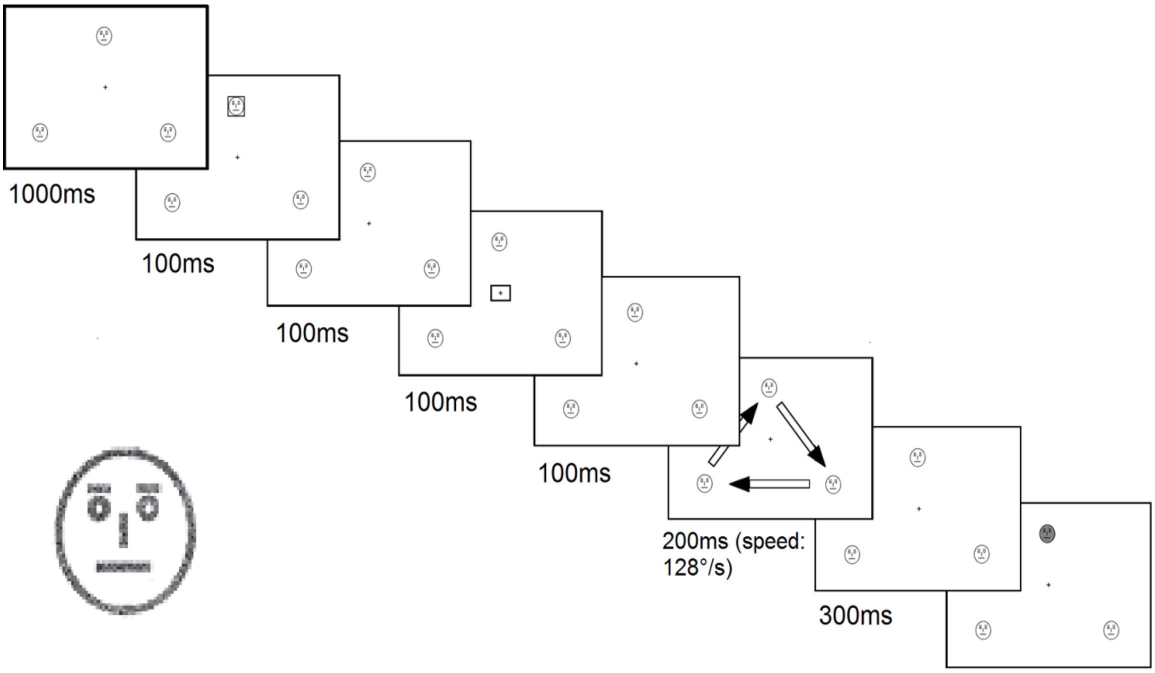


Figure 3.1: *A graphic representation of the procedure in Experiment 2. This represents a valid location trial in the face condition. The depicted arrows in panel 6 are for illustrative purposes only. The face stimulus employed is presented in detail in the bottom-left of the figure.*

Location versus Valid Object versus Invalid trials) x 2 (Condition Order: Object first versus Face first) mixed-design ANOVA. The median reaction times for each condition are presented in table 3.1. The main effect of Condition was not significant ($F (1, 36) = 1.53$, $p = .224$, $\eta^2 = .041$). The main effect of Cue Validity was also non-significant ($F (2, 72) = 1.864$, $p = .162$, $\eta^2 = .049$). The Cue Validity x Condition interaction was not significant ($F (2, 72) = 1.709$, $p = .188$, $\eta^2 = .045$), nor was the three-way interaction between Condition, Cue Validity and Condition Order ($F (2, 74) = 2.006$, $p = .142$, $\eta^2 = .053$). However, both Cue Validity and Condition significantly interacted with Condition Order (Condition x Condition Order: $F (1, 36) = 6.903$, $p = .013$, $\eta^2 = .161$; Cue Validity x Condition Order: $F (2, 72) = 4.724$, $p = .012$, $\eta^2 = .116$). To ascertain the nature of these interactions, planned comparisons using paired t-tests (two-tailed) were conducted on the median reaction times for each cue validity within each stimulus type with each condition order examined separately. The size of the cueing effects was calculated by subtracting the median valid location/object reaction time from the median invalid reaction time: thus, a negative value indicates an ICE, while a positive value indicates a facilitatory cueing effect. This interaction is displayed graphically in figure 3.2.

Table 3.1
Experiment 2 reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) for each cue validity within each stimulus type for each condition order.

		Condition			
		Ellipse		Face	
Condition Order	Validity	RTs	Errors	RTs	Errors
Ellipse-Face	Location	325 (88)	0.7	314 (86)	0
	Object	319 (96)	0.4	304 (89)	0
	Invalid	307 (94)	0.4	306 (77)	0.9
	Location CE	-18*		-8	
	Object CE	-12*		2	
Face-Ellipse	Location	273 (46)	0.4	306 (69)	2.6
	Object	275 (46)	0	294 (58)	2.9
	Invalid	286 (50)	0.9	307 (70)	2.6
	Location CE	13		1	
	Object CE	11		13*	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* p < .05

When participants completed the ellipse condition first, significant location-based (M = -17.4ms; (t (20) = 2.796, p = .011, d = 0.19) and object-based (M = -11.3ms; t (20) = 2.47, p = .023, d = 0.12) ICEs were present in the ellipse condition. In the face condition, neither a location (M = - 8.4ms; t (20) = 1.703, p = .104, d = 0.1) nor object-based (M = 1.5ms; t (20) = 0.259, p = .798, d = -0.02) ICE was observed.

A different pattern emerged in the participants who completed the face condition first. Here, there was a significant object-based facilitatory cueing effect (M = 12.5ms; t (16) = 2.753, p = .014, d = -0.19) but no location ICE (M = -0.2ms; t (16) = 0.038, p = .97, d < 0.01) in the face condition. For the subsequent ellipse condition, neither a significant location-based (M = 12.5ms; t (16) = 1.55, p = .141, d = -0.26) nor object-based (M = 10.2ms; t (16) = 2.753, p = .189, d = -0.21) ICE was found.

To examine if any differences obtained were due to a speed-accuracy trade-off, the error data was also analysed using the same 2 x 3 x 2 mixed-model ANOVA used for the reaction times. No significant effects were found (all Fs < 2.8, all ps > .06), suggesting that error rates were similar across the variables examined.

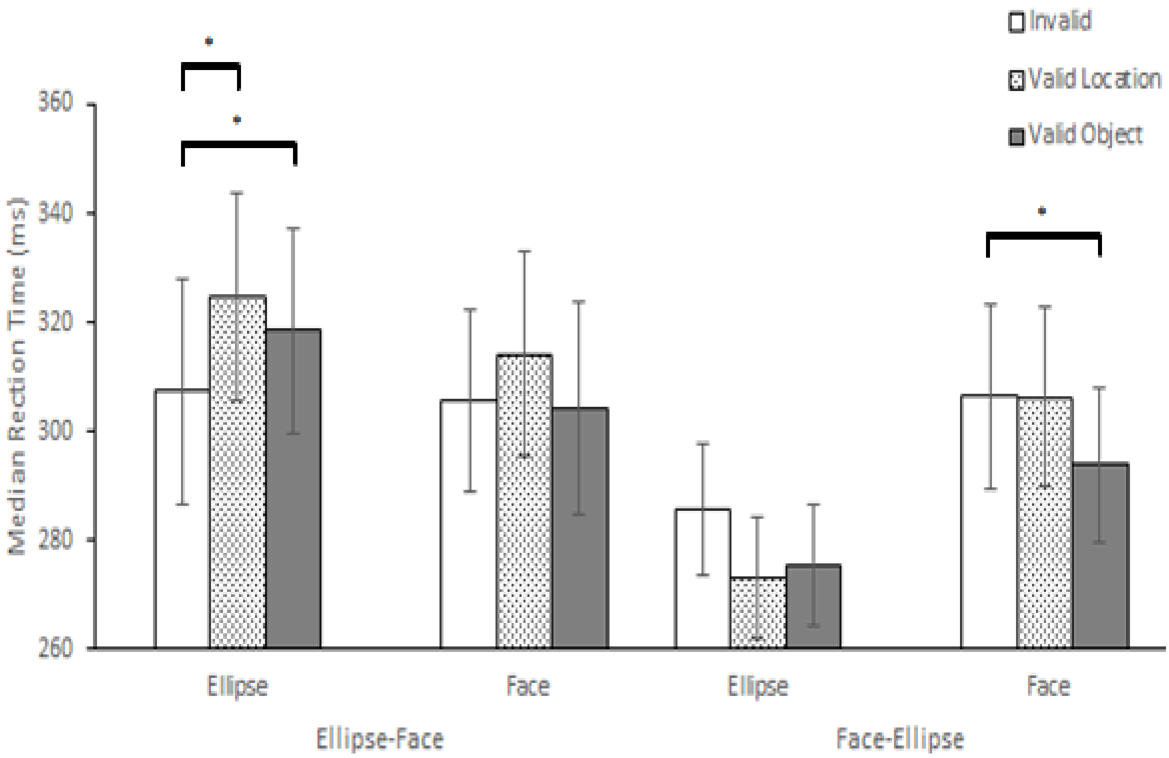


Figure 3.2: *Reaction times (ms) for each cue validity for ellipses and schematic faces for participants that completed the ellipse condition first and participants that completed the face condition first. Error bars represent +/- 1 SEM.*
* $p < .05$

3.2.3 Discussion

In Experiment 2, neither object-based nor location-based ICEs were found for schematic faces. Whether the ellipse generated an ICE appeared to be affected significantly by condition order. When the ellipse condition was completed first, significant location-based and object-based ICEs were produced for the ellipse. However, if the ellipse condition was completed after the face condition, no ICEs were found. Similarly, the face condition when completed first produced significant object-based facilitation, but when completed second produced no cueing effects. This experiment provides the first known examination of cueing effects for faces in a dynamic display. Unlike previously published work that has consistently found ICEs for faces in detection tasks using non-emotional faces (Fox et al., 2002; Rutherford & Raymond, 2010; Silvert & Funes, 2016; Taylor & Therrien, 2005), no evidence of ICEs was found for faces in this task. Although the present experiment differs from these studies in a variety of ways, the most obvious difference is the change from a static display to a dynamic display. This change is important given that in static displays, identifying the relative contributions of location-based and object-based ICEs is difficult if not impossible. When these frames of reference were dissociated as in this study, faces did not produce object-based IOR. Thus, this experiment provides preliminary evidence that faces may not be subject to object-based ICEs, with the ICEs of previous work being primarily location-based effects. If this is the case, this would provide greater support for a habituation or reorienting account of attentional inhibition than the detection cost theory, as the former provide a mechanism to explain why faces do not produce ICEs while the latter would predict no difference between faces and other stimuli.

In this experiment, faces produced a significant facilitatory object-based cueing effect. This is particularly important as neither the habituation hypothesis nor the detection cost theory of ICEs provides an explanation for this effect. The detection cost theory attributes facilitatory cueing effects entirely to spatial processes and so does not predict object-based facilitation separately from location-based facilitation. In contrast, the habituation hypothesis can explain object-based facilitation, but only when predictive cues are used. This is because habituation (and therefore attentional inhibition) is not present when associative learning can take place, as habituation is a form of nonassociative learning. However, it can be explained by the reorienting hypothesis' account of facilitation. In this case, the reason why facilitation is observed for faces is simply that participants remain oriented to a face once it has been cued (at least for the duration of the experimental trial), even if it moves to a new location. It has been previously suggested that the attentional system may prefer to track objects that move following cueing if there is no intervening stimulus (Ro & Rafal, 1999). Although this experiment included a cue-back which could have served this function, this effect may be emphasised by a stimulus such as a face, to the point where ICEs are not observed.

An unexpected finding was the fact that the condition order interacted significantly with the cueing effects. This manifested most distinctly for the ellipse condition, which produced location-based ICEs (d = -0.19) and object-based ICEs (d = -0.12) when completed first, but when completed after the face condition produced facilitatory effects, both location-based (d = 0.26) and object-based (d = 0.21). Although these cueing effects were non-significant, the difference in effect size suggested this manipulation affected the results in a non-trivial way. While not apparent to the same extent, this difference in cueing effects was also present in Experiment 1, with the object same condition of this experiment only producing ICEs when completed first as opposed to after the object change condition. In Experiment 1, it was proposed that the object change condition may have been responsible for this order effect. However, as there was no condition comparable to this in Experiment 2, this cannot be the explanation at least for Experiment 2. This finding appears broadly consistent with Rutherford and Raymond's (2010) finding that the "context" of the display has an influence on cueing effects. In this study, the effects of emotional stimuli on ICEs did not manifest on a trial-by-trial basis, but only after repeated exposure to the relevant stimulus. Specifically, non-threatening stimuli (everyday objects, neutral faces) and threatening stimuli (spiders, angry faces) both produced comparable ICEs when presented randomly throughout a block. However, in a blocked design, angry faces produced a smaller ICE than neutral faces, although no difference was observed between spiders and everyday objects. Additionally, when presented in “mini-blocks” of 4, 8 or 12 trials that consisted exclusively of angry faces or neutral faces, the first trial of a new mini-block differed significantly in the magnitude of the ICE depending on the content of the previous mini-block. Thus, after a mini-block of neutral faces, ICEs were significantly greater than after a mini-block of angry faces. Applying this finding to the present experiment, the face condition, which produced an object-based facilitation effect when completed first, may have produced a context which favoured orienting to the objects which led to facilitation in the subsequent ellipse condition. The ellipse condition, which produced ICEs when completed first, may have had a similar effect on the subsequent face condition, which produced no object-based cueing effects and a location-based ICE when completed second. This contrasts with the object-based facilitation and no location-based ICE observed when the face condition was completed first.

Rutherford and Raymond’s (2010) study demonstrates that IOR can be modified by factors beyond characteristics in the current display, with previous repeated exposure to threatening stimuli appearing to reduce cueing effects in subsequent displays. However, Rutherford and Raymond's (2010) experiments present a specific affective context by using threatening stimuli. Furthermore, they propose that the effect on attention is mediated by an increase in arousal as would be generated by exposure to threatening stimuli. In contrast, Experiment 2 did not use emotional stimuli. Therefore, for the context explanation to hold, it would have to be the case that the context affected by the condition order in this experiment was not an affective one, but rather a cognitive one: a change in attentional set. In this account, the ellipse condition encouraged participants to maintain the attentional inhibition “attentional set”, which led to a location-based ICE and an abolished facilitatory object-based cueing effect in the face condition. When the face condition was completed first, it encouraged facilitatory cueing effects, which led to the ellipse condition producing facilitation. The idea that attentional inhibition may reflect a particular attentional set is consistent with the work of Dodd, Van der Stigchel and Hollingworth (2009). This study found that IOR was only present for natural scenes in a visual search task, with facilitation found for three other tasks. Dodd et al. (2009) argue that facilitation may reflect a variety of processes, such as additional encoding of particular objects or ensuring an original impression of part of a scene is consistent with other information. However, it is unclear why schematic faces would produce a different attentional set to shapes. Furthermore, the finding that attentional set affects attentional inhibition is not unanimous: Pratt, Sekuler and McAuliffe (2001) found attentional set to have no effect on ICEs, with similar ICEs observed regardless of the type of target expected by participants.

A more simple explanation may be that the order effect was a consequence of low-level stimulus properties. In the study of object-based cueing effects, it has been made clear that the outline of an object is a highly salient cue as to its identity (Reppa et al., 2012). This is relevant because the ellipses and faces used in this study had an identical outline. Although it is improbable that any of the participants believed the conditions used the same objects, it is possible that their identical outlines may have led to them being parsed similarly at some level of attentional processing, with the first viewed object taking precedence for subsequent displays. While such an effect has not been observed in attentional inhibition studies previously, Ristic and Kingstone (2005) found a comparable effect in a gaze cueing task. In the centre of the display, an ambiguous stimulus which could be perceived either as a schematic car or a pair of eyes with a hat was presented. The "eyes" of the stimuli looked to either the left or the right of the display which served as the cue. Then, a target appeared either at the location where the "eyes" looked (validly cued) or at the opposite location (invalidly cued). In one block, participants were told the stimulus was a car, while in the other block they were told the stimulus was a pair of eyes, with participants completing both blocks. In the eyes condition, participants showed faster reaction times for valid targets compared to invalid targets, while no difference was found in the car condition. However, if the car condition was completed after the eyes condition, participants then responded faster to valid targets. Thus, despite explicit information to the contrary, participants persisted in treating the ambiguous stimulus as a pair of eyes. As the resulting cueing effects for the second display differed from those of the first display, presumably the prior information contributed to but did not entirely determine the cueing effects that would be observed.

A final possibility is that this order effect is simply methodological. As eye movements were not controlled, it is possible that participants did not fixate on the fixation point throughout the experiment and may have oriented their attention differently at different points of the experiment or to different stimuli (e.g. participants oriented more frequently to the objects instead of the fixation point in the face condition rather than the ellipse condition). Although this cannot be entirely ruled out, it is considered unlikely. Firstly, participants were instructed to maintain fixation on the fixation point at all times. Secondly, as participants were told that the cue is not predictive of the target location, the optimal strategy to detect the target would be to fixate at an equal distance from the possible target locations, which would correspond in the present experiments to the fixation point (located at the centre of the screen). There is evidence from a multiple object tracking study that in the absence of instruction, participants tend to fixate at a point of equal distance from the possible targets (Fehd & Seiffert, 2008).

Experiment 2 found ICEs for an ellipse while finding object-based facilitation for a schematic face. The facilitatory cueing effect for faces was particularly unexpected, as previous experiments have found ICEs consistently for comparable (non-emotional) face stimuli. The primary reason for the difference between the present experiment and previous work is the use in this experiment of a dynamic display, contrasting with the static displays of previous experiments. This suggests that the ICEs found for faces in previous experiments may reflect a location-based effect rather than an ICE generated by the faces themselves. It appears that once cued, the attentional system may continue to attend a face in a dynamic display for some period of time, which may explain the attentional benefit (i.e. facilitation) obtained. However, these findings are mitigated by the finding of an order effect, with these cueing effects only obtained when the relevant condition was completed first. Two explanations are posited for this order effect: one is that the first condition produced an attentional set which was applied to the second condition, while the second explanation is that the stimuli were responded to similarly due to the objects used in the two displays sharing low-level properties. An additional relevant factor that was not considered in Experiment 2 was the relative complexity of the stimuli used, with the schematic face containing more features than the ellipse. Thus, the differences in cueing effects may be attributable to the relative complexity of each stimulus. It has generally been found that object-based cueing effects, whether inhibitory or facilitatory, increase in magnitude as objects become more complex (Reppa et al., 2012). However, this would appear to suggest that the face should have produced greater ICEs than the ellipses, the opposite effect observed here. Reppa et al.'s (2012) observation is based exclusively on static displays, so one possibility is that the effect of complexity differs in dynamic displays. To explore the effect of stimulus complexity, Experiment 3 replicated Experiment 2 but used a scrambled face instead of an ellipse for the non-face condition. The scrambled face used contained the same features as the schematic face, but presented in a non-face arrangement. If complexity by itself was driving the results, these two stimuli should produce similar cueing effects as they are identical in their features. However, if one of the cueing effects was unique to faces, then this would be apparent regardless of the shared features. Additionally, studies that have compared face and scrambled face stimuli in static displays have produced inconsistent results. Fox et al. (2002) used scrambled faces and schematic faces as cues in a static spatial cueing task and found that while neutral faces did produce ICEs, neither angry faces nor scrambled faces did. Fox et al. (2002) propose that the ambiguous nature of the scrambled face may have been perceived as threatening. In this explanation, the salience of a threatening (angry face) or potentially threatening (scrambled face) was sufficient to overcome ICEs, while for a more neutral stimulus (an expressionless face) ICEs were not affected. This is consistent with the habituation and reorienting hypotheses. If this explanation holds, then participants may show comparable cueing effects for the schematic face and scrambled faces (or even increased facilitation for the scrambled face). In contrast, if the scrambled face is not perceived as a face, it may produce an object-based ICE. However, Taylor and Therrien (2005; 2008) found both faces and scrambled face targets produced ICEs in detection and discrimination tasks, with scrambled faces producing greater ICEs than faces in detection tasks and faces producing greater ICEs than scrambled faces in discrimination tasks. Additionally, the difference in results between Fox et al. (2002) and Taylor and Therrien (2005; 2008) may be due to the differences in their designs, as Fox et al. (2002) used faces as cues and Taylor and Therrien (2005; 2008) used faces as targets. The obtained results may also be affected if an order effect comparable to Experiment 2 is present in this experiment. If the face and scrambled face stimuli produce different cueing effects, their shared outlines might also produce an order effect if the order effect identified in Experiment 2 is related to the shared stimulus properties, but may not if this order effect is related to participants' attentional set.

3.3 Experiment 3

3.3.1 Method

3.3.1.1 Participants

Thirty-eight participants volunteered for this experiment. Twenty-two of the participants were female. Participant age ranged from 17 to 55 years (M = 25 years). All participants had normal or corrected-to-normal vision. Assuming an effect size of d = 0.2 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 36 participants would produce a power of .8. Participants were recruited until 36 were tested and then all remaining recruited participants were tested, giving an actual power of .84. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

3.3.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting schematic faces and one condition presenting scrambled versions of the faces. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or scrambled faces). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

3.3.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix B). The apparatus used in this experiment was identical to that of Experiment 2.

3.3.1.4 Stimuli

The face stimulus was the same as that in Experiment 2 (which was originally used in Fox et al., 2002 as a neutral face). The scrambled face was created by re-arranging the internal features of the schematic face in a random arrangement. The scrambled face used by Fox et al. (2002) was not used in this experiment as Fox et al. (2002) created their scrambled face using the features of an angry schematic face. To ensure that these differing features did not affect results, the features used in the scrambled face were identical to that of the face used. The scrambled face stimulus, as well as the stimuli used in subsequent experiments, are presented in figure 3.3.

3.3.1.5 Procedure

Excluding differences in stimuli, the procedure was identical to that of Experiment 2.

3.3.2 Results

Prior to analysis, all reaction times below 100ms were excluded from analysis (N=70, 1% of trials). Responses indicating no target appeared during a probe trial were also eliminated (N = 16, <1% of trials). There was a total of 23 responses to catch trials, representing an error rate of 10%. Note that while 10% of incorrect responses to catch trials may seem noteworthy, this is due to the very small number employed in this experiment: 20 out of 38 participants made no incorrect responses. Of the remaining 18 participants, the average number of errors was 1.3.

Median reaction times were analysed using a 2 (Condition: Face versus Scrambled Face) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) x 2 (Order: Face first versus Scrambled Face first) mixed-model ANOVA. The reaction times for each condition and cue validity combination are presented in table 3.2. The effect of Condition was significant ($F(1, 36) = 6.487$, p

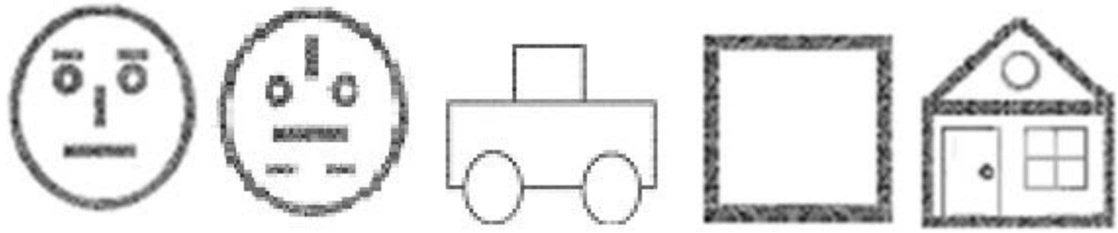


Figure 3.3: *The stimuli used in Experiments 3-6: schematic face (Experiments 3-6), scrambled face (Experiment 3), schematic car (Experiment 4), square (Experiment 5) and schematic house (Experiment 6). These images are approximately 20% smaller than their sizes in the experiment.*

= .015, η^2 = .153), suggesting that participants responded to the two conditions differently. Additionally, the main effect of Cue Validity was found to be significant (F (2, 72) = 3.427, p = .038, η^2 = .087). Thus, it appears that for these objects, the cue validity of the cue did affect responses. The order that the conditions was completed in did not interact significantly with either the Condition (F (1, 36) = 0.15, p = .701, η^2 = .004) or the Cue Validity (F (2, 72) = 1.913, p = .155, η^2 = .05). Thus, the order the conditions were completed in did not affect reaction times or the effect of cue validity. Although not statistically significant, there was marginal evidence for an interaction between Condition and Cue Validity (F (2, 72) = 2.415, p = .097, η^2 = .063). Thus, the validity of the cue may have affected responses differently between the two conditions. Finally, the three-way interaction of Condition, Cue Validity and Condition Order was not significant (F (2, 72) = 0.324, p = .724, η^2 = .009).

With regard to the significant effect of condition, it was found that reaction times in the scrambled face condition (M = 271ms, SEM = 7.5) were significantly shorter than reaction times for the face condition (M = 284ms, SEM = 8.5).

The significant effect of cue validity was further examined using Bonferroni corrected post-hoc tests. Across both conditions, the invalid reaction times (M = 280ms, SEM = 7.6) were significantly longer than the valid object reaction times (M = 274ms, SEM = 7.4, p = .044, d = 0.13). However, the invalid reaction times did not differ significantly from the valid location reaction times (M = 279ms, SEM = 8.2, p = 1, d = 0.03). Thus, it appears that there was a significant object-based

Table 3.2
Experiment 3 reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) made for each cue validity within each stimulus type.

	Condition			
	Face		Scrambled	
Validity	RTs	Errors	RTs	Errors
Location	283 (55)	0.5	275 (51)	0.2
Object	283 (49)	0.2	266 (46)	0.1
Invalid	287 (53)	0.3	274 (47)	0.3
Location CE	4		8*	
Object CE	4		-1	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* p < .05

facilitatory cueing effect for both schematic faces and scrambled faces. Although there were no significant interactions, there was some evidence that condition and cue validity interacted. Additionally, direct comparison with Experiment 2 is not possible without examining the within-condition effects. Thus, the obtained results were explored in more detail with planned comparisons using paired two-tailed t-tests. As no order effect was identified, the t-tests were calculated for each condition regardless of the condition order. For the face condition, there was no location-based ICE (M = 4.1ms; t (37) = 1.505, p = .141, d = 0.08) nor was there an object-based cueing effect (M = 4.3ms; t (37) = 1.61, p = .116, d = 0.09). For the scrambled face condition, a significant object-based facilitatory cueing effect was present (M = 8ms; t (37) = 2.287, p = .028, d = 0.17), but no location-based cueing effect was found (M = -1.6ms; t (37) = 0.391, p = .698, d = 0.03). This is illustrated in figure 3.4.

The same 2 x 3 x 2 ANOVA was conducted on the error data. No significant effects were found (all Fs < 1, all ps > .38), suggesting that participants committed errors equally across the conditions.

3.3.3 Discussion

In Experiment 3, participants completed a dynamic cueing task using either schematic faces or scrambled faces. Participants appeared to respond similarly to both stimuli, with valid object

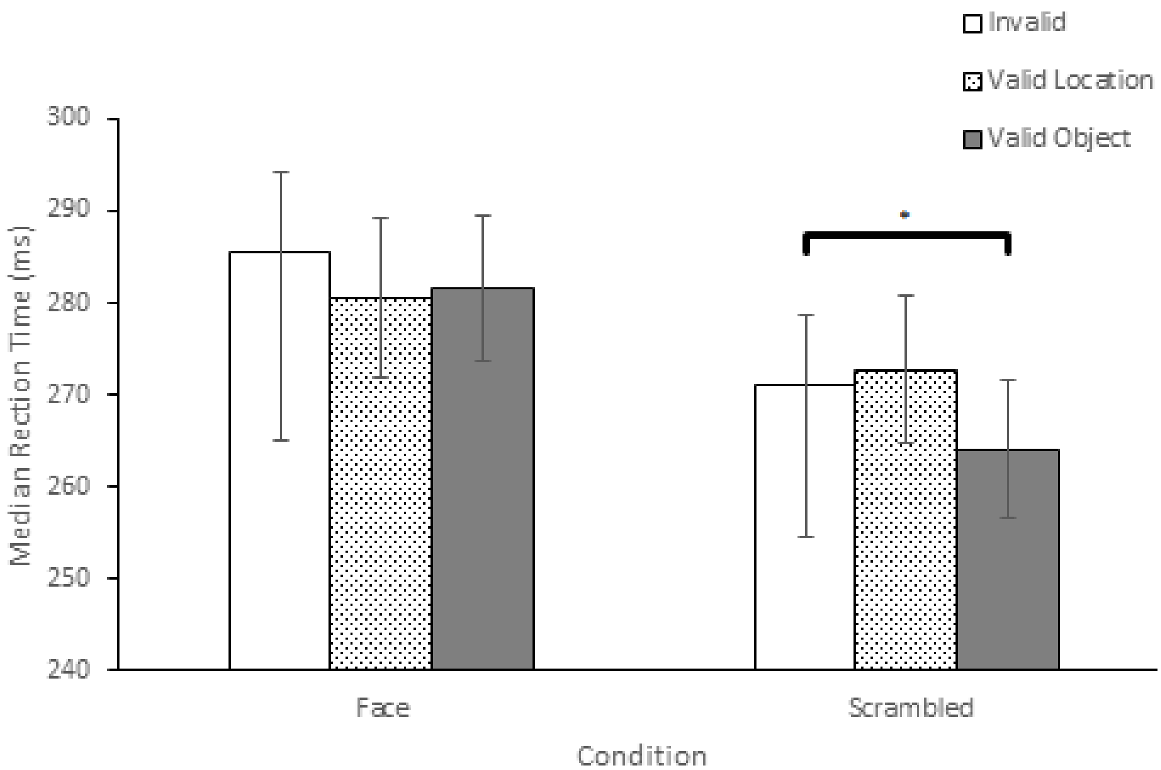


Figure 3.4: R*eaction times (ms) for each cue validity for schematic faces and scrambled faces. Error bars represent +/- 1 SEM.*
* $p < .05$

reaction times being significantly shorter than invalid object reaction times, a facilitatory cueing effect. Examining the data more closely suggested that this result was driven primarily by the scrambled face condition, which produced a larger facilitatory object-based cueing effect than the schematic face.

These results are consistent with Experiment 2 in that neither of these face-like stimuli produced ICEs. This supports the earlier finding that faces are not subject to object-based ICEs. Additionally, the fact that a specifically facilitatory object-based cueing effect was replicated, rather than a simple null result, adds credence to the idea that faces may in fact produce object-based facilitation. These data are broadly consistent with the findings of Fox et al. (2002), who found ICEs for neutral faces but no ICEs for scrambled faces. They account for this result by arguing that the scrambled face was perceived as a face and given that its scrambled features could not be interpreted as a particular emotion, it was perceived as threatening. This threat would be particularly salient and capable of overriding ICEs, in line with the habituation hypothesis. Although the results of

Experiment 3 differ in that the neutral face used here did not produce an ICE, the fact that scrambled faces produce a greater facilitatory effect could be explained by the increased threat (and therefore biological relevance) or reduced habituation to this ambiguous stimulus, as proposed by Perez-Duenas et al. (2014) and Dukewich (2009) respectively.

In this experiment, no order effects were found. This contrasts with Experiments 1 and 2, both of which found that the cueing effects observed for a condition were affected by whether that condition was completed first or second. In the light of the Experiment 2 results, it was proposed that the source of the order effect could be explained in one of two ways: it could be related to the attentional set (i.e. a spatial cueing task involving shapes produces an “attentional inhibition” attentional set where previously cued objects are selected against by the attentional system, whereas a spatial cueing task involving faces leads to an attentional set that encourages tracking cued objects) induced by the first condition or it could be due to the shared stimulus properties between the conditions. The fact that Experiment 3 did not find an order effect is evidence against the shared stimulus properties explanation. In Experiment 2, the similarity of the stimuli was simply because they shared outlines. However, in Experiment 3, the stimuli shared both outlines and the same internal features, albeit the internal features were in different locations. Despite the increased similarity of the stimuli, the order effects disappeared. This argues against the notion that the order effect in Experiment 2 was attributable to the shared stimuli. However, it is possible that any order effect related to stimulus similarity may have been obscured by the fact that both stimuli produced facilitatory cueing effects, unlike Experiment 2 where the ellipse and faces produced cueing effects in opposing directions. Although it is not entirely clear why the use of schematic faces in a detection task would alter participants' attentional sets, the lack of order effects could be because participants applied a similar attentional set to both sets of stimuli as both stimuli were face-like.

An additional unexpected finding was the lack of location-based cueing effects. This stands in opposition to Experiments 1 and 2, which found location-based cueing effects for both stimuli. However, it is worth noting that location-based cueing effects were weak or absent for faces in Experiment 2 depending on the condition order. This raises the possibility that face-like stimuli in dynamic displays may also disrupt location-based ICEs. Alternatively, it is possible that the characteristics of this display do not favour location-based ICEs. It has generally been observed that ICEs, whether location-based or object-based, require relevant representations to be generated. That is, when objects are ambiguous, object-based cueing effects are weaker or absent (Schendel, Robertson, & Treisman, 2001; Tipper et al., 1994). Similarly, location-based cueing effects are not observed in displays that lack location information or that emphasise object representations over location representations (e.g. Tipper et al., 1999). Although neither explanation can be definitively chosen, the fact that location-based ICEs were found in Experiments 1 and 2 argues against the claim that this display type does not favour location-based ICEs.

One question that remains is whether participants viewed the scrambled faces as faces or as objects. Given that object-based ICEs have been consistently found for all classes of non-face objects tested to date (see Reppa et al., 2012 for a review), the fact that the scrambled faces did not produce object-based ICEs would suggest they were treated as faces. However, it cannot be stated with certainty whether they were treated as faces or not. Accordingly, it is necessary to compare schematic faces with an object that is similar in complexity but is unambiguously not a face. If the habituation account is correct, then any stimulus of sufficient salience to not be habituated to may not show object-based ICEs. Experiment 4 addressed these issues by comparing a schematic car, an object which is more explicitly not a face, to a schematic face. Provided the facilitatory cueing effect is attributable to the stimuli in Experiment 3 both being perceived as faces, and it is faces alone that produce a facilitatory cueing effect, then object-based facilitation should be observed only for the schematic face and not for the car. However, if object complexity interacts with cueing effects and/or the schematic car is of sufficient salience to not show habituation, then object-based facilitation may be observed in this condition.

3.4 Experiment 4

3.4.1 Method

3.4.1.1 Participants

Thirty-one participants completed the present experiment. Twenty of the participants were female. Participant age ranged from 17 to 56 years (M = 23 years). All participants had normal or corrected to normal vision. Assuming an effect size of d = 0.2 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 36 participants would produce a power of .8. Unfortunately due to time constraints this requirement was not met. For this sample, the actual power was .74. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University’s and the BPS guidelines for ethical research.

3.4.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting schematic faces and one condition presenting schematic cars. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or cars). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

3.4.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix B). The apparatus used in this experiment was identical to that of Experiment 2.

3.4.1.4 Stimuli

The face stimulus was the same as that in Experiment 2 (which was originally used in Fox et al., 2002 as a neutral face). The schematic car was a novel stimulus created using the same geometric elements (albeit resized) as used in the schematic face. The stimulus represented the side view of a car and consisted of a square placed on top of a rectangle, with two ellipses located at the bottom of the rectangle. The car stimulus is presented in figure 3.3.

3.4.1.5 Procedure

Excluding differences in stimuli, the procedure was identical to that of Experiment 2.

3.4.2 Results

Reaction times below 100ms (N=21, <1% of trials) were removed prior to analysis, as were incorrect responses (N=85, 2% of trials). The reaction time data are summarised in table 3.3. Median reaction times were analysed using a mixed-model repeated measures ANOVA, specifically a 2 (Condition: Car versus Face) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid cues) x 2 (Condition Order: Car first versus Face first) ANOVA. A significant main effect of Condition was found ($F(1, 29) = 10.969$, $p = .002$, $\eta^2 = .274$), indicating that reaction times differed between the face condition and object condition. The main effect of Cue Validity was also significant ($F(2, 58) = 4.722$, $p = .013$, $\eta^2 = .14$), indicating that the different cues employed did affect participants' responses. No interactions were found in this analysis (all Fs < 1.7, all ps > .2).

Table 3.3
Experiment 4 reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) for each cue validity within each stimulus type.

	Condition			
	Face		Car	
Validity	RTs	Errors	RTs	Errors
Location	329 (67)	3.5	299 (47)	0.5
Object	317 (62)	3.2	297 (47)	0.4
Invalid	325 (70)	3.5	305 (58)	0.1
Location CE	-4		6	
Object CE	8		8*	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* p < .05

With regard to the significant main effects, reaction times for the face condition (M = 323ms, SEM = 10.3) were significantly longer than the reaction times for the car condition (M = 300ms, SEM = 8.1). For the main effect of cue validity, Bonferroni corrected post-hoc tests found the reaction times for invalid trials (M = 314ms, SEM = 9.3) did not differ from the reaction times for valid location trials (M = 313ms, SEM = 8.5, p = 1). However, the reaction times for valid object trials (M = 306ms, SEM = 8.5) were significantly shorter than the reaction times for invalid trials (M = 314ms, SEM = 9.3, p = .015). This suggests that for both cars and faces, a valid object cue facilitated participant responses by approximately 8ms, but no location cueing effect was present.

To allow more direct comparison to previous experiments, the cueing effects for the face and car conditions were calculated separately. As no order effect was identified, the t-tests were calculated for each condition regardless of the condition order. As in previous reports, the means displayed are the invalid reaction times minus the valid reaction times. Thus, a negative value indicates an ICE while a positive value indicates a facilitatory effect. For the face condition, there was no location-based ICE (M = -3.4ms; t (30) = 0.654, p = .518, d = 0.05) nor was there an object-based cueing effect (M = 7.8ms; t (30) = 1.767, p = .087, d = 0.12). For the car condition, a significant object-based facilitatory cueing effect was present (M = 8.9ms; t (30) = 2.149, p = .04, d = 0.16), but no location-based cueing effect was found (M = 6ms; t (30) = 1.036, p = .309, d = 0.11). This is illustrated in figure 3.5.

Examining the error data (misses on probe trials) using the same mixed-model ANOVA revealed a significant effect of Condition (F (1, 29) = 7.943, p = .009, η^2 = .215). Examining the means revealed that a significantly greater number of misses were made in the face condition (M = 2.4 misses, SEM = 0.8) compared to the car condition (M = 0.3 misses, SEM = 0.1). No other significant effects were found (all Fs < 0.2, all ps > .87). Importantly, there was no evidence of a difference in error rate in relation to cue validity.

3.4.3 Discussion

In Experiment 4, no significant ICEs were present for either schematic faces or cars. The primary finding was that the car stimulus produced a significant facilitatory cueing effect. As in Experiments 2 and 3, schematic faces again did not produce ICEs. This is consistent with proposals that faces may not be subject to object-based inhibition. However, schematic cars also did not produce ICEs. This was an unexpected finding given that non-face objects in Experiments 1 and 2 produced significant ICEs and more generally, the consistent finding of object-based ICEs at the SOA used in this experiment (Reppa et al., 2012). This finding makes it clear that it is not exclusively biological relevance that can prevent the generation of ICEs as implied by Perez-Duenas et al. (2014). In contrast, Dukewich's (2009) habituation account, as well as the reorienting hypothesis, are consistent with the possibility that non-biological objects may not produce ICEs. Although Dukewich (2009) allows for the possibility that highly salient objects would not show ICEs, it is not obvious why a schematic car in a detection task would be salient enough to not show habituation. As discussed previously, it is possible that ICEs are influenced by participants' attentional set. A feature that cars and faces share is their propensity for motion. Although motion clearly does not disrupt object-based ICEs for many objects (e.g. Tipper et al., 1991), for these objects the motion is a relevant characteristic that can influence how an object should be attended to. Thus, it is possible

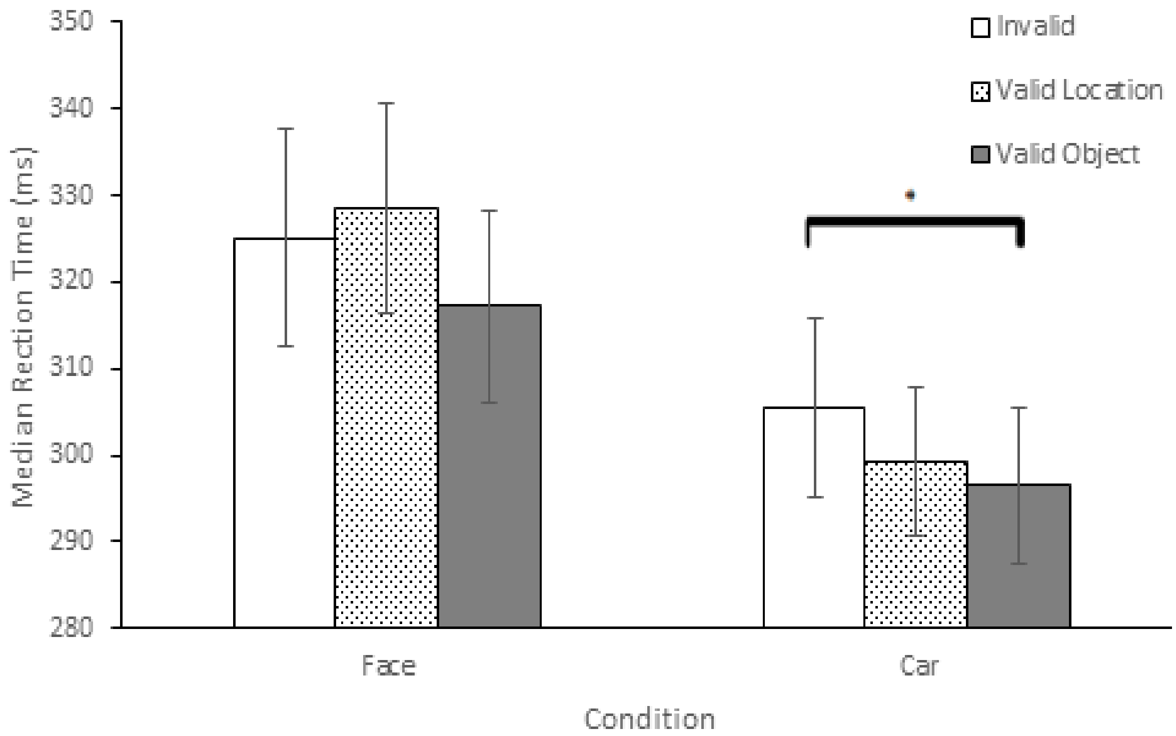


Figure 3.5: *Reaction times (ms) for each cue validity for schematic faces and schematic cars. Error bars represent +/- 1 SEM.*
* p < .05

that when an object that is expected to move does move, that participants' attentional set is biased to re-examining the object, leading to a facilitatory object-based cueing effect.

The facilitatory cueing effects may also be a particular product of the schematic stimuli used. This is consistent with research into the face in the crowd effect, which has found that particular features when used in schematic faces lead to faster reaction times in detecting these faces. For example, Purcell and Stewart (2010) found that faces with internal features that opposed the contour of the face's circumference were detected more quickly than those where the internal features followed the contour. Coelho, Cloete and Wallis (2010) similarly found that inward pointing internal features were detected more quickly than radial internal features. Although neither of these findings apply specifically to the facilitatory cueing effects obtained for scrambled schematic faces and schematic cars in the present experiments, they illustrate the possibility that stimulus properties may be driving these effects.

As in Experiment 3, location-based cueing effects were not observed. In the discussion of

Experiment 3, it was suggested that either the display type used did not favour location-based cueing effects or the face-like stimuli disrupted location-based ICEs as well as object-based ICEs. Given the similarities between Experiments 3 and 4, this experiment does not provide a way to disentangle the explanations posited.

Although Experiments 3 and 4 expand neatly on the finding of Experiment 2 that schematic faces do not produce object-based ICEs by observing a similar pattern of results for both scrambled faces and schematic cars, there are several open questions in relation to the experimental designs employed. For example, all four experiments presented used a single SOA. This could have affected results for a number of reasons. Firstly, it may be that the facilitatory cueing effects observed for face-like stimuli and schematic cars are specific to the 900ms SOA employed in these experiments. Although this would be surprising given that facilitatory cueing effects have not been reported at SOAs of this length previously, the possibility exists that these objects do produce ICEs but at a different time course to normal objects. This has been demonstrated previously in IOR research, with Klein and Pontefract (1994) failing to find ICEs in a discrimination task when a single SOA was used, with Lupiáñez et al. (1997) demonstrating that ICEs were present but only at longer SOAs than in detection tasks by using a range of SOAs. Secondly, regardless of the SOA(s) used, the range of SOAs in an experiment has been found to affect the cueing effects observed. For example, Gabay and Henik (2010) found reduced facilitatory cueing effects at short SOAs as the proportion of trials at long SOAs increased. Conversely, Milliken, Lupiáñez, Roberts and Stevanovski (2003) found that increasing the proportion of short SOAs increased both facilitatory and inhibitory cueing effects. If the facilitatory cueing effect found here is specific to this SOA and that later SOAs would produce ICEs, then adding a longer SOA would reduce the facilitatory cueing effects observed here. However, it should be noted that these findings appear to be specific to discrimination tasks, with Milliken et al. (2003) not observing this pattern of results in a detection task.

An additional point of note is the use of hollow objects in Experiments 2 to 4. There is evidence that the "solidity" of an object can influence cueing effects. Lines of evidence supporting this argument include the fact that illusory objects produce weaker object-based cueing effects compared to objects that have visible outlines (Jordan & Tipper, 1999) and the fact that filled objects produce greater ICEs than hollow objects (Reppa & Leek, 2003, 2006; Smith et al., 2016). The comparatively weak object-based effects for shapes in Experiment 2 compared to Experiment 1 may be attributable to this design choice. More importantly, the lack of object-based ICEs found for face-like stimuli and schematic cars might be related to this stimulus property.

Taking these points into consideration, Experiment 5 replicated Experiment 2 with several important design choices changed. Firstly, three SOAs were used in the present experiment: in addition to the 900ms SOA of previous work, a shorter (750ms) and a longer (1500ms) SOA were used. This allows a specific examination of these SOAs on the cueing effects for faces and shapes as well as a more general assessment to see how the use of a range of SOAs may affect the results relative to a single SOA. Secondly, the background of the display was changed from white to grey and the (white) stimuli were given thicker outlines. This was done with the expectation that object-based cueing effects would increase in magnitude as the objects would now be seen as filled rather than hollow. To reduce the chance of order effects being present, squares were used instead of ellipses for the object condition.

3.5 Experiment 5

3.5.1 Method

3.5.1.1 Participants

Thirty-two participants (24 females) volunteered for the study. The age of participants ranged from 18 to 62 years (M = 24). All participants reported normal or corrected-to-normal vision. Assuming an effect size of d = 0.19 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 22 participants would produce a power of .8. As recruitment was faster than anticipated, this was increased to 32 participants to achieve a power of .95. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

3.5.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting faces and one condition presenting squares. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or squares). The third independent variable was the SOA, which consisted of three levels (750ms, 900ms, 1500ms). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

3.5.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix C). The apparatus used in this experiment was identical to that of Experiment 2.

3.5.1.4 Stimuli

The face stimulus was the same as that in Experiment 2 (which was originally used in Fox et al., 2002 as a neutral face). For the object condition, a square was created using straight lines from the schematic face. The two objects were matched for area.

3.5.1.5 Procedure

The procedure was comparable to that of Experiment 2. However, the post-motion SOA could now be one of three lengths: 150ms, 300ms and 900ms. This accommodates the three possible total SOAs of 750ms, 900ms and 1500ms respectively. The number of trials was also changed to equally distribute trial types across the three SOAs. Thus, for both the square condition and face condition, there were a total of 141 trials, with 6 catch trials and 135 probe trials. This corresponds to 15 probe trials for each combination of SOA and cue validity for each condition.

3.5.2 Results

Reaction times <100ms (N = 6, <1% of trials) were removed prior to analysis. Incorrect responses (misses) were also removed before analysis (N = 109, 1% of trials). A 2 (Condition: Square versus Face) x 3 (SOA: 750ms versus 900ms versus 1500ms) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) x 2 (Condition order: Square first versus Face first) repeated-measures ANOVA was conducted on the median reaction times. The results are displayed in table 3.4. There was no main effect of Condition ($F (1, 30) = 0.276$, $p = .603$, $\eta^2 = .009$) or Cue Validity ($F (2, 60) = 0.186$, $p = .831$, $\eta^2 = .006$). There was an effect of SOA ($F (2, 60) = 8.064$, $p = .003$, $\eta^2 = .212$). There was a significant interaction between Condition and Cue Validity ($F (2, 60) = 3.193$, $p = .048$, $\eta^2 = .096$), as well as a significant interaction between Condition and Condition Order ($F (1, 30) = 9.17$, $p = .005$, $\eta^2 = .234$). All other interactions were non-significant (all Fs < 2.2, all ps > .08).

Examining the significant main effect of SOA, Bonferroni corrected post-hoc tests found that the reaction times for the 900ms SOA (M = 346ms, SEM = 15.8) were significantly shorter than the reaction times for the 750ms SOA (M = 369ms, SEM = 17; $p < .001$) and the reaction times for the 1500ms SOA (M = 371ms, SEM = 15.8; $p = .015$). No difference was found between the 750ms and 1500ms SOAs ($p = 1$). The interaction of condition order and stimulus type was also examined using two-tailed paired t-tests. When the square condition was completed first, the reaction times for

Table 3.4

Reaction times (ms) and percentage of errors (standard deviations in brackets) for each cue validity within each SOA and stimulus type in Experiment 5.

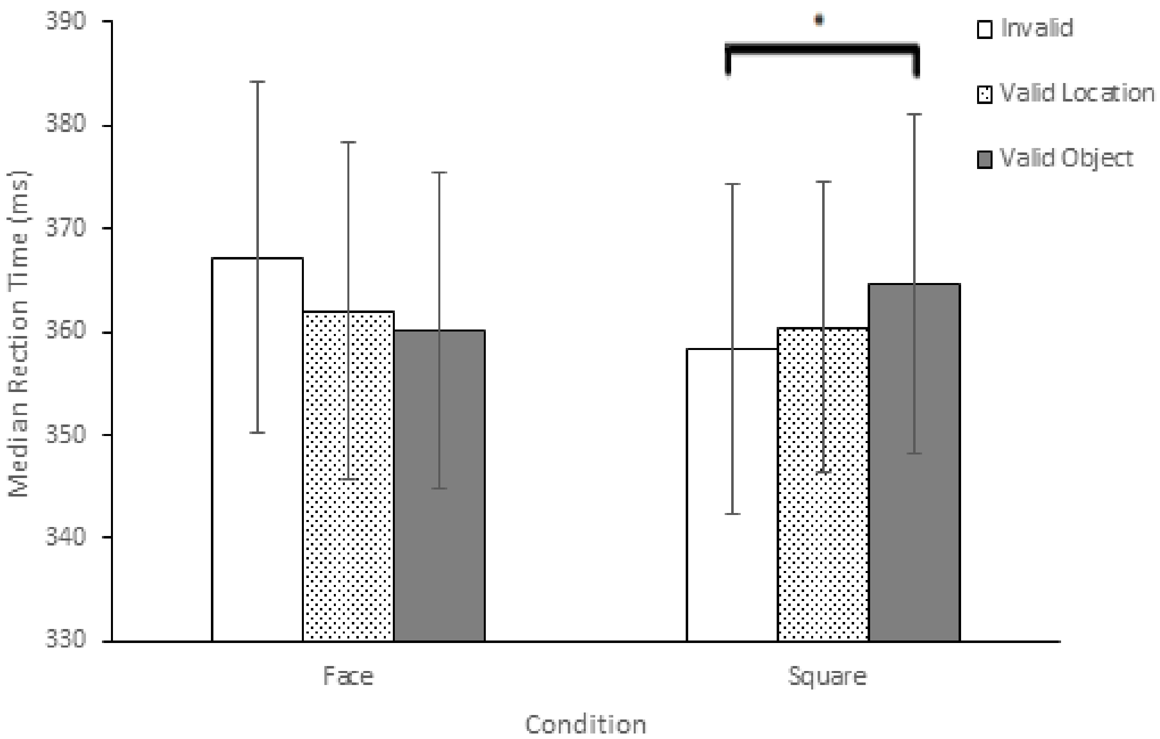
		Cue-target SOA (ms)							
		750		900		1500		Average	
Target	Validity	RTs	Errors	RTs	Errors	RTs	Errors	RTs	Errors
Square	Location	371 (85)	1.3	339 (74)	0.8	372 (90)	2.3	360 (79)	1.5
	Object	368 (93)	0.2	340 (89)	0.4	386 (114)	1.5	365 (93)	0.7
	Invalid	361 (100)	1	350 (94)	0	364 (96)	0.6	358 (91)	0.5
	Location CE	-10		11		-8		-2	
	Object CE	-7		10		-22**		-7*	
Face	Location	369 (113)	1	345 (86)	0.4	373 (96)	3.3	362 (93)	1.6
	Object	371 (97)	1.9	348 (103)	1.5	362 (77)	2.9	360 (87)	2.1
	Invalid	376 (112)	1	352 (102)	0.6	374 (91)	1.9	367 (97)	1.2
	Location CE	7		7		1		5	
	Object CE	5		4		12		7	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* p < .05
** p < .01

this task (M = 370ms, SEM = 23.1) were longer than those for the subsequent face task (M = 355ms, SEM = 23.2). However, this difference was non-significant (t (16) = 1.505, p = .152, d = 0.16). When the face condition was completed first, the reaction times for this task (M = 373ms, SEM = 22.8) were longer than those for the subsequent square task (M = 351ms, SEM = 79). This difference was significant (t (14) = 3.607, p = .003, d = 0.26). Thus, in both condition orders the first condition completed was slower than the second condition by 15ms (square first) and 22ms (face first) respectively, although only the latter was significant. This is assumed to be a practice effect.

To examine the interaction of Cue Validity and Condition, planned comparisons of the median reaction times for each condition were made using two-tailed paired t-tests. For each condition, the invalid reaction time was compared to the valid location reaction time for the location cueing effect and the valid object reaction time for the object cueing effect: positive values indicate a facilitatory cueing effect, while negative values indicate an ICE. For the square condition, a significant object-centred ICE was found ($M = -6.3$ms; $t(31) = 2.095$, $p = .044$, $d = 0.07$) while no location cueing effect was found ($M = -2.1$ms; $t(31) = 0.549$, $p = .587$, $d = 0.02$). For the face condition, an object-based facilitatory cueing effect that approached statistical significance was identified ($M = 7$ms; $t(31) = 1.822$, $p = .078$, $d = 0.08$), while no location cueing effect was found ($M = 5.2$ms; $t(31) = 1.62$, $p = .115$, $d = 0.06$). This is presented in figure 3.6. Although cue validity did not interact with SOA, the cueing effects and effect sizes were calculated for each stimulus type for each SOA to further examine the time course of these effects. For the face condition at the 750ms SOA, a weak facilitatory location-based cueing effect was found ($M = 6.8$ms, $d = 0.06$), while there was less evidence for any object-based cueing effect ($M = 4.6$ms, $d = 0.04$). For the face condition at the 900ms SOA, neither a location-based cueing effect ($M = 7.4$ms, $d = 0.08$) nor an object-based cueing effect ($M = 4$ms, $d = 0.04$) was observed. At the 1500ms SOA, no location-based cueing effect was found ($M = 1.4$ms, $d = 0.02$), while there was evidence for an object-based facilitatory cueing effect ($M = 12.3$ms, $d = 0.15$). For the square condition, the 750ms SOA produced a location-based ICE ($M = -9.8$ms, $d = 0.1$) and a weak object-based ICE ($M = -7.1$ms, $d = 0.07$). For the 900ms SOA, the cueing effects were in a facilitatory direction with a location cueing effect of $M = 11.3$ms ($d = 0.13$) and an object cueing effect of 9.9ms ($d = 0.11$). Finally, the 1500ms SOA produced a location-based ICE ($M = -7.9$ms, $d = 0.08$) and an object-based ICE ($M = -21.7$ms, $d = 0.2$). When examined using paired samples two-tailed t-tests, only the square object-based ICE at 1500ms was significant ($t(31) = 2.805$, $p = .009$).

Given the facilitatory effect in the square condition at the 900ms SOA, the square condition cueing effects were re-examined post-hoc without this SOA. This increased the object-based ICE to -14.4ms ($t(31) = 2.833$, $p = .008$, $d = 0.15$) and the location-based ICE to -8.8ms ($t(31) = 1.786$, $p = .084$, $d = 0.1$).



F**igure 3.6**: *Reaction times (ms) for each cue validity for schematic faces and squares collapsed across SOAs. Error bars represent +/- 1 SEM.*
* p < .05

The same repeated-measures ANOVA was repeated for the error data (misses on probe trials). A significant effect of SOA was found ($F(2, 60) = 5.803$, $p = .005$, $\eta^2 = .162$). The fewest misses occurred at 900ms (M = 0.6 misses, SEM = 0.2), with more misses occurring at 750ms (M = 0.9 misses, SEM = 0.4) and 1500ms (M = 1.9 misses, SEM = 0.5) respectively. Bonferroni corrected post-hoc tests revealed only the comparison between the 900ms and 1500ms SOAs was statistically significant ($p = .025$). Importantly, there was no evidence of a difference in error rates in relation to cue validity.

3.5.3 Discussion

In Experiment 5, the principal aim was to extend the findings of Experiment 2 to a design incorporating multiple SOAs. Specifically, it was expected that the square condition would produce significant ICEs, while the face condition would not produce ICEs. The results obtained were broadly consistent with these predictions.

In this experiment, no significant ICEs were found in the face condition, with the direction of the cueing effects instead being facilitatory. Although the significant facilitatory cueing effects of earlier experiments were not replicated, the lack of ICEs provides further support for the notion that faces are not subject to ICEs. Importantly, the lack of ICEs for faces in previous experiments cannot be attributed to the single SOA used in those experiments, as ICEs were not present at any of the three SOAs used. In fact, the largest facilitatory cueing effect was found at the longest (1500ms) SOA. While the majority of research into cueing effects for faces in static displays has used a single SOA, Silvert and Funes (2016) found ICEs consistently for faces across three SOAs of 500ms, 750ms and 1000ms. Again, the difference in results is best attributed to the use of a dynamic display, consistent with the claim that the ICEs observed in earlier experiments are of a location-based nature.

The square condition across all SOAs produced a significant object-based ICE. However, contrary to the expectation that the use of a solid object would increase the magnitude of the cueing effect over the hollow objects used in Experiment 2, the cueing effect was actually smaller (-6ms; d = -0.07) compared to that observed in Experiment 2 (-11ms; d = -0.12). This appears attributable at least in part to the unexpected finding of a facilitatory cueing effect at the 900ms SOA: without this SOA, the cueing effect was increased to -14ms (d = -0.15). It is unclear why a facilitatory cueing effect was present for squares specifically at the 900ms SOA in this experiment. In contrast to Experiment 2, the order in which the conditions were completed did not affect the obtained results. It was suggested that this could be due to participants adopting a particular attentional set for one block which was then applied to the second block. Alternatively, it could be a consequence of the stimuli sharing identical outlines, which led to them being perceived similarly at some level of processing. Despite the fact that Experiment 3 seemed to speak against this proposal, the lack of order effects in Experiment 5 suggests that the stimulus similarity explanation is the best fit, as this experiment used a square in the object condition, an object more distinct from the schematic face.

With the exception of the facilitatory cueing effect in the 900ms SOA in the square condition, the cueing effects for each condition were generally comparable at each SOA, with facilitatory but non-significant cueing effects in the face condition and ICEs in the square condition. However, the 1500ms SOA produced the cueing effects of the largest magnitude in both the square and the face condition. Thus, it appears the 1500ms SOA may be best suited to investigating cueing effects in dynamic displays in a blocked design that compares objects producing inhibitory and facilitatory cueing effects.

An open question from Experiment 4 was the fact that a schematic car produced a facilitatory object-based cueing effect. One possibility is that the participants had top-down expectations that the car would move, which created a bias to examine the new location of the car, leading to a facilitatory cueing effect. An alternate explanation may be that the facilitation observed is related specifically to low-level characteristics of the schematic stimuli used rather than the affordances of the stimuli. To further explore the object-based facilitatory cueing effect for schematic objects, Experiment 6 replicated Experiment 5 but used a schematic house in the object condition instead of a square. If the facilitatory object-based cueing effect was attributable to a belief regarding the object's motion, then a schematic house should not produce this effect and would presumably produce an ICE. However, if schematic objects more generally produce facilitatory cueing effects, this would be equally expected for a schematic house.

3.6 Experiment 6

3.6.1 Method

3.6.1.1 Participants

Twenty-nine participants (16 females) volunteered for the study. The age of participants ranged from 18 to 41 years (M = 24 years). All participants reported normal or corrected-to-normal vision. Assuming an effect size of d = 0.18 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 30 participants would produce a power of .8. Unfortunately due to time constraints this requirement was not met. For this sample, the actual power was .79. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

3.6.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting schematic faces and one condition presenting schematic houses. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or houses). The third independent variable was the SOA, which consisted of two levels (750ms and 1500ms). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

3.6.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix D). The apparatus used in this experiment was identical to that of Experiment 2.

3.6.1.3 Stimuli

The face stimulus was identical to that used in Experiments 2-5. The schematic house was created using elements of the square and face stimuli from the previous experiment. The outline consisted of an isosceles triangle on top of a rectangle. An attempt was made to match the complexity of the face by including internal elements (in the form of a ground level window, a dormer window and a door). These internal features were asymmetrical and were positioned specifically to minimise their similarity to a face. The objects were matched for area as closely as possible (with a face area of 1583 pixels compared to a house area of 1605 pixels). The house stimulus is presented in figure 3.3.

3.6.1.4 Procedure

The procedure was identical to that of Experiment 5, except that schematic houses replaced the squares and the 900ms SOA was removed. Ten practice trials were carried out followed by two blocks of experimental trials, with 132 trials per block. Block order was counterbalanced across participants. Six of the trials per block (5%) were catch trials. There were 21 trials for each combination of cue validity and SOA.

3.6.2 Results

Six reaction times (<1% of trials) were removed from participants' data as anticipations (<100ms). Among non-catch trials, 63 misses (1% of trials) were found and removed from subsequent analysis. A 2 (Condition: House versus Face) x 2 (SOA: 750ms versus 1500ms) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) repeated-measures ANOVA was conducted on the median reaction times. As condition order only interacted with cueing effects in Experiments 1-2 and not in subsequent experiments, condition order was not included in the ANOVA: its inclusion did not change the obtained results. The median reaction times and error rates are presented in table 3.5. The only significant main effect was that of Cue Validity ($F(2, 56) = 3.237$, $p = .047$, $\eta^2 = .104$). No other main effects were significant (all Fs < 2.9, all ps > .09). Bonferroni corrected post-hoc tests revealed that reaction times to valid object trials (M = 337ms, SEM = 15.6) were significantly shorter than reaction times to invalid trials (M = 346ms, SEM = 17.6, p = .028). Reaction times to valid location trials (M = 340ms, SEM = 15.5) did not differ significantly from RTs for either invalid trials (p = .453) or valid object trials (p = 1). Thus, both conditions generated significant facilitatory object-based cueing effects, of 9.1ms (face; d = 0.09) and 9.2ms (house; d = 0.11) respectively. No significant interactions were present (all Fs < 1, all ps > .4). This is illustrated in figure 3.7.

Table 3.5
Reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) made for each cue validity within each stimulus type and SOA in Experiment 6.

		Cue-target SOA (ms)			
		750		1500	
Target	Validity	RTs	Errors	RTs	Errors
House	Location	341 (80)	1.3	330 (73)	1.1
	Object	336 (82)	0	328 (99)	0.5
	Invalid	346 (97)	0.3	338 (111)	0.8
	Location CE	5		8	
	Object CE	10		10	
Face	Location	347 (93)	0.7	341 (105)	1.5
	Object	346 (99)	1.3	337 (95)	1.3
	Invalid	358 (111)	0.7	342 (103)	0.8
	Location CE	7		1	
	Object CE	12		5	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.

The same 2 x 2 x 3 repeated-measures ANOVA was also conducted on the error data. No significant results were found (all $Fs < 2.7$, all $ps > .09$), suggesting that participants committed errors equally across all conditions.

3.6.3 Discussion

In Experiment 6, both schematic faces and schematic houses produced a significant object-based facilitatory cueing effect. In Experiment 4, it was found that schematic cars produced object-based facilitation. It was suggested that this could be because of a change in attentional set due to experience of cars moving, leading to a bias to following the cued car to its new location or may simply be due to an effect specific to the schematic stimuli used. Given the same object-based facilitatory cueing effect was found for schematic houses, this effect appears to be applicable to schematic objects generally. This supports the suggestion that in dynamic displays, schematic objects of greater complexity than empty shapes produce object-based facilitation rather than ICEs.

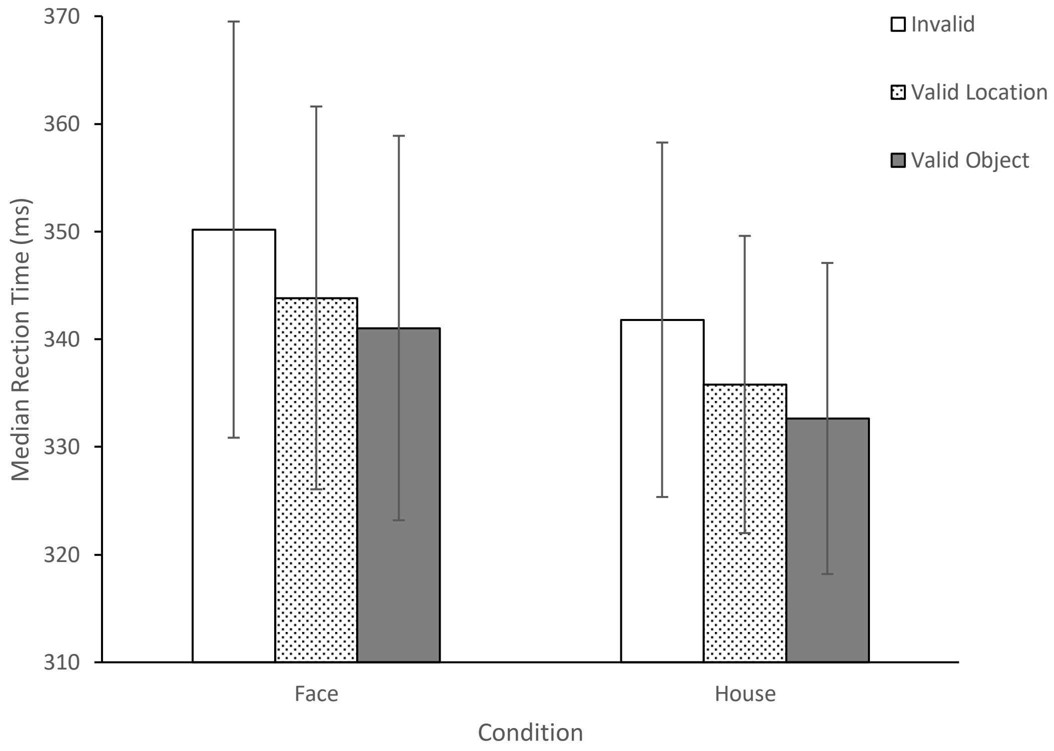


Figure 3.7: *Reaction times (ms) for each cue validity for schematic faces and schematic houses collapsed across SOAs. Error bars represent +/- 1 SEM.*

Although previous research has suggested that faces may be unique in not showing ICEs in certain circumstances (e.g. Perez-Duenas et al., 2014), in the present experiment schematic faces and schematic houses showed essentially the same cueing effect (9ms; d = 0.09 for faces, d = 0.11 for houses). Thus, at least when schematic objects are used, the cueing effect obtained does not differ between faces and other objects. This result speaks against a biological-specific explanation and favours a more general explanation of these cueing effects, such as Dukewich's (2009) habituation hypothesis.

3.7 General Discussion

The five experiments presented in this chapter explored the nature of cueing effects for schematic faces in dynamic displays. Additionally, comparisons were made between schematic faces and other objects, which included shapes and other schematic objects. Across the five experiments, three key findings were observed. In all experiments, schematic faces produced object-based facilitation and were never observed to produce either object-based or location-based ICEs. In the three experiments which used schematic objects (scrambled faces, cars, houses), object-based facilitation was observed for these objects. Again, ICEs were not observed, whether location-based or object-based. Finally, there were two experiments that used shapes (ellipses and squares). In both of these experiments, shapes produced object-based ICEs.

Unlike Experiment 2 which produced order effects, Experiments 3-6 did not show order effects. This suggests that this finding may have been a Type II error, as it was present in only one of five experiments. However, if this effect was a genuine one, then the likely source of this effect is the fact that the two stimuli had identical contours, which may have led to the stimuli in the second block being processed similarly to the stimuli of the first block. This is supported by Experiment 5 not producing order effects, which was a replication of Experiment 2 but using distinct stimuli outlines for the two blocks.

Considering the overall findings of these five experiments, all schematic objects examined (faces, scrambled faces, cars and houses) produced significant object-based facilitatory cueing effects. Additionally, location-based cueing effects were not observed in any display in which schematic objects were used. However, object-based and location-based ICEs were observed for squares in this paradigm. Thus, it appears that for schematic objects, in dynamic displays the predominant cueing effect is one of facilitation, not of inhibition. This is an unexpected finding as in experiments using non-predictive cues such as these, facilitatory cueing effects are not typically observed beyond SOAs of 300ms (Samuel & Kat, 2003). In contrast, these experiments found them robustly at SOAs of 750ms, 900ms and 1500ms.

Although unexpected, the finding is broadly consistent with two theories of attentional inhibition. In the reorienting hypothesis, facilitation can be observed in response to a cue provided participants maintain their attention at the cued location or object in question. Thus, provided participants maintained their attention to cued schematic faces or objects for the duration of the trial, the finding of facilitation is consistent with this hypothesis. While the lack of facilitation being observed beyond 300ms in previous experiments provides indirect evidence against this account, there is no direct evidence from these experiments to contradict this explanation. In the habituation hypothesis, it is predicted that attentional inhibition would not be observed for salient or intense stimuli. Again, provided the schematic objects employed were of sufficient salience to the attentional system, the lack of attentional inhibition for schematic faces and objects are consistent with the habituation hypothesis. It is not apparent how this finding would be explained by detection cost theory, as this account suggests facilitation is only attributable to location-based effects, rather than object-based effects. However, both the habituation and reorienting explanations rely on assumptions regarding either participants' orienting behaviour or the strength of the stimuli. In both cases, this would suggest that schematic objects have unique effects on attention relative to shapes which produced ICEs. While there is some support for faces exhibiting such attentional effects (e.g. Cerf et al., 2009; Crouzet et al., 2011; Langton et al., 2008), it is not so clear why schematic objects would also show this benefit. Furthermore, while the habituation hypothesis can adequately explain a lack of attentional inhibition for salient stimuli, it does not provide a mechanism to explain the facilitation observed.

One reason why schematic objects may produce facilitation while simple shapes do not may relate to the biased-competition hypothesis of attention (Desimone & Duncan, 1995). According to the biased-competition hypothesis, attentional effects interact both cooperatively and competitively at multiple levels of selection. In a search task, there are criteria with regard to the target being searched for, with objects meeting these criteria being favoured by the visual system. These criteria may be spatial, object-based, feature-based or apply to other forms of attention. When targets and nontargets can be distinguished easily on the given dimension, then attention is biased most to the objects that fit the specified criteria. If targets and nontargets are similar, then they provide stronger competition for attention, reducing search performance. Given that these different search criteria make use of different neural areas, it is proposed that the attentional bias and competition apply simultaneously throughout the attentional system (Duncan, 2006). Thus, this model predicts that once an object is selected, other characteristics of that object will be similarly biased regardless of their task relevance, leading to interactions between spatial, object-based and feature-based attention.

This interactivity was specifically tested in a three-experiment study by Kravitz and Behrmann (2011). In their first experiment, two rectangles were presented on either side of a fixation cross. In one condition, both rectangles were the same colour (identical), while in a second condition the rectangles were different colours (nonidentical). One end of one of the rectangles was cued, followed by the appearance of a target at one of five locations: the same location as the cue (valid), a different location in the same object (within-object), the same location in the opposite rectangle (between-object), a location in neither rectangle located nearer to the cued rectangle than the uncued rectangle (near-object) or a location in neither rectangle located at an equal distance from both rectangles (far-object). Additionally, the near-object location was closer to the centre of the cued rectangle than the far-object location: this was done as it has been demonstrated that targets appearing outside of a cued object are subject to greater facilitation the closer they are to the centre of the cued object (Kravitz & Behrmann, 2008). The task was a discrimination one, with participants having to identify one of two targets that appeared. In addition to the typical finding that targets at the valid location were responded to more quickly than at other locations, it was also found that the difference between valid targets and between-objects targets was significantly smaller for identical rectangles than nonidentical rectangles. This suggests that object-based attention interacted with a feature, with the shared colours of the objects benefitting target detection across different objects. A third finding of note was a significant difference in the near-object reaction times between the identical and nonidentical conditions, with the reaction times being slower in the identical condition compared to the nonidentical condition. This was interpreted as both rectangles being attentionally selected in the identical condition, which would make the near-object target further away from the centre of attentional selection compared to if only the cued rectangle was selected. Given the spatial gradient of attention, this distance from the cued centre of mass of attention was responsible for the slowed reaction times. In their second experiment, two objects were compared on their shapes instead of their colours, with the shapes either both rectangles (identical) or one rectangle and one barbell (nonidentical). This experiment produced a similar pattern of results, with the difference between valid targets and between-object targets again reduced in the identical condition compared to the nonidentical condition. Unlike in the first experiment, the overall reaction times for near-object targets did not differ between the identical and nonidentical conditions, but a significant difference was found in the difference scores, with greater difference scores for near-object targets in the identical condition compared to the nonidentical condition. In their final experiment, Kravitz and Behrmann (2011) explored whether the category of an object could have a similar effect. In this experiment, an uppercase letter H was compared to either a lowercase h (identical category) or a 4 (nonidentical category). The lowercase h and 4 were the same object but presented either upright or inverted to rule out low-level image characteristics as affecting the results. Unlike in previous experiments, the task was a detection task rather than a discrimination task. The results of this experiment were comparable to those of their second experiment, with the difference score between valid targets and between-object targets in the identical category condition significantly smaller than in the nonidentical category condition. In summary, Kravitz and Behrmann's (2011) experiments suggest that facilitation applies not only to a cued object, but to other objects that share perceptual or semantic properties.

Kravitz and Behrmann's (2011) finding can be applied to the present experiments. For all objects, attention effects may arise from cues that target a specific location or object. However, simple shapes and schematic objects differ in the features and category information they provide. Although shapes and schematic objects both have specific features, the primary feature of the shapes is their outline, whereas schematic objects have multiple parts that could influence attention. Similarly, a shape does provide category information but presumably contains much less semantic content than a schematic object. It is proposed that the more "varieties" of attention that are indicated by the cued stimulus there are, the greater the facilitatory (or inhibitory) effect of the cue. For shapes that provide limited feature- and category-based information, the facilitatory effect of the cue is insufficient to prevent the appearance of ICEs. However, the extra activation of the attentional system afforded by the multiple features and higher-level semantic information of schematic objects proved sufficient to override ICEs. The activation of multiple representations of attention appears consistent with the fact that both object-based and location-based ICEs are not present for schematic objects. Given the influence of the object's features and category, it seems reasonable that the facilitatory effects are stronger at the object's new location compared to its cued location, although the multiple forms of attention lingering at the location of the cue do appear to provide a weaker facilitatory effect. This is supported by the observation that the object-based facilitatory effect is greater than the location-based facilitatory cueing effect.

Another point to note with the biased-competition hypothesis is the fact that in the present experiments, each object in the display was identical. Given the results of Kravitz and Behrmann (2011) that uncued objects which shared properties with the cued object also showed a facilitatory effect, this would suggest that all objects in the display would be facilitated. This may suggest that the fact that object-based facilitation was observed is inconsistent with this hypothesis, as two identical objects received differing amounts of facilitation. However, although the objects were identical images, they still differed with regard to both their location and the specific spatiotemporal identity. Thus, while the uncued objects may have been facilitated due to shared featural and categorical information with the cued object, the cued object would have benefited uniquely with regard to location-based and object-based attention. This suggests that the observed cueing effects may be increased further by using objects of differing features and categories in the display. One source of support for this is the fact that Experiment 1, which used a variety of shapes in each display, produced ICEs of greater magnitude than Experiment 5, which only used one object image (as measured by effect size; Experiment 1 object-based ICE d = 0.23; Experiment 5 object-based ICE d = 0.15).

Given the distinct lack of facilitatory cueing effects identified in comparable studies (i.e. at SOAs beyond 400ms using non-predictive cues, facilitation has not been observed previously; Reppa et al., 2012; Samuel & Kat, 2003), it seems surprising that this object-based facilitatory cueing effect for schematic objects has not been observed previously. However, it is important to note that studies of cueing effects using dynamic displays have consistently used simple shapes (e.g. Abrams & Dobkin, 1994; Christ, McCrae, & Abrams, 2002; Gibson & Egeth, 1994; Tas et al., 2012; Tipper et al., 1991, 1994; Vivas et al., 2008; Weaver et al., 1998). Thus, these experiments may well represent the first exploration of complex objects in a dynamic spatial cueing task. While this may seem at odds with the observation that more complex objects appear to produce larger ICEs in static displays (Reppa et al., 2012), the inter-relationship between spatial and object-based attention does not render these findings as incompatible with the observation that complex objects produce object-based facilitation in dynamic displays.

Despite these experiments, the significance of faces with regard to their cueing effects remains an open question. Presently, the experiments support the notion that schematic objects generally produce object-based facilitation in dynamic displays, with schematic faces not appearing to have any unique properties. This is due to Experiments 4 and 6 producing comparable object-based facilitation for schematic faces and schematic cars and houses respectively. One method that may help to differentiate the cueing effects produced by faces compared to other complex objects would be to use photographic stimuli instead of schematic stimuli. If the biased-competition account does explain these cueing effects, then even greater facilitation may be expected for photographic objects than schematic ones, as they may provide even greater category and feature information than schematic objects. However, if there is a particular property of these schematic stimuli that is leading to this effect, such as the observation that schematic faces are detected faster if they have inward pointing features (Coelho et al., 2010), photographic stimuli may not show the facilitatory cueing effects found for schematic stimuli. Additionally, if social salience does contribute to the facilitatory cueing effect observed for faces, we may expect even greater facilitation when real faces are used instead of schematic faces.

Experiments 2-6 demonstrated that schematic objects and schematic faces produce object-based facilitation in dynamic displays. While this finding can be broadly explained by reorienting and habituation accounts of attentional inhibition, this by itself cannot explain why specifically schematic objects are treated differentially in terms of orienting or stimulus salience. The biased-competition theory appears to account for the present data. According to this theory, attentional effects (including object-based attention, location-based attention and others such as attention to specific object features and category information) apply in an additive manner. Thus, the more "varieties" of attention that are activated, the greater the attentional effects that will be observed. As schematic objects and faces provide greater feature and category information than shapes, this leads to a strengthening of the cue due to it activating these attentional features to a greater extent than when shapes are cued, leading to increased facilitation. This activation may also be responsible for the lack of location-based ICEs for these objects. However, from these experiments it is not clear if object-based facilitation would extend to photographic stimuli as opposed to the schematic stimuli employed to date. Whether the cueing effects for faces are distinct from other complex objects or not is also unclear. Chapter 4 presents a replication of Experiment 6 using photographs of faces and houses to replace the schematic stimuli. Additionally, a static version of this experiment was conducted to examine if the typical location-based and object-based ICEs were observed for this combination of paradigm and stimuli.

Chapter 4: Inhibition Regained: Inhibitory Cueing Effects for Photographic Objects but Not Faces in Dynamic Displays

4.1 Introduction

In Chapter 3, five experiments were presented, all of which found facilitatory object-based cueing effects for four types of schematic objects: these were respectively faces, scrambled faces, cars and houses. The only object which did not produce object-based facilitation was a square, used in Experiment 5. Similarly, location-based cueing effects were only found for this square, which produced a location-based ICE. These findings are broadly consistent with the reorienting and habituation accounts of attentional inhibition, but it is not apparent why schematic objects would have differential effects on attention relative to shapes. The reason why a schematic object produced facilitation while a square produced an ICE may be simply related to object complexity generally. Alternatively, it may be specifically that schematic objects produce object-based facilitation rather than "complex" objects per se. Furthermore, it is unclear whether the cueing effects for schematic faces are qualitatively different from the cueing effects for other schematic objects. To explore these questions, it is necessary to use different stimuli.

Schematic stimuli may differ from real stimuli in a number of ways. Sagiv and Bentin (2001) present an ERP study that compared a number of representations of faces, including photographs and photorealistic paintings (grouped together as natural faces), as well as stylised sketches and simplistic line drawings (grouped as schematic faces). It was found that in terms of their N170 component, sketches of faces produced a significantly smaller (in terms of amplitude) response compared to the other three representations of faces. Additionally, these stimuli groupings diverged significantly in terms of the face inversion effect, with natural faces producing a significant larger amplitude N170 when inverted and schematic faces producing a significantly smaller amplitude N170 when inverted. Sagiv and Bentin (2001) argue that there are two perceptual modules employed in the processing of faces, which they term physiognomic (i.e. specific face details) and holistic (i.e. the general face configuration). They suggest that schematic faces activate holistic processing but not physiognomic processing, while natural faces activate both types of processing. Schematic stimuli also differ in terms of the attentional phenomena they produce. Hietanen and Leppanen (2003) compared schematic faces and real faces in a gaze cueing variant of the Posner cueing task. In this task, a face is presented in the centre of the display and the cue is generated by the face looking towards one of the two target locations. When schematic faces have been used, participants show significant facilitation in response to this cue (e.g. Friesen & Kingstone, 1998; Frischen, Bayliss, & Tipper, 2007). However, Hietanen and Leppanen (2003) found that when real faces were used in this task, the facilitatory effect was weaker compared to schematic faces. One explanation for this may be that the reduced detail of schematic faces compared to real faces reduces "noise" for the attentional system, allowing the cue to have a greater impact. Alternatively, the cueing effect from schematic faces may not be related to the social nature of the stimulus and may be driven by a different factor, such as the motion of the eyes facilitating responses in the same direction (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012). This provides a clear illustration of how the cueing effects in the present experiment may be distinct between schematic faces and real faces. For example, the increased level of detail may reduce the facilitatory effect of the cue if this extra level of visual processing interferes with the attentional system. On the other hand, the increased social salience of a real face may further increase the attentional facilitation produced. Experiment 7 aimed to explore the distinction between schematic and real stimuli for both faces and objects by replicating Experiment 6 using photographic stimuli. If complex objects produce object-based facilitation, it would be expected that both houses and faces produce facilitation in this experiment. However, if the facilitation is related to the specific properties of schematic objects, houses and faces may produce ICEs. This chapter also presents a control experiment which examines whether these objects produce ICEs in a static paradigm.

4.2 Experiment 7

4.2.1 Method

4.2.1.1 Participants

Thirty participants (20 female) completed Experiment 7. The age of participants ranged from 18 to 62 years (M = 26 years). Normal or corrected-to-normal vision was reported by all participants. Assuming an effect size of d = 0.17 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 33 participants would produce a power of .8. Unfortunately due to time constraints this requirement was not met. For this sample, the actual power was .75. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

4.2.1.2 Design

The experiment employed a within-subjects design. All participants completed two conditions, with the order of these conditions being counterbalanced across all participants. The conditions differed only in the objects presented in the display, with one condition presenting photographic faces and one condition presenting photographic houses. The first independent variable examined was cue validity, comprising three levels: valid location, valid object and invalid. The second independent variable was the condition (faces or houses). The third independent variable was the SOA, which consisted of two levels (750ms and 1500ms). The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

4.2.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix D). The apparatus used in this experiment was identical to that of Experiment 2.

4.2.1.4 Stimuli

Photographs of a face and a house were used as the stimuli in this experiment. A face was randomly selected from the KDEF inventory (Lundqvist, Flykt, & Ohman, 1998) using a publicly available random number generator. This chose the first female face from the A set. The neutral facial expression was chosen for this experiment to reduce any effect of emotion on the cueing effects obtained. A photograph of a new-build house publicly available from Zoopla was used for the house stimulus. Both stimuli were presented in greyscale and were matched for size (face stimulus 1954 pixels, house stimulus 1971 pixels).

4.2.1.5 Procedure

With the exception of the differing stimuli, the procedure was identical to that of Experiment 6.

4.2.2 Results

Ten anticipations (<100ms) were removed from the data in total (<1% of trials). Thirty-nine misses (0.5% of trials) were made in probe trials and were excluded from subsequent analysis. A 2 (Condition: House versus Face) x 2 (SOA: 750ms versus 1500ms) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) repeated-measures ANOVA was conducted on the median reaction times. The reaction times and error rates are presented in table 4.1. There was a significant main effect of SOA ($F(1, 29) = 5.014$, $p = .033$, $\eta^2 = .147$), but no other main effects were found to be significant (all Fs < 1.9, all ps > .17). However, one interaction proved significant, the three-way interaction between Condition, SOA and Cue Validity ($F(2, 58) = 6.25$, $p = .003$, $\eta^2 = .177$). All other interactions were non-significant (all Fs < 2, all ps > .15).

The main effect of SOA was assessed using Bonferroni corrected post-hoc tests. This determined

Table 4.1
Reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) made for each cue validity within each stimulus type in Experiment 7.

		Cue-target SOA (ms)			
		750		1500	
Target	Validity	RTs	Errors	RTs	Errors
House	Location	371 (112)	0.5	349 (84)	0.6
	Object	363 (103)	0.5	346 (89)	0.8
	Invalid	351 (87)	0.5	344 (84)	1.3
	Location CE	-20**		-5	
	Object CE	-12*		-2	
Face	Location	353 (95)	0.3	345 (84)	0.5
	Object	348 (80)	0.5	349 (77)	0.3
	Invalid	363 (94)	0.1	340 (74)	0.3
	Location CE	10		-5	
	Object CE	15*		-9	

Negative values for cueing effects indicate ICEs, while positive values indicate facilitation.
* p < .05
** p < .01

that the reaction times for the 750ms SOA (M = 358ms, SEM = 16.4) were significantly longer than the reaction times for the 1500ms SOA (M = 346ms, SEM = 14.2).

The three-way interaction observed between Condition, SOA and Cue Validity was then examined in further detail. This was done using 2 (Condition) x 3 (Cue Validity) repeated-measures ANOVA for each SOA separately. For the 750ms SOA, no main effects were significant, but there was a significant interaction between Condition and Cue Validity (F (2, 58) = 4.228, p = .019, η^2 = .127). For the 1500ms SOA, no significant effects were observed, suggesting that reaction time did not differ due to either the experiment condition or the cue validity at this SOA. The interaction between Condition and Cue Validity for the 750ms SOA was examined using paired samples t-tests, which compared the invalid and valid location median reaction times to produce the location-based cueing effect and the invalid and valid object median reaction times to produce the object-based cueing effect. As before, positive values indicate the effect is facilitatory, while negative values indicate an inhibitory effect. For the face condition, no location cueing effect was found (M = 10ms; t (29) = 1.199, p = .24, d = 0.11), while a significant facilitatory object-based cueing effect was found

(M = 15.5ms; t (29) = 2.323, p = .027, d = 0.18). For the house condition, a significant location-based ICE was observed (M = -19.9ms; t (29) = 3.105, p = .004, d = 0.2), as was a significant object-based ICE (M= -11.2ms; t (29) = 2.085, p = .046, d = 0.12). To summarise this interaction, cueing effects did not appear to exist at the 1500ms SOA, but were found at the 750ms SOA. The 750ms SOA produced another interaction, with cueing effects being facilitatory for the face condition and inhibitory for the house condition. This is illustrated in figure 4.1.

The same repeated-measures ANOVA was also conducted on the error data (misses on probe trials). No significant effects were identified (all Fs < 2.3, all ps > .14), suggesting that the results were not influenced either by a speed-accuracy trade off or by certain trials being more difficult than others.

4.2.3 Discussion

In Experiment 7, significant cueing effects were found for both faces and houses when photographic stimuli were used. As in previous experiments which used schematic faces, real faces produced a significant object-based facilitatory cueing effect, while no location-based cueing effect was observed. However, contrary to experiments using schematic objects, real houses produced significant object-based and location-based ICEs.

In this experiment, real faces produced a pattern of results comparable to that when schematic faces were used. Thus, the facilitatory object-based cueing effect observed in previous experiments was not restricted exclusively to schematic faces, supporting the observation that faces are not subject to object-based ICEs. Additionally, it appears that schematic faces and real faces are treated similarly in terms of cueing effects. This is consistent with previous research that has found comparable cueing effects for faces regardless of the type of face stimuli employed. For example, Fox et al. (2002) and Perez-Duenas et al. (2014) both found faces with particular facial expressions (anger and fear) did not generate ICEs, with Fox et al. (2002) using schematic faces and Perez-Duenas et al. (2014) using real faces. This remains the case for the more typical ICE result, with

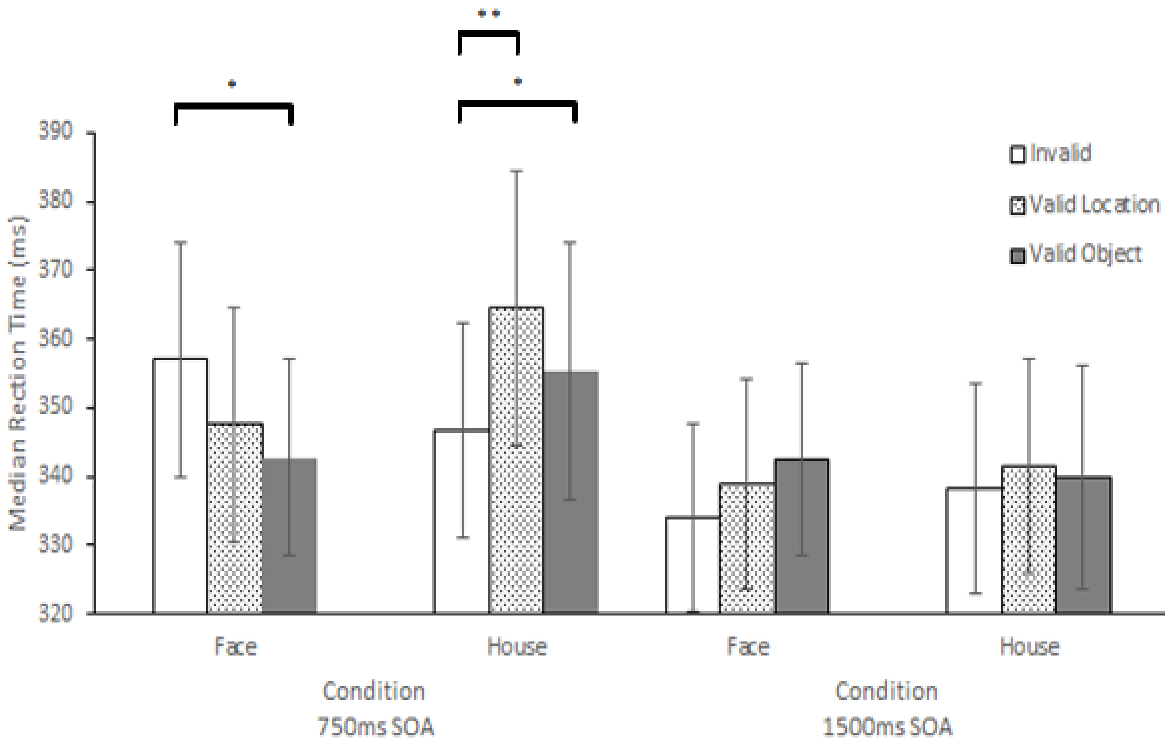


Figure 4.1: *Reaction times (ms) for each cue validity for photographic faces and houses at the 750ms SOA and 1500ms SOA. Error bars represent +/- 1 SEM.*
* p < .05
** p < .01

Baijal and Srinivasan (2011) and Verkuil et al. (2009) demonstrating this with schematic faces and a variety of experiments showing this to be the case for real faces (e.g. Lange et al., 2008; Silvert & Funes, 2016; Taylor & Therrien, 2005).

Unlike faces, real houses were found to produce a different cueing effect from schematic houses. In Experiment 6, schematic houses produced a significant object-based facilitatory cueing effect, while in Experiment 7, real houses produced both a significant object-based ICE and a significant location-based ICE. Despite what appeared to be a consistent object-based facilitatory cueing effect for complex objects in Experiments 3-6, it appears that this effect is restricted to schematic objects. Furthermore, the finding of location-based ICEs for houses in this experiment provides further evidence that the lack of a location-based ICE for schematic objects is attributable in some way to the objects themselves rather than the characteristics of the display.

Another unexpected finding from this experiment was the significant interaction between cue validity and SOA, with no cueing effects found at the 1500ms SOA. In a typical spatial cueing paradigm, ICEs are normally observed for up to 2 seconds, although depending on the exact design ICEs can be observed beyond this timeframe up to approximately 4 seconds (see Samuel & Kat, 2003 for a review). This suggests that for real objects, cueing effects may decay more rapidly compared to schematic objects or simple shapes. This was supported by Niimi, Shimada and Yokosawa (2017) who found that when real objects were used as cues, ICEs emerged at an SOA of 240ms and declined rapidly over time, with reduced effects at SOAs of 440ms and 640ms. In contrast, the use of a square as a cue led to a more typical cueing effect distribution, with a facilitatory effect at 240ms and much stronger ICEs at 440ms and 640ms compared to real objects. Although not explicitly tested, the time course observed by Niimi et al. (2017) would suggest that no cueing effects would be observed at 1500ms for real objects, consistent with the present experiment. However, it is important to note that Niimi et al.'s (2017) experiment was unique among studies examining cueing effects as it used 41 distinct cue types: as the use of this many unique cues has not been explored, it is possible that it is this manipulation that led to the different time course for ICEs.

Throughout the presented experiments, it has been consistently demonstrated that faces do not generate ICEs, contrasting with previous research demonstrating ICEs for faces (Baijal & Srinivasan, 2011; Lange et al., 2008; Stoyanova et al., 2007; Silvert & Funes, 2016). The prima facie explanation for this is that these experiments used static displays, while the experiments in this thesis used dynamic displays. Consequently, when ICEs for faces are found, they appear to be of a location-based nature, which explains why no object-based ICEs have been found. However, it is necessary to note that location-based ICEs for faces have not been observed in the experiments presented here, which weakens the argument that ICEs for faces are necessarily location-based. For example, it may be that the particular face stimuli employed do not generate any kind of ICEs, rather than faces in general not producing ICEs. While this argument may seem weak, it was found to be the case with houses, as schematic and photographic house stimuli produced dramatically different cueing effects. To investigate whether ICEs can be generated for face stimuli, Experiment 7 was replicated using a static display instead of a dynamic display. It was expected that both faces and houses would produce significant ICEs in this experiment.

4.3 Experiment 8

4.3.1 Method

4.3.1.1 Participants

Twenty-two participants (18 female) participated in Experiment 8. Participant age ranged from 18 to 42 years (M = 22 years). All participants reported normal or corrected-to-normal vision. Fewer participants were recruited for this experiment because the effect size of the ICEs obtained tends to be greater in static displays compared to dynamic ones. For example, Avila (1995) reports an ICE of 46ms (Experiment 1, d = 1.08) and Fox et al. (2002) report an ICE of 60ms (Experiment 1, d = 1.13) in static displays, whereas Tipper et al. (1994) report an object-based ICE of 17ms (Experiment 1, estimated d = 0.31) in a dynamic display. Even with a conservative estimated effect size of d = 0.3, power analysis determined only 17 participants were necessary for a power of 0.8. By recruiting 22 participants, a power of .91 was achieved. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

4.3.1.2 Design

The experiment employed a within-subjects design. The first independent variable examined was cue validity, comprising two levels: valid and invalid. As a static display was employed, there was no distinction between valid location and valid object in the design for this experiment. The second independent variable was the SOA, which consisted of two levels (750ms and 1500ms).

The dependent variable was the time taken for participants to respond with a keypress to the appearance of the target.

4.3.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix E). The apparatus used in this experiment was identical to that of Experiment 2.

4.3.1.4 Stimuli

The stimuli used in this experiment were identical to Experiment 7.

4.3.1.5 Procedure

The procedure was modelled on Experiment 7 and was in most respects the same as that experiment. The primary difference was the abolition of motion. Thus, each object remained in the same place for the duration of each trial. As the motion component lasted 200ms, 200ms was added to the final frame of each trial to ensure the SOAs remained the same for this experiment. As the use of a static design meant the cue validities of valid object and valid location were no longer separable, this experiment only used a total of two instead of three cue validities. If the cue and target were at the same location, this was a valid cue: if the target was at either of the two non-cued locations, this was an invalid cue. All objects were equally likely to serve as the cue and target respectively. Two blocks were completed, with one block using the face stimulus for each object and the other block using the house stimulus. There were 132 trials in each block. Six of these trials were catch trials (5%). Of the remaining 126 trials, each SOA was represented with 63 trials. Of the cue validities, 42 were valid trials and 84 were invalid trials, maintaining the same percentage of valid to invalid trials as in previous experiments.

4.3.2 Results

Two anticipations (<100ms) were removed before data analysis. Misses (failing to respond to probe trials) were also removed, of which there were 28 (<1% of trials). A 2 (Condition: House versus Face) x 2 (SOA: 750ms versus 1500ms) x 2 (Cue Validity: Valid versus Invalid trials) repeated-measures ANOVA was conducted on the median reaction times. The mean median reaction times and error rates are presented in table 4.2. The main effect of SOA was significant ($F(1, 21) = 23.698$, $p < .001$, $\eta^2 = .53$), indicating that median reaction times did differ between the SOAs. The main effect of Cue Validity was also significant ($F(1, 21) = 46.186$, $p < .001$, $\eta^2 = .687$), suggesting that responses differed between invalid and valid trials. SOA and Cue Validity also interacted significantly ($F(1, 21) = 7.347$, $p = .013$, $\eta^2 = .259$). All effects and interactions not reported were non-significant ($p > .2$).

The main effect of SOA was examined with Bonferroni corrected post-hoc tests. This revealed that the reaction times were significantly longer for the 750ms SOA (M = 361ms, SEM = 15.4) compared to the 1500ms SOA (M = 331ms, SEM = 14.4).

Regarding the main effect of Cue Validity, Bonferroni corrected post-hoc tests found that invalid trials (M = 336ms) were significantly faster than valid trials (M = 356ms, $p < .001$).

The interaction of SOA and Cue Validity was explored using two paired samples t-tests, one for each SOA. Face and house conditions were collapsed as condition was not part of the interaction. At the 750ms SOA, a significant ICE was found (M = -26.7ms; $t(21) = 6.61$, $p < .001$, $d = 0.37$) and although the effect was smaller, the ICE remained significant at 1500ms (M = -13.1ms; $t(21) = 3.592$, $p = .002$, $d = 0.2$). Thus, valid trials (750ms SOA M = 374ms; 1500ms SOA M = 338ms) were significantly slower than invalid trials (750ms SOA M = 347ms; 1500ms SOA M = 325ms) at both SOAs. This is illustrated in figure 4.2.

The same repeated-measures ANOVA was repeated on the error data (misses on probe trials). No significant effects were found (all $Fs < 3.6$, all $ps > .07$), suggesting that there is no relation between

Table 4.2
Reaction times (ms) and percentage of errors (standard deviations in brackets) for each cue validity within each stimulus type and SOA in Experiment 8.

		Cue-target SOA (ms)			
		750		1500	
Target	Validity	RTs	Errors	RTs	Errors
House	Valid	368 (68)	0	338 (64)	0.3
	Invalid	341 (67)	1.3	322 (63)	0.6
	ICE	-27***		-16**	
Face	Valid	380 (82)	0.3	338 (76)	0.6
	Invalid	354 (77)	0.2	327 (71)	1.3
	ICE	-26**		-11*	

* p < .05
** p < .01
*** p < .001

the errors participants made and the findings of this experiment.

4.3.3 Discussion

Experiment 8 replicated Experiment 7 but removed the motion component, rendering the display a static one. In this experiment, both houses and faces produced significant ICEs. Consistent with previous research, this demonstrates that faces do produce ICEs in static displays (Baijal & Srinivasan, 2011; Lange et al., 2008; Stoyanova et al., 2007; Silvert & Funes, 2016). This provides evidence against the notion that in the dynamic experiments, faces did not produce location-based ICEs because they are incapable of doing so. Rather, it appears that static displays produce stronger ICEs than dynamic displays, which mitigate any object-based facilitation.

An additional finding was that ICEs were weaker at the long SOA (1500ms) compared to the short SOA (750ms), although both were statistically significant. This finding is consistent with Experiment 7, which found cueing effects were only significant at the 750ms SOA and not at the 1500ms SOA. One explanation, as suggested in Experiment 7, is that cueing effects decay more rapidly for real objects compared to other types of objects, as found by Niimi et al. (2017). Alternatively, this may reflect a more general decay of cueing effects over time, although this is less supported by previous

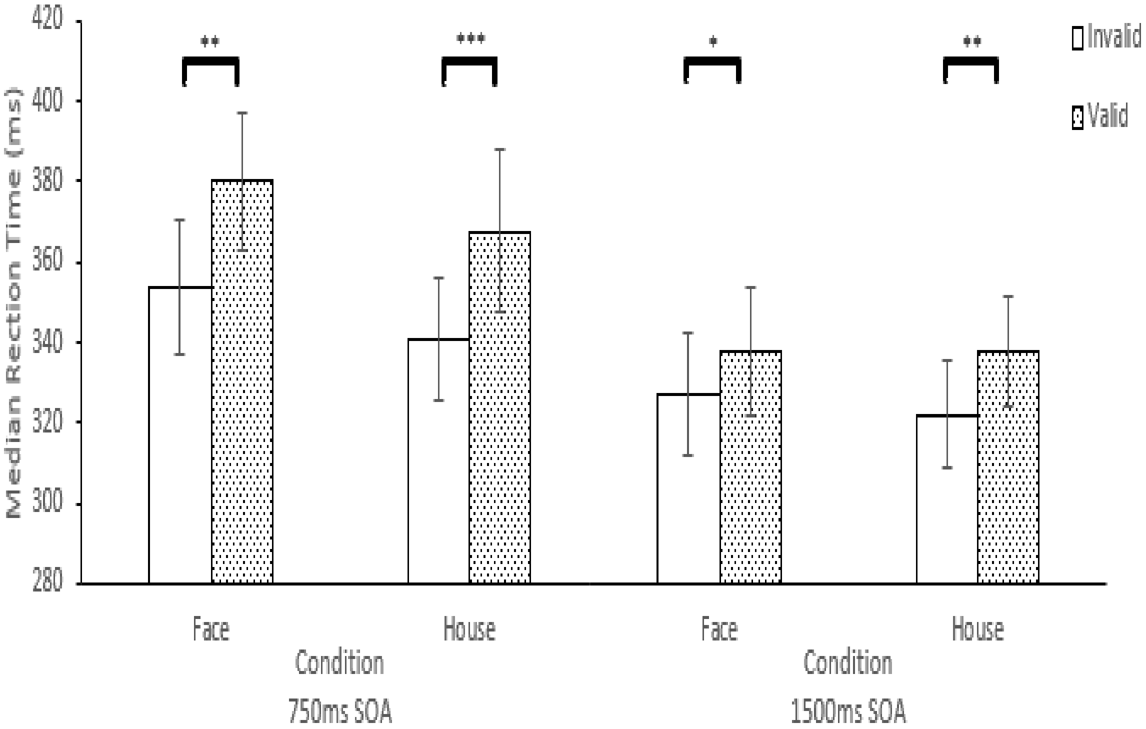


Figure 4.2: R*eaction times (ms) for each cue validity for photographic faces and houses at the 750ms SOA and 1500ms SOA. Error bars represent +/- 1 SEM.*
* p < .05
** p < .01
*** p < .001

experiments. Given this finding was found for an exclusively object-based cueing effect in Experiment 7, for this explanation to hold the object-based cueing effect would have to weaken over time, which was not found in either Experiments 5 or 6. Indeed, in Experiment 5 the cueing effects for both faces and objects were of greatest magnitude at the longest SOA (1500ms).

4.4 General Discussion

Chapter 3 demonstrated consistent object-based facilitation for a variety of objects, including faces, cars and houses. However, given that all objects tested in those experiments were schematic, it was unclear whether this property was related to the facilitatory cueing effects observed. Accordingly, Experiments 7 and 8 compared photographic faces and houses in a dynamic and static display respectively.

Experiment 7 found significant object-based and location-based ICEs for houses, while faces produced a significant object-based facilitatory cueing effect. However, these cueing effects were only found at the short SOA, with no cueing effects found at the long SOA. Experiment 8 found significant ICEs for both faces and houses. These effects were significant regardless of SOA, although the cueing effects were of reduced magnitude at the long SOA compared to the short SOA.

Based on five experiments in Chapter 3, which demonstrated object-based facilitation for all objects except simple shapes, it appeared that complex objects in dynamic displays consistently generated facilitation. The biased-competition hypothesis was offered as a possible account to explain this finding. Specifically, it was proposed that schematic objects provide a greater range of featural and categorical information compared to shapes and when this information is subject to attention following a cue, attentional effects (such as the facilitatory benefit of a cue) increase in magnitude.

Although this appeared to account well for the data generated by schematic objects, it is less supportive of the data produced by Experiment 7, which compared photographic houses and photographic faces and found photographic houses to produce significant ICEs. Just as schematic houses have a greater level of featural and categorical information than a shape, it would be expected for a photographic house to provide even more featural and categorical information compared to a schematic house. This would suggest that facilitation should have been even more strongly observed for photographic houses. One possibility is that feature and category-based attention contribute differentially to the facilitatory cueing effects observed. For example, it may be that photographic houses provide a more salient representation of featural information due to the extra level of detail, but provide relatively less categorical information due to noise associated with low-level image features such as texture, contrast etc. that are not present in a schematic object. If this was the case, then it could be that category-based attention provides a greater facilitatory effect than feature-based attention and this explanation would remain consistent with the results of Experiment 7.

Another consideration is the distinction between the cueing effects for static and dynamic displays. In static displays, increasing the featural and categorical information provided by cued objects appears to increase the magnitude of ICEs. For example, Grison et al. (2005) used displays of photographic faces, with coloured cues and targets appearing on one of the two faces. The faces could be upright or inverted during both the cue phase and the target phase, providing four combinations of how the faces were displayed (i.e. upright at cue and target phase, upright-inverted, inverted-upright and inverted-inverted). Significant ICEs were present for all four combinations, but were greatest when faces were upright at both phases and smallest when faces were inverted at both phases. Grison et al. (2005) argued that the increase in ICEs is directly attributable to the ease at which semantic information could be extracted from the stimuli, with upright faces having a natural attentional advantage compared to inverted faces. This finding is in direct opposition to the claim that increasing semantic information increases facilitatory effects, despite this claim being consistent with the results of the experiments in this thesis. However, rather than treating these findings as incompatible, a simple possibility is that these varieties of attention can contribute to either ICEs or facilitatory cueing effects, with the net contribution dependent on characteristics of the display and task demands. When displays are static and have short SOAs, facilitation dominates and facilitatory cueing effects increase as feature and category-based information provided by the display objects increases. Similarly, static displays with long SOAs are dominated by ICEs and accordingly, ICEs increase with feature and category-based information. This could similarly explain why photographic stimuli produce ICEs while schematic objects produce facilitation. However, the results of the experiments presented in this thesis suggest that this may not be as straightforward in dynamic displays, as complex objects can produce either facilitatory or inhibitory cueing effects depending on the representation (schematic versus photographic) and identity (i.e. faces produce facilitation regardless of representation) of the stimuli. Additionally, it is worth noting that despite the range of SOAs used in the thesis experiments, all SOAs employed would be considered “long” in a typical cueing paradigm, with short SOAs being typically considered to be 300ms or less. In contrast, the shortest SOA used in these experiments was 750ms. One reason why SOAs of 300ms or less were not considered is due to methodological constraints. Unlike a static cueing display, a dynamic display must allow time for the objects to move. In the current experiment, this motion lasted for 200ms. Allowing for time to display and remove the cue and then present the target, an SOA of 300ms would not be possible without changing characteristics of the display. It is also important that the motion is not too fast, as this may prevent spatiotemporal continuity, which would reduce or remove object-based cueing effects. For this reason, few studies have examined cueing effects at short SOAs using dynamic displays (see Lamy & Tsal, 2000; Soto & Blanco, 2004 for counterexamples). Accordingly, it is unclear if different cueing effects based on object representation and identity would be present in a dynamic display at a short SOA. Research in static displays would suggest that objects in dynamic displays would produce facilitatory cueing effects at short SOAs regardless of the stimuli characteristics. However, given the differences observed in static and dynamic displays at long SOAs, research would be required to establish if this is the case.

Another point to note with the biased-competition hypothesis is the fact that in the present experiments, each object in the display was identical. Given the results of Kravitz and Behrmann (2011) that uncued objects which shared properties with the cued object also showed a facilitatory effect, this would suggest that all objects in the display would be facilitated. This may suggest that the fact that object-based facilitation was observed is inconsistent with this hypothesis, as two identical objects received differing amounts of facilitation. However, although the objects were identical images, they still differed with regard to both their location and the specific spatiotemporal identity. Thus, while the uncued objects may have been facilitated due to shared featural and categorical information with the cued object, the cued object would have benefited uniquely with regard to location-based and object-based attention. This suggests that the observed cueing effects may be increased further by using objects of differing features and categories in the display. One source of support for this is the fact that Experiment 1, which used a variety of shapes in each display, produced ICEs of greater magnitude than subsequent experiments which only used one object image (as measured by effect size; Experiment 1 object-based ICE d = 0.23; Experiment 5 object-based ICE d = 0.15; Experiment 7 object-based ICE d = 0.12).

It is also worth noting that in contrast to photographic houses, which produced a different cueing effect to schematic houses, photographic faces produced a similar object-based facilitatory cueing effect to schematic faces. Although previous experiments supported the notion that faces were responded to in a similar manner to other schematic objects, this suggests that faces may have a qualitatively different effect on attention compared to other objects. This is consistent with the notion that attention is influenced by emotional or biologically relevant stimuli. For example, Richards and Blanchette (2004) found that nonwords that were associated with a negative emotion via classical conditioning were responded to more slowly in a Stroop paradigm than nonwords that were conditioned to be neutral. Although emotion was not relevant to the task, emotion negatively affected performance. In search tasks, emotional stimuli are detected more quickly than non-emotional stimuli (Eastwood, Smilek, & Merikle, 2001). This effect appears to be cross-modal, with Brosch, Grandjean, Sander and Scherer (2009) observing that participants responded significantly faster to targets at the location of a nonword spoken in an angry voice compared to a neutral voice. Pourtois, Schettino and Vuilleumier (2012) present a framework which proposes that emotional signals amplify perceptual representations in a way comparable to selective attention. It is suggested that this emotional influence and attentional influence are distinct systems that amplify emotional or relevant information and can produce additive effects on subsequent responses. Although distinct from exogenous attention, it is suggested that emotional information can act in a reflexive manner, leading to effects that can arise unconsciously and irrespective of task demands. However, it is acknowledged that this emotional information is not resistant to context or participants' goals, which can mitigate the strength of emotional information. Pourtois et al. (2012) emphasise that emotional stimuli are not immune to perceptual constraints applicable to other stimuli, but that the detection of emotional stimuli can exert a unique influence on perception and attention.

The amygdala is proposed to play a central role with regard to the effects of emotional stimuli. The mechanism by which the amygdala influences perception in response to emotional information takes two forms. Firstly, amygdala activity can be produced shortly after the presentation of relevant stimuli, suggesting it responds directly to appropriate cues. Additionally, the amygdala has direct connections to sensory areas of cortical regions through which it can exert an influence by providing feedback signals (Vuilleumier, 2005). Such feedback is suggested to increase the representation of emotional stimuli (Stolarova, Keil, & Moratti, 2006). While this model can provide an explanation as to why faces are responded to differently compared to other objects, it is important to note that all faces used in the thesis experiments were non-emotional. Given the emphasis on emotion in Pourtois et al.'s (2012) model, it is unclear whether these neutral faces provide sufficient emotional information to act as proposed by this model. However, there is evidence that the amygdala is integral to the processing of social relevance regardless of emotion (Wang & Adolphs, 2017). Traditionally, the amygdala was emphasised as contributing particularly to the processing of stimuli relating to fear and anxiety. For example, amygdala damage was associated with a reduced ability to recognise and respond to fearful stimuli (e.g. Adolphs, Tranel, Damasio, & Damasio, 1994; LaBar, LeDoux, Spencer, & Phelps, 1995). However, subsequent research has identified the amygdala plays a role in a greater variety of socially relevant stimuli than previously supposed. It has been found to respond comparatively to emotional faces regardless of the emotion displayed (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006), but particularly to threat-related facial expressions (fear and anger: Mattavelli et al., 2014), and individual neurons in the amygdala have been identified as selectively encoding whole faces (Rutishauser et al., 2011). Beyond faces, the amygdala has also been found to respond more strongly to animate compared to inanimate stimuli (Yang, Bellgowan, & Martin, 2012) and in relation to personal space, with amygdala activation found in response to proximity of another person (Kennedy, Glascher, Tyszka,

& Adolphs, 2009). Thus, the amygdala may play a role with regard to attentional effects unique to faces and may act in a way comparable to its action in response to emotional stimuli proposed by Pourtois et al. (2012).

In recent work, a clear distinction has been made between ICEs (a perceptual effect) and IOR (a saccadic effect). For example, Hilchey et al. (2014) used both central and peripheral targets across two experiments. Initial oculomotor facilitation was found when participants had to respond to all targets with a saccade, which then became inhibition for targets appearing one second after the cue. However, when oculomotor activity was reduced by having participants only respond to 20% of targets with a saccade, neither oculomotor facilitation nor inhibition was observed, while peripheral targets still produced an inhibitory effect. Given this inhibitory effect occurred in the absence of oculomotor activation, it appears to be perceptual rather than saccadic. The experiments presented in this thesis have consistently supported the notion that faces do not produce object-based ICEs. However, it is unclear whether faces in a dynamic display would generate IOR: the paradigm used to date would not support IOR as the oculomotor system was suppressed. Furthermore, while object-based ICEs were affected by object representation and identity, it is unknown if IOR would be similarly affected. Given that the primary driver of IOR is activation of the oculomotor system, it seems reasonable that perceptual differences in objects in a display may not affect the manifestation of IOR as it does ICEs. For example, Hilchey, Pratt and Christie (2016) found the IOR effect to be comparable between displays that contained placeholders and displays that did not, while ICEs were significantly reduced for placeholder-absent displays compared to placeholder-present displays. Although they did not manipulate object characteristics per se, the fact that perceptual differences in the display affected ICEs but not IOR supports the possibility that perceptual characteristics do not affect IOR.

In addition to only testing ICEs as opposed to IOR, the experiments of the present thesis have only considered peripheral cues rather than central cues. Traditionally, IOR was believed to apply only to peripheral cues, with studies using central cues typically finding no sign of inhibition (e.g. Posner & Cohen, 1984; Ristic & Kingstone, 2006; Stevens, West, Al-Aidroos, Weger, & Pratt, 2008). It is now generally believed that central cues can produce IOR provided a saccade is prepared following the cue (e.g. Rafal et al., 1989; but see Chica, Klein, Rafal, & Hopfinger, 2010 for a failed replication). If this is the case, then ICEs should not be observed with central cues. However, an interesting alternative possibility was raised by Henderickx, Maetens and Soetens (2012). This study conducted a series of experiments using a novel paradigm which presented both a central and a peripheral cue in each trial. Firstly, a central cue was presented, which was a square of one of three colours. This was followed by two peripheral cues that appeared simultaneously at the two possible target locations, which were squares of different colours. Participants were instructed to orient to the peripheral cue that was the same colour as the central cue. Participants then detected a target that could appear at either of the two locations. In this design, ICEs were observed, with slowed responses to the location of the peripheral cue of the same colour as the central cue compared to a differently coloured peripheral cue at the longest SOA (500ms), with facilitation found at shorter SOAs. This supports the notion that ICEs are generated endogenously when the cue is salient to task demands. To rule out the possibility that the cueing effect was related to priming (i.e. the central cue primed the peripheral cue which caused an automatic exogenous attentional shift rather than an endogenous one) or perceptual grouping more generally, the experiment was replicated with a grey word replacing the central cue. This word was a colour and indicated to participants which peripheral cue should be oriented to. This produced the same pattern of results. Additionally, ICEs were not found if the central cue was presented simultaneously with the peripheral cues nor if the central cue was presented after the peripheral cue. This suggests that these cues only led to ICEs if there was sufficient time between the presentation of cue and target to adjust a saliency map corresponding to the cued colour. On this basis, Henderickx et al. (2012) argue stimulus saliency is a necessary prerequisite to generate endogenous ICEs. However, stimulus saliency does not appear to account for Rafal et al.'s (1989) finding of IOR using central cues, as stimuli did not differ between conditions, suggesting saliency was not a relevant factor. One possibility is that saliency representations are activated as part of saccadic programming, which might lead to saliency-related effects independent of stimuli when saccades are generated or prepared (Findlay, 2009). Alternatively, stimulus saliency may be necessary for endogenously generated ICEs but not IOR. Given that saccades were not used in the experiments of Henderickx et al. (2012), it is unclear if stimulus saliency is a relevant factor with regard to endogenous IOR. Nonetheless, it is possible that the use of different stimuli may affect IOR as it does ICEs and these effects may be more prominent when a central cue is used.

Chapter 5 presents a replication of Experiment 7 using a saccadic response to explore whether the object-based facilitatory effect for faces is specific to the perceptual domain or whether it can additionally be found when the oculomotor system is activated. Additionally, the use of a central cue similarly provides evidence as to whether these effects can be reproduced independently of peripheral cueing.

Chapter 5: Inhibition of Return Is Not Found for Faces in Dynamic Displays: An Eyetracking Experiment

5.1 Introduction

In Chapter 4, it was demonstrated that photographs of objects produced a different pattern of cueing effects compared to the cueing effects for schematic objects presented in Chapter 3. Specifically, while ICEs were not present for any schematic object in the experiments of Chapter 3 (excluding squares), significant ICEs were found for a photographic house stimulus. However, schematic and photographic versions of faces produced similar facilitatory cueing effects. A static variant of this cueing task was also conducted, which produced ICEs for both photographic faces and photographic houses. This confirmed that the faces used in these experiments do produce location-based ICEs. The finding that schematic objects produce facilitatory cueing effects appears compatible with the biased-competition hypothesis of attention, which proposes that once an object is the subject of attentional selection, all shared properties of this object in other objects are similarly activated. Thus, the location, object, feature and category information from this selected object also guide attention to other objects which share these characteristics. Accordingly, when an object is cued, this cue activates each form of attention relevant to the cued object. When a simple shape is cued, this activates object-based and location-based attention as well as feature-based and category-based attention. However, the feature and category information a shape provides is less than that provided by a schematic object. Thus, the facilitatory benefit of a cue is less for a shape than a schematic object due to the increased activation of feature and category attention provided by the latter. Although this interpretation is complicated by the fact that ICEs and not facilitation were observed for photographic houses, it is possible that these features of attention can contribute to either facilitatory or inhibitory cueing effects depending on characteristics of the display and task. As photographic and schematic faces produced comparable cueing effects in contrast to photographic and schematic houses, cueing effects for faces may be influenced by a distinct cognitive and/or neural mechanism that responds to social relevance such as the amygdala (Wang & Adolphs, 2017).

Experiments 1 to 8 have provided insights into the study of ICEs and facilitatory cueing effects. However, ICEs, a perceptual phenomenon, are distinct from IOR, a saccadic form of inhibition (Hilchey et al., 2014). Although these experiments have demonstrated that faces in dynamic displays are not subject to ICEs, it is less clear whether faces are subject to IOR. Although the exact cognitive mechanism as to why faces do not produce an observable ICE is unclear, it is presumably related in some way to a perceptual characteristic of the face. Given IOR is the consequence of oculomotor activation (Hilchey et al., 2014), it may be less influenced by perceptual characteristics compared to ICEs. This was supported by Hilchey et al. (2016), which found that the magnitude of ICEs was affected by display characteristics (the presence or absence of placeholders indicating possible target locations), whereas IOR was not affected by this manipulation. Another factor that has not been manipulated across these experiments is the type of cue employed, with all experiments using a peripheral cue. In general, IOR does not appear to be observed when central cues are used (e.g. Ristic & Kingstone, 2006; Stevens et al., 2008), although one possible exception is when a saccade is prepared in response to the cue (Rafal et al., 1989; but see Chica, Klein et al., 2010). If saccade preparation is necessary for central cues to produce attentional inhibition, this would preclude central cues generating ICEs. However, Henderickx et al. (2012) found evidence that central colour cues do produce ICEs independent of exogenous attention. Henderickx et al. (2012) argue that saliency representations are necessary for central cues to produce attentional inhibition. If this is the case, then stimuli of differing saliency may produce differences in IOR when central cues are used. Additionally, the thesis experiments have not monitored eye movements. Although it is considered unlikely that any of the observed effects can be attributed to differences in overt orienting between conditions, it cannot be strictly ruled out. Experiment 9 extends the paradigm of Experiments 1-8 by adding the use of eyetracking to consider if attentional effects observe extend to IOR. By having participants respond with saccades for each trial, the oculomotor system is activated which should lead to IOR. This contrasts with previous experiments where participants were instructed to maintain fixation throughout the experiment, conditions which led to ICEs rather than IOR. Additionally, the cue employed was in the form of an arrow, in response to which participants had to produce a saccade. Thus, the cue required a response as well as the target. This was done to provide insight into the open question of whether IOR can be generated using central cues and whether saccadic cueing effects differ as a function of stimuli. Finally, eye movements were recorded and so overt orienting was accounted for, unlike in the previous experiments.

5.2 Experiment 9

5.2.1 Method

5.2.1.1 Participants

Twenty-seven participants (16 female) participated in Experiment 9. Participant age ranged from 18 to 56 years (M = 23 years). All participants reported normal or corrected-to-normal vision. Assuming an effect size of d = 0.17 (the average effect among significant effects in previous experiments), power analysis determined that recruiting 33 participants would produce a power of .8. Unfortunately due to time constraints this requirement was not met. For this sample, the actual power was .69. The experiment was granted approval by the Durham University Ethics Committee and conducted in accordance with Durham University's and the BPS guidelines for ethical research.

5.2.1.2 Design

The design employed was identical to that used in Experiment 7.

5.2.1.3 Apparatus

Participants were provided an information sheet which they were required to read through, which informed them of their rights and the experimental protocol and completed a consent form once the experimenter answered any questions they had (see Appendix F). This experiment was created and run in Open Sesame 3.1.3. An Eyelink II was used for eyetracking. A 36" LCD monitor with a refresh rate of 100Hz was used to display the stimuli, although only an area of the screen comparable to the area used in previous experiments (which used a 21" monitor) was used. Responses were recorded exclusively using the Eyelink II, so no serial response box was employed.

5.2.1.4 Stimuli

The stimuli used in this experiment were identical to Experiment 7.

5.2.1.5 Procedure

The procedure was modelled on Experiment 7, but with modifications to incorporate the change in response. At the beginning of each trial, the display was presented for 1000ms. After this time, the central fixation cross was replaced with an arrow pointing at one of the three objects. This was the cue. This arrow was presented until participants made a saccade to the object that the arrow was directed to or 1000ms elapsed. Following this, the fixation cross reappeared with a black square surrounding it to remind participants to re-fixate. As with the cue, this displayed until gaze was detected at the fixation point or 1000ms elapsed. Then the objects moved clockwise to the location held by the previous object. Once motion completed, either 150ms or 900ms elapsed depending on the SOA before the appearance of the target, a grey version of the display object replacing one of the three objects. Participants were instructed to make a saccade to this object as soon as they detected it. If no objects changed (i.e. for catch trials), participants were instructed to maintain fixation. The display remained on screen after target presentation until participants saccaded to one of the objects or 2500ms passed. For the three phases of each trial where saccade detection was necessary, this was done by defining a region of interest around the cued object for the cue phase, the fixation cross for the re-fixation phase and the three objects for the target phase. This region was a square of 10mm by 10mm (0.9° of visual angle) for the fixation cross and a square

47mm by 47mm (4° of visual angle) for each object. In comparison, the fixation cross consisted of two lines of 7mm (0.6° of visual angle) and the objects occupied square regions of 35mm by 35mm (3° of visual angle). Participants completed two blocks with one block using photographs of faces as the display objects and the other block using photographs of houses. Each block contained 132 trials, with 126 probe trials and 6 catch trials. The order of the blocks was counterbalanced among participants.

5.2.2 Results

Sixty-seven anticipations (<100ms, ~1% of trials) were removed before data analysis. The same cut-off was used as for manual reaction times as previous work has demonstrated that it is possible for participants to accurately saccade to a face within 100ms of its appearance to a level of accuracy significantly different from chance (Crouzet et al., 2010). Misses (failing to respond to probe trials) were also removed, of which there were 114 (~2% of trials). Reaction times were measured as the time taken for gaze to be detected at the target following the target's appearance. A 2 (Condition: House versus Face) x 2 (SOA: 1365ms versus 2124ms) x 3 (Cue Validity: Valid Location versus Valid Object versus Invalid trials) repeated-measures ANOVA was conducted on the median reaction times. As the pre-target procedure required two saccades from participants, this meant there was variability in the SOAs, with 1365ms and 2124ms being the average SOA in each condition across all participants. Participant SOAs ranged from 970ms to 1669ms for the short SOA and 1725ms to 2459ms for the long SOA. Although this represents considerable variation, there was no overlap between the two SOAs. The mean median reaction times and error rates are presented in table 5.1.

No main effects were found to be significant (all Fs < 3.1, all ps > .09). However, one interaction proved significant, the three-way interaction between condition, SOA and cue validity ($F(2, 52) = 4.096$, $p = .022$, $\eta^2 = .136$). All other interactions were non-significant (all Fs < 2.2, all ps > .12).

The three-way interaction observed between condition, SOA and cue validity was then examined

Table 5.1

Reaction times (ms), cueing effects (CE) and percentage of errors (standard deviations in brackets) for each cue validity within each stimulus type and SOA in Experiment 9.

		Cue-target SOA			
		1365ms		2124ms	
Target	Validity	RTs	Errors	RTs	Errors
House	Location	360 (49)	2.3	348 (43)	1.2
	Object	359 (47)	2.1	346 (38)	0.8
	Invalid	349 (46)	2.5	345 (40)	0.7
	Location CE	-11*		-3	
	Object CE	-10		-1	
Face	Location	364 (47)	2.3	345 (33)	1.9
	Object	353 (46)	2.6	355 (44)	1.2
	Invalid	367 (59)	1.5	349 (44)	0.5
	Location CE	3		4	
	Object CE	14		-6	

Negative values for cueing effects indicate IOR, while positive values indicate facilitation.
* $p < .05$

in further detail. This was done using 2 (Condition) x 3 (Cue Validity) repeated-measures ANOVA for each SOA separately. For the 1365ms SOA, no main effects were significant, but there was a significant interaction between condition and cue validity ($F(2, 52) = 4.377$, $p = .018$, $\eta^2 = .144$). For the 2124ms SOA, no significant effects were observed (all Fs < 1.4, all ps > .26), suggesting that reaction time did not differ due to either the experiment condition or the cue validity at this SOA. The interaction between condition and cue validity for the 1365ms SOA was examined using paired samples t-tests, which compared the invalid and valid location reaction times to produce the location-based cueing effect and the invalid and valid object reaction times to produce the object-based cueing effect. As before, positive values indicate the effect is facilitatory, while negative values indicate an inhibitory effect. For the face condition, neither a location-based (M = 3.2ms; $t(26) = 0.397$, $p = .695$, $d = 0.06$) nor an object-based cueing effect (M = 14.4ms; $t(26) = 1.779$, $p = .087$, $d = 0.27$) was found. For the house condition, significant location-based IOR was observed (M = -10.9ms; $t(26) = 2.384$, $p = .025$, $d = 0.22$), although no significant object-based IOR was found (M = -9.6ms; $t(26) = 1.865$, $p = .073$, $d = 0.2$). However, the effect sizes were larger or comparable to that of previous experiments, suggesting that houses did produce both location-based and object-based IOR, while faces produced a significant object-based facilitatory cueing effect. To summarise this interaction, cueing effects did not appear to exist at the 2124ms SOA, but were found at the 1365ms SOA. The 1365ms SOA produced another interaction, with cueing effects being facilitatory for the face condition and inhibitory for the house condition. This is presented in figure 5.1.

The same repeated-measures ANOVA was also conducted on the error data (misses on probe trials). No significant effects were identified (all Fs < 2.7, all ps $\geq .1$), suggesting that the results were not influenced either by a speed-accuracy trade off or by certain trials being more difficult than others.

5.2.3 Discussion

In Experiment 9, the cueing effects generated by photographic houses and photographic faces were examined when saccadic responses were used. This served to build on Experiment 7, which found location-based and object-based ICEs for houses and object-based facilitation for faces, by examining if comparable results were found for IOR, a saccadic rather than perceptual phenomenon. Additionally, a central cue was used instead of the peripheral cues used in previous experiments. The principal finding was a three-way interaction between condition, SOA and cue validity. This manifested in the form of no cueing effects being identified at the long SOA (2124ms), while significant cueing effects were found at the short SOA (1365ms). Furthermore, an interaction between condition and cue validity was found at the short SOA, with houses producing location-based and object-based IOR, while faces produced an object-based facilitatory cueing effect. Although these cueing effects were not statistically significant, the effect sizes were greater than or comparable to those observed for previous experiments: a summary of the object and location-based cueing effects for each experiment are presented in figures 5.2 and 5.3 respectively. This suggests that just as is observed for ICEs, photographic objects produced location-based and object-based IOR. Similarly, just as photographic faces do not produce ICEs, they also do not produce IOR and produce a saccadic facilitatory object-based cueing effect instead.

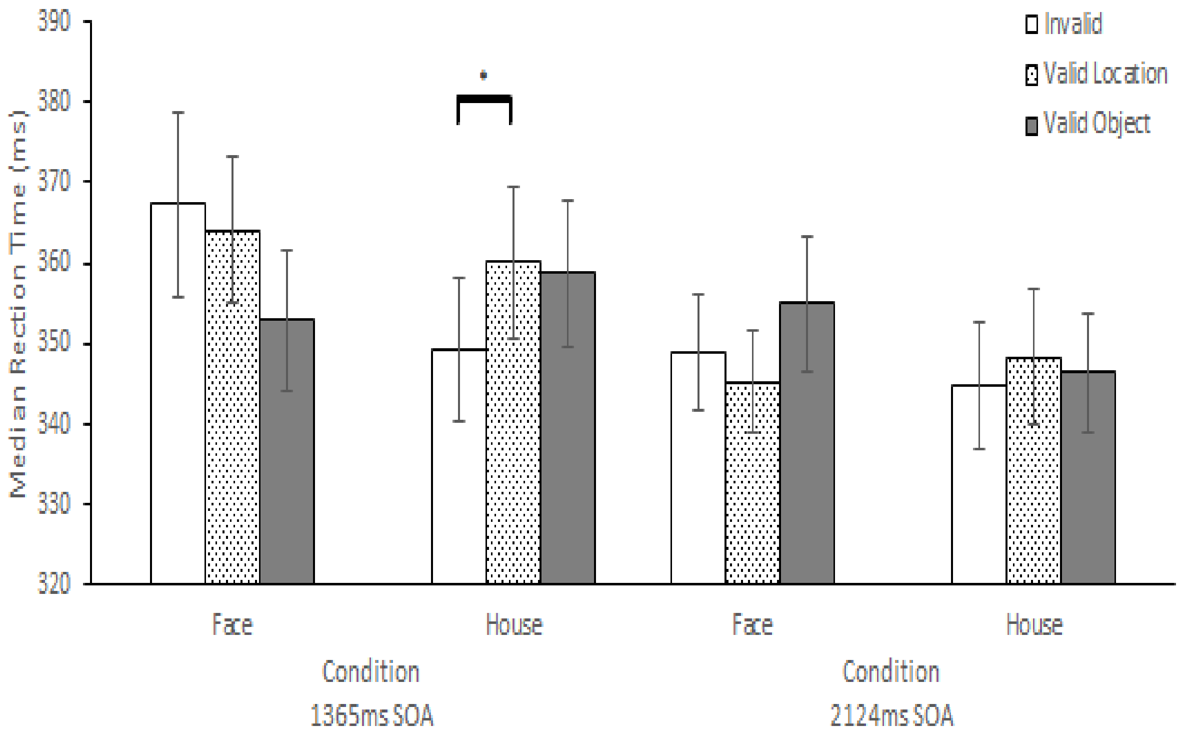


Figure 5.1: *Reaction times (ms) for each cue validity for photographic faces and houses at the 1365ms SOA and 2124ms SOA. Error bars represent +/- 1 SEM.*
* $p < .05$

One surprising finding was that, as evident from figures 5.2 and 5.3, the cueing effects in Experiment 7 and Experiment 9 were similar in all conditions. Although these experiments used identical stimuli, this was not expected because of the two major changes in paradigm that were made between these experiments. These will be discussed in turn.

Firstly, saccadic responses were used instead of manual responses. This is important because the mode of response is a primary indicator as to whether the inhibitory cueing effect observed is IOR or an ICE. When saccadic responses are used, the common pattern of results is initial oculomotor facilitation in response to a cue, which is then replaced with oculomotor inhibition and a response bias against the cued location (Hilchey et al., 2014). This is in line with the definition of IOR proposed by Posner et al. (1985). When manual responses are used, the general cueing effects observed appear to be the same: that is, there is initial facilitation in response to a cue which then leads to an inhibitory cueing effect. However, they are distinct from IOR in important ways. Firstly, when the oculomotor system is not engaged reliably by the cue, no oculomotor facilitation is observed.

Similarly, the inhibitory cueing effect observed does not apply to oculomotor responses, but only manual responses. Both of these were found to be the case by Hilchey et al. (2014) when using a paradigm which only required oculomotor activation on 20% of trials. Despite this, an inhibitory cueing effect was reliably observed, which Hilchey et al. (2014) gave the theoretically neutral name of ICE. In light of this experiment and others (e.g. Sumner et al., 2004; Taylor & Klein, 2000), it is accepted that IOR and ICE are distinct phenomena. Given that inhibitory cueing effects, whether ICEs or IOR, have been reliably observed in both static and dynamic displays, it is not surprising that the house stimulus produced comparable cueing effects across the experiments. However, in addition to not showing ICEs, faces did not produce either object-based or location-based IOR and instead showed a facilitatory cueing effect. This suggests that the mechanism that leads to this facilitatory effect does not simply act perceptually as would be suggested if IOR was preserved, but also affects oculomotor inhibition. This appears most consistent with the habituation hypothesis, as habituation could apply to any level of the neural system (Dukewich, 2009) and so could have comparable effects on oculomotor and perceptual inhibition. In contrast to previous experiments, overt orienting was monitored and so at least in terms of overt orienting, this finding cannot be explained by the reorienting hypothesis. This is because the pattern of overt orienting necessary to complete an experiment trial (by making eye movements to the cued object and then to the centre of the screen during the cue phase and then an eye movement to the target) is exactly the pattern of orienting that would lead to IOR according to this account. However, the presence of saccadic facilitation may be explained if participants remained oriented covertly to cued faces despite their eye movements. Traditionally, it has been argued that covert attention was necessarily tied to the oculomotor system (the oculomotor readiness hypothesis: Klein, 1980; later formulated as premotor theory: Rizzolatti, Riggio, Dascola, & Umilta, 1987). However, there is increasing evidence that at least for endogenous attention, covert and overt orienting can be dissociated. This includes the observation that cueing effects are only observed for central predictive cues and not non-predictive cues when eye movements are not possible, whether due to eye abduction (Smith et al.,

2012) or by presenting target stimuli outside of participants' oculomotor range (Casteau & Smith, 2018). Similar findings have been reported for individuals who cannot make eye movements (Gabay, Henik, & Gradstein, 2010; Smith et al., 2004). These findings suggest covert attention can be moved endogenously independent of eye movements, but exogenous shifts of attention may not be possible without a comparable eye movement. Thus, participants may have remained oriented to cued faces and this orienting led to facilitation, consistent with the reorienting hypothesis.

A second unexpected finding was that despite the use of a central cue, the cueing effects observed in earlier experiments using peripheral cues persisted. Studies investigating cueing effects almost exclusively use peripheral cues as IOR is not typically observed when central cues are used (Ivanoff & Saoud, 2009; Ristic, Friesen, & Kingstone, 2002; Ristic & Kingstone, 2006, 2012; Stevens et al., 2008; Tipples, 2002; Weger & Pratt, 2008). In light of this work, the fact that photographic houses produced significant object-based and location-based IOR in response to a central cue was unexpected. However, it is consistent with two previous studies. Firstly, Rafal et al. (1989) found an uninformative central arrow to lead to IOR, but only when a saccade was prepared or executed. According to this experiment, IOR but not ICEs could be generated in response to a central cue. However, this finding has been questioned by subsequent work. Most notably, Chica, Klein et al. (2010) attempted to replicate this finding and did not find IOR in the conditions where it was observed by Rafal et al. (1989). More recently, Henderickx et al. (2012) provided evidence that ICEs might be produced by central cues under certain circumstances. In their experiment, ICEs were observed when a two-step cueing procedure was used. Firstly, a central cue indicated the colour that participants were to focus on. Next, a peripheral cue appeared at each of two possible target locations, with one cue being the same colour as the central cue. The logic behind this second step is that exogenous attention is controlled for as both locations are equally peripherally cued, while only one location is centrally cued. In contrast, if only one location was cued, any cueing effect could reasonably be attributed to exogenous attention. Despite both locations being peripherally cued,

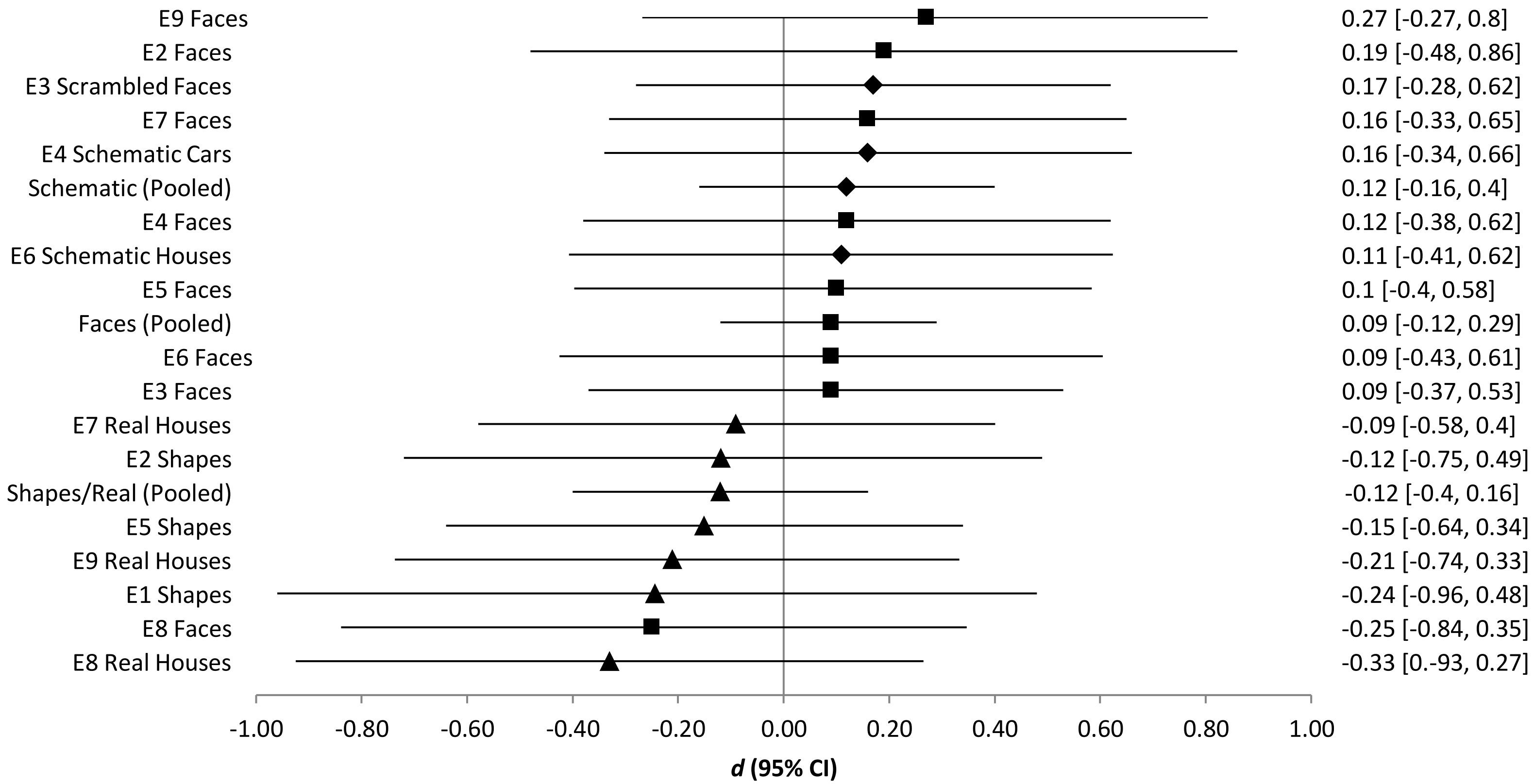


Figure 5.2: *The mean object-based cueing effect for each category of stimuli across the nine experiments of the thesis. Negative values indicate an inhibitory effect, while positive values indicate a facilitatory effect. Square data points indicate face cueing effects, diamond data points indicate schematic object cueing effects and triangle data points indicate shape/real object cueing effects. The values for Experiment 1 and Experiment 2 are derived only from blocks that were completed first as condition order significantly interacted with these cueing effects. The values for Experiment 5 are derived from two of three SOAs, as the 900ms SOA produced significantly different responses in both conditions. Experiments 7 and 9 reflect the cueing effects from the short SOA only, as the long SOA did not produce significant cueing effects. Experiment 8 used a static design which prevented distinguishing between object and location-based cueing effects: thus, the values for this experiment are the general cueing effects and are identical to those presented in Figure 5.3. All other values are collapsed across SOA and condition order where applicable.*

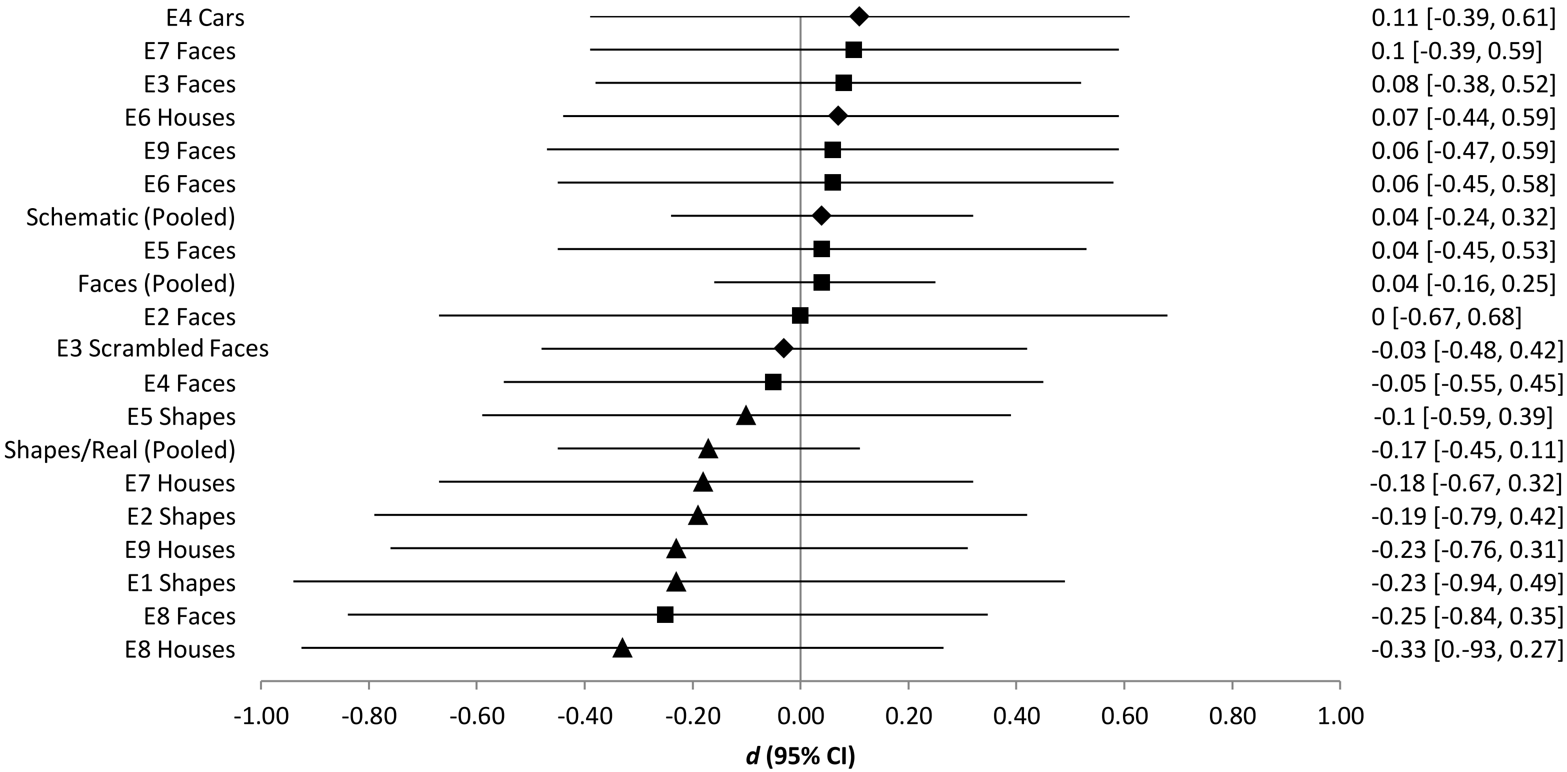


Figure 5.3: *The mean location-based cueing effect for each category of stimuli across the nine experiments of the thesis. Negative values indicate an inhibitory effect, while positive values indicate a facilitatory effect. Square data points indicate face cueing effects, diamond data points indicate schematic object cueing effects and triangle data points indicate shape/real object cueing effects. The values for Experiment 1 and Experiment 2 are derived only from blocks that were completed first as condition order significantly interacted with these cueing effects. The values for Experiment 5 are derived from two of three SOAs, as the 900ms SOA produced significantly different responses in both conditions. Experiments 7 and 9 reflect the cueing effects from the short SOA only, as the long SOA did not produce significant cueing effects. Experiment 8 used a static design which prevented distinguishing between object and location-based cueing effects: thus, the values for this experiment are the general cueing effects and are identical to those presented in Figure 5.2. All other values are collapsed across SOA and condition order where applicable.*

responses to the centrally cued location were significantly slower relative to the other location, suggesting an ICE. Acknowledging how previous research did not show attentional inhibition in response to central cues, Henderickx et al. (2012) explain their finding in terms of saliency. By providing participants a specific colour to prioritise for attentional selection, one of the locations was made more salient, with this salience driving the ICE observed. If it is the case that photographic stimuli are more salient than schematic stimuli and salience is a contributor to ICEs, then this could explain the result that central cues produced ICEs for houses observed here. In contrast, previous experiments using central cues used shapes (Ivanoff & Saoud, 2009; Ristic & Kingstone, 2006, 2012), letters or text (Stevens et al., 2008; Tipples, 2002; Weger & Pratt, 2008) as targets, with only one prior experiment using more complex schematic objects (Ristic et al., 2002). Given the differences in representation between schematic and real objects demonstrated earlier, this experiment, along with Henderickx et al. (2012), support the notion that central cues can generate IOR, but that this is conditional on stimuli characteristics.

In this experiment, the object and location-based cueing effects were closely related in each condition. For the house condition which produced IOR, both object-based and location-based IOR were found. Similarly, the face condition, which produced object-based facilitation, did not produce location-based IOR. As presented in figures 5.2 and 5.3, this is consistent with previous experiments, with this pattern of results present in each experiment. This result may appear inconsistent with the proposal that differences in cueing effects are driven specifically by stimulus characteristics as intuitively, these stimulus characteristics should affect only object effects, not location effects. However, these findings are consistent with an interactive view of attention such as the biased-competition hypothesis. This suggests that the feature, category, object and location information associated with each object contributed to a single attentional effect (facilitation for faces and inhibition for houses) rather than distinct location and object-based cueing effects. Thus, when cueing effects are observed, they reflect the influence of each "variety" of attention, which contribute respectively to either inhibitory or facilitatory cueing effects. The net behavioural result in dynamic displays appears to be conditional on stimulus, display and task characteristics.

In summary, Experiment 9 replicated Experiment 7 using an eyetracking paradigm, which includes saccadic responses and central cues. Despite these changes, the pattern of results found in this experiment was comparable to Experiment 7. In this experiment, participants' responses were slowed following a cue when the stimuli in the display were photographs of houses, leading to significant location-based and object-based IOR. However, when the stimuli were photographs of faces, a cue led to significant object-based facilitation. However, these effects were only present at the short SOA, with no cueing effects observed at the long SOA. Thus, just as inhibition was not present for faces when manual responses were used, it was also not present when saccadic responses were used, suggesting that oculomotor inhibition is also affected by the presence of faces. Additionally, central cues produced IOR for houses, suggesting that central cues can lead to IOR, with this appearing to be dependent on stimuli characteristics.

Chapter 6: General Discussion

6.1 Introduction

This thesis investigated whether faces produce object-based ICEs. This is important as it provides an avenue to differentiating between accounts of attentional inhibition in the specific context of object-based ICEs. Specifically, the habituation hypothesis and reorienting hypothesis predict that faces may not produce observable ICEs if the stimuli are of sufficient salience or are oriented to respectively, while detection cost theory would predict ICEs for faces would be consistently observed. While research has consistently demonstrated the presence of ICEs for faces in static displays, these studies do not provide any indication that the cueing effects observed are specifically of an object-based nature, rather than a location-based one. Accordingly, the studies in this thesis used a dynamic display variant of the spatial cueing task first used by Weaver et al. (1998). Shapes, schematic objects and real objects were used in the present experiments, in addition to faces. This was done as experiments using dynamic displays to date have primarily used simple objects. An eyetracking experiment was also conducted to determine if these effects persisted for saccadic responses and therefore IOR rather than ICEs. In the present chapter, the major findings of Experiments 1 to 9 will be discussed and placed into the research context of previous studies and theoretical accounts of cueing effects. Additionally, limitations of these experiments will be considered to support improved practice in future work. Finally, future studies to expand on the findings presented will be suggested.

6.2 Key Findings

6.2.1 Faces Do Not Produce Observable Object-based ICEs

It was traditionally believed that inhibition was highly insensitive to the stimuli content. This conclusion was supported by studies that showed ICEs for faces, regardless of the representation (schematic or photographic) or emotional content of the faces (Baijal & Srinivasan, 2011; Hu et al., 2014; Lange et al., 2008; Park et al., 2012; Silvert & Funes, 2016; Stoyanova et al., 2007; Taylor & Therrien, 2005, 2008; Verkuil et al., 2009). However, in contrast to this position, Experiments 2-7 and 9 all demonstrated that faces do not produce observable object-based ICEs or IOR. The difference between previous work and these experiments was the use of a dynamic display, which dissociated spatial and object-based frames of reference. In contrast, there was a reliable object ICE for simple shapes. This dissociation suggests that the ICEs of previous experiments are location-based rather than object-based. Consistent with this interpretation, a significant ICE was present for faces in Experiment 8, a static replication of Experiment 7.

It is important to note that although none of the conducted experiments found observable ICEs or IOR for faces, it cannot be stated conclusively that faces do not produce ICEs in these tasks. This is because both facilitatory and inhibitory cueing effects can be present simultaneously in the same display (e.g. Tipper et al., 1999). Thus, these experiments show that at the SOAs observed (between 750 and 1500ms), the net combination of inhibition and facilitation for faces was facilitatory. It may be the case that faces produce inhibitory effects that are masked by a larger facilitatory effect or even that faces produce a net ICE at a shorter or longer SOA than examined in any of the thesis experiments.

With regard to theoretical accounts of ICEs, the finding that faces do not produce ICEs is broadly consistent with a habituation account such as that proposed by Dukewich (2009). In this account, ICEs are a form of habituation to stimulus characteristics and/or responses made to the stimulus. Thus, targets that appear at cued locations or on cued objects are responded to more slowly than targets at uncued locations because the cued location/object has been stimulated more frequently than the uncued location/object and is therefore subject to greater habituation. However, if a stimulus is particularly salient, it would not be subject to habituation and therefore, according to this account, would not show ICEs. Thus, provided the faces used in these experiments were sufficiently salient, this account explains the absence of ICEs for faces. The reorienting hypothesis can also explain the obtained results. According to this account, ICEs are only observed when attention is oriented away from a previously attended stimulus. Thus, provided participants maintained their attention towards faces rather than orienting away from them, the lack of an observable ICE is consistent with the reorienting hypothesis. In contrast, it is more difficult for detection cost theory to account for this finding. Detection cost theory attributes ICEs to an attentional cost in integrating the cue and target, suggesting that ICEs are primarily a product of highly similar cues and targets. In the present experiments, the relationship between cue and target was identical regardless of the stimuli employed, so it does not explain an absence of cueing effects for faces. In summary, with regard to current accounts of ICEs, the habituation hypothesis and reorienting hypothesis, but not detection cost theory, can explain this result.

6.2.2 Non-schematic Objects Produce Object-based ICEs

In addition to examining the cueing effects for faces, all the experiments conducted examined at least one other stimulus, stimuli which were broadly classified as objects. While Experiments 1, 2 and 5 all found significant ICEs for various classes of shapes, Experiments 3, 4 and 6 did not find ICEs for their respective objects (scrambled faces, schematic cars and schematic houses). At the first indication, this presented the possibility that object-based cueing effects were not as prevalent as previously thought. Although many studies have found object-based inhibition in dynamic displays, these studies have exclusively used shapes (e.g. Abrams & Dobkin, 1994; Gibson & Egeth, 1994; Tas et al., 2012; Tipper et al., 1991, 1994; Vivas et al., 2008; Weaver et al., 1998). However, Experiments 7 and 9 demonstrated object-based ICEs and IOR for photographs of houses, indicating that object-based cueing effects do generalise beyond shapes. While this finding may not appear to be of much significance, it is worth noting as the first demonstration of object-based inhibition for a complex object in a dynamic display. It also makes the dissociation between ICEs for faces and other objects in dynamic displays clear, with faces not producing ICEs in any of 7 dynamic experiments, while all other objects produced ICEs in 5 of 8 dynamic experiments. The presence of

ICEs for shapes and real objects is consistent with the three theories of ICEs (reorienting hypothesis, habituation hypothesis and detection cost theory) discussed.

6.2.3 Faces Produce Object-based Facilitation

While faces were not observed to produce ICEs in any experiment using a dynamic display, faces also produced significant object-based facilitation in three experiments. In the remaining experiments, the direction of the cueing effect was facilitatory, with an average effect size of d = 0.14. This effect is comparable to that of other object-based cueing effects and appears reliable given its consistent presence in the experiments conducted. Thus, in addition to explaining why ICEs are not present for faces, it should be considered why they produce a specific facilitatory effect. According to the habituation hypothesis, facilitation would be observed under two circumstances. Firstly, it is observed when associative learning is possible (such as when predictive cues are used). Additionally, facilitation is predicted when the cue and target occur closely together in time, which would lead to an increase in the strength of the orienting response. However, neither of these are applicable to the present experiments, as the cues used were non-predictive and targets occurred at least 750ms after the cue was presented: facilitation is not typically observed beyond 300ms in spatial cueing tasks. Thus, although it explains the lack of ICEs well, the habituation hypothesis does not appear able to explain the facilitatory cueing effect for faces. The finding of facilitatory object-based cueing effects can also not be explained by the detection cost theory in its current form. In this account, facilitation is observed due to the presence of spatial orienting (overt orienting to the location of the cue) and/or spatial selection (prioritising attending to the cued area). Both of these effects are restricted to the location of the cue: thus, they cannot explain facilitation for an object that has moved from this location.

However, the reorienting hypothesis can explain this result. If participants remain oriented to the cued face stimulus, then this would produce faster reaction times to cued faces compared to uncued faces, as the orienting of attention provides a benefit to reaction times (Berlucchi, 2006).

This is consistent with the findings of the three thesis experiments. One potential barrier to this explanation is the presence of the cue-back (i.e. an abrupt onset at the fixation cross) in each experiment. Abrupt visual onsets capture attention strongly (Yantis & Jonides, 1996), which would suggest that attention would be withdrawn from the cued face following this onset. If the facilitation is due to directed attention, then it would be necessary for participants to direct their attention again to the face that was cued after withdrawal. However, at least with regard to overt shifts of attention in visual search and memory tasks, there is evidence participants do immediately refixate with some frequency (Dodd et al., 2009; Gilchrist & Harvey, 2000; Smith & Henderson, 2009; see Klein & Hilchey, 2011 for a review). Although it is likely that the exact purpose of these refixations is dependent on the task (e.g. there is evidence that refixations assist with recall in visual memory tasks; Zelinsky, Loschky, & Dickinson, 2011), it seems reasonable to assert that the general purpose of a refixation is to gain more information from the object or location refixated. This information may serve as memory rehearsal (Zelinsky et al., 2011) or be specifically task-relevant information that was not obtained or maintained following the first fixation (Hayhoe, Bensinger & Ballard, 1998). However, in the present experiments no such information was required and as the target could occur with equal probability at any of three faces, returning attention to the cued face would impair task performance. Participants were explicitly told this was the case at the start of the experiment, so it seems unlikely that they would volitionally direct their attention in this manner. However, the significance of social stimuli may be such that participants do this automatically in some circumstances. There is some evidence that participants direct or maintain attention to faces, even to the detriment of task performance. Bindemann, Burton, Hooge, Jenkins and de Haan (2005) used a go/no-go localisation task where participants were presented with either a horizontal or vertical line on each side of a fixation point. Participants had to identify whether the vertical line was on the left or right side of the fixation point. In addition, an image was presented at the fixation point, which could consist of an upright face, an inverted face, an object (one of three fruits), a flag (one of three countries' national flag) or text. There was also a blank condition where no image was presented at the fixation point. In all four experiments, an upright face at the fixation point led to significantly longer reaction times compared to any other stimulus. Cerf et al. (2009) examined this in an eyetracking paradigm in which participants were given various tasks in response to images which contained people. In one task, participants had to identify the location of a probe object and in some trials, were told specifically that the design would not be found on a face. Surprisingly, this instruction did not affect the likelihood of participants saccading to faces and in fact, participants took longer to saccade away from a face when given this instruction compared to when they were given no specific instruction. This seems to indicate that actively avoiding looking at faces is sufficiently effortful to affect performance adversely in search tasks. Although these studies do provide some support for the notion that participants may maintain attention at faces even when it is not in their best interest (with regard to the task), these studies do not provide evidence for the specific proposed circumstance in the present experiments, which would require refixating on the face after attention has been moved.

An alternative explanation for object-based facilitation for faces comes from biased-competition accounts of attention (Desimone & Duncan, 1995; Duncan, 2006). The biased-competition theory suggests that attentional effects apply at multiple levels of selection, which can include location-based, object-based and feature-based attention, as well as higher-level semantic information such as object category. Once an object is selected, shared properties and features of this object are similarly selected in other objects regardless of task relevance. For example, if a cued object receives an attentional benefit in the form of facilitated responses, objects that share perceptual or semantic properties with the cued object also receive an attentional benefit (Kravitz & Behrmann, 2011; Wegener, Galashan, Aurich, & Kreitner, 2014). A possible corollary of this is that the more properties of an object that are activated by a cue, the greater the cueing effect observed. In a typical spatial cueing paradigm, which used two boxes either side of a fixation cross, the cue would lead to attentional selection of location-based and object-based attention. This leads to a brief period of facilitation that then gives rise to inhibition, possibly due to habituation. However, in comparison to a shape, a stimulus such as a face provides greater feature and semantic information, which can lead to selection at these levels in addition to object and location-based selection. This could produce a facilitatory cueing effect of greater magnitude and/or duration than observed for simple shapes, which may explain the facilitatory cueing effect observed for faces. However, it is important to note that to date, this has only been considered in terms of objects separate from the cued object being facilitated on account of their sharing properties with the cued object. This is distinct from the mechanism required to explain the data in these experiments, which is that multiple cued properties within an object increase facilitatory cueing effects for the same object. While both the reorienting hypothesis and biased-competition accounts can explain the facilitatory effects observed, the current evidence base appears more supportive of the reorienting hypothesis. To date, only two studies (Kravitz & Behrmann, 2011; Wegener et al., 2014) have demonstrated that cueing effects are influenced by both cued and uncued properties of a cued object, while the literature demonstrating the ability of faces to capture attention is more comprehensive (e.g. Bindemann et al., 2005; Cerf et al., 2009; Crouzet et al., 2010; Langton et al., 2008).

Broadly speaking, the cueing effects for faces did not appear to be affected by the type of stimuli employed, with both schematic and real faces producing facilitatory cueing effects. However, a closer examination of the effect sizes of the cueing effects between schematic and real faces suggests that a difference may exist, as the cueing effect was greater for real faces compared to schematic faces (average schematic face effect size: $d = 0.11$; real face effect size: $d = 0.18$). However, caution is advised in drawing a conclusion from this observation for several reasons. Firstly, schematic faces were studied in five experiments, while real faces were only examined in a single experiment. Thus, it is unclear how representative the average effect size for real faces is. Secondly, these experiments also differed regarding their task difficulty (the subtlety of the luminance change to be detected), the solidity of the objects (contour-defined versus surface-defined), the strength of the cue (e.g. the thickness of the border and whether the border following the object outline or was an empty square placed over the object) and the SOAs employed (which ranged from one to three distinct SOAs). However, it is interesting to note that this pattern was maintained in a comparison between Experiments 6 and 7 (schematic effect size d = 0.09; real effect size d = 0.18), experiments which were identical in response type, object solidity, cue strength and SOAs. Nonetheless, while cueing effects may differ between real and schematic faces, further experiments are necessary to establish the replicability of this finding. Importantly, the facilitatory nature of the cue was not affected by the face representation used.

6.2.4 Schematic Objects Produce Object-based Facilitation

In addition to the facilitation found for faces, three experiments demonstrated object-based facilitatory cueing effects for scrambled schematic faces, schematic cars and schematic houses. Given the persistence of ICEs in spatial cueing tasks with SOAs beyond 300ms, this was an unexpected result. On first impression, it was assumed that the complexity of the objects was responsible for these cueing effects, given the fact that in Experiments 1 to 6 all non-shape objects appeared to produce object-based facilitation. However, this is unlikely to be the explanation, given that in Experiments 7 and 9, photographic house stimuli produced significant ICEs. Additionally, in static displays increased object complexity has been found to correspond to an increase in the magnitude of the cueing effect (whether inhibitory or facilitatory; Reppa et al., 2011).

Both of the explanations discussed as to why faces produce object-based facilitation could apply to schematic objects, at least in principle. The reorienting hypothesis suggests that the object-based facilitation observed is the by-product of attention being maintained at the object in question. Just as participants may maintain their attention at a cued face, they may prefer to follow cued schematic objects through a dynamic display. Why might participants follow specifically schematic objects and not shapes or photographs of houses? One possibility may be that shapes and houses are more familiar to participants than schematic objects. Most individuals have considerable direct or indirect visual experience with simple shapes. Similarly, while houses exist in a great variety of designs, most houses have a comparable configuration of features that will be familiar to most participants. While this configuration may be sufficient in some cases for schematic objects and they may be recognised as the class they are designed to represent, by and large these objects only bear a superficial resemblance to real objects. Thus, the maintenance of attention at an object could serve as an information-gathering strategy. Niimi et al. (2017) proposed that familiarity may affect the time course of ICEs. In their study, two experiments were conducted. In experiment 1, one of 41 distinct cues was used in each trial, with 40 of the cues taking the form of a photographic object, such as a chair and the remaining cue being a square. In experiment 2, only the square cue was used. Three SOAs were used of 240ms, 440ms and 640ms respectively. Although significant ICEs were observed for both experiments, the time course differed, with experiment 1 showing ICEs of 30ms, 25ms and 20ms at the 240ms, 440ms and 640ms SOAs, while experiment 2 showed an ICE of approximately 30ms for each SOA. This is attributed to the stimuli employed, which are likely to be less familiar to participants than a simple square. Additionally, the wide array of stimuli also meant that there were fewer trials that employed any given cue in experiment 1 compared to experiment 2, which may have further emphasised an information gathering strategy.

This has also been supported by work that has identified attentional facilitation for tasks that are unrelated to visual search or traditional cueing tasks. For example, Dodd and Van der Stigchel (2009) presented participants with real-world scenes and monitored their eye movements. Participants had one of four tasks for each scene: a visual search task, a memory task, a pleasantness task (how pleasant did they rate the scene) or free viewing. In any of the tasks, probes (a green circle) could appear: participants were instructed to look at any probe when it was detected. While IOR was observed for visual search tasks, facilitation was observed for the other three tasks. While there is no clear impetus for why free viewing would lead to facilitation, in the case of memory and rating a scene for a specific quality, returning to previous fixations to obtain further information as necessary may be more beneficial than inhibiting them.

The biased-competition hypothesis may also explain the facilitatory effect found for schematic stimuli. This account would suggest that schematic stimuli would provide greater opportunity for attentional selection due to a greater range of salient characteristics, which may include specific featural, semantic or categorical properties not present in simpler objects, in addition to the location-based and object-based attentional mechanisms applicable to all objects. Thus, when a schematic object is selected by an attentional system such as by a cue, the selection can “spread” to other properties of the same object, leading to a stronger cueing effect as manifested by the observation of attentional facilitation rather than inhibition.

However, there are problems with these explanations. With regard to the reorienting hypothesis, the notion of familiarity has not been tested explicitly in a spatial cueing task. With this in mind, there is little evidence that schematic objects could maintain attention to the extent required. Additionally, for the biased competition hypothesis to hold, it is necessary to reconcile the fact that photographic objects, which would surely serve as an increase in semantic and feature-level information relative to shapes, did not produce facilitation. This suggests that at least by itself, increasing feature and semantic information does not change cueing effects from inhibitory to facilitatory. One explanation for this may pertain to interactions with the particular forms of the stimuli used. For example, as the schematic objects used contain less detail than the photographic objects, it is possible that photographic objects contain a greater level of feature information, while schematic objects may provide a stronger cue to category information due to the absence of low-level visual properties found in the photographic stimuli. If this is the case, it is possible that the increased category information provided by schematic objects leads to a greater facilitatory effect. The exact mechanism by which attentional selection for one property (e.g. category information) can activate attentional mechanisms for other properties is also currently unknown. Additionally, while there is evidence for faces having a clear effect on the deployment of attention, there is no such evidence for schematic objects representing a stronger case for attention capture than either shapes or photographic objects, which weakens support for either theory.

6.2.5 The Uniqueness of Faces in Attentional Orienting

One of the driving forces for the present thesis was that faces may uniquely not be subject to IOR/ICEs due to the privileged status of faces in terms of capturing and maintaining attention (Cerf et al., 2009; Langton et al., 2008; Sato & Kawahara, 2014). In general, this idea was supported by the fact that excluding Experiment 8 (which used a static display), faces did not produce ICEs (Experiments 2-7) or IOR (Experiment 9). This finding is consistent with the notion that for displays with faces or other social signals, attention may be governed or at least influenced by specific social processing systems (Adolphs, 2009).

While it is clear that faces in dynamic displays do not produce ICEs, this does not entail that faces are special. Instead, they may not be subject to ICEs on account of a more general saliency mechanism, such as that implied by Dukewich's (2009) habituation hypothesis. Experiments 4 and 6 support this notion by finding that schematic cars and schematic houses also did not produce ICEs. In these experiments, these stimuli produced comparable (facilitatory) cueing effects to that of schematic faces.

From the thesis experiments, it is not possible to state conclusively whether the cueing effects for faces are qualitatively different to the cueing effects for schematic objects. However, it is noted that both schematic and photographic faces produced the same facilitatory cueing effects, whereas only schematic houses produced facilitatory cueing effects (compared to ICEs for photographic houses). Additionally, photographic faces produced a greater facilitatory cueing effect than schematic faces ($d = 0.18$ for real faces compared to average $d = 0.11$ for schematic faces), although it is noted that this is based on a single experiment for real faces. Additionally, faces do not appear to be subject to either ICEs or IOR, indicating that neither of these mechanisms applies to faces. However, it is possible that schematic houses/cars are also not subject to IOR as this was not tested in the current experiments. Although limited, this does provide evidence that faces may uniquely modulate the mechanisms that lead to ICEs and IOR.

The overriding of ICEs by faces is consistent with work showing unique attentional orienting effects by faces. This has been demonstrated in the gaze cueing literature. Friesen and Kingstone (1998) were the first to demonstrate that participants were significantly faster to identify targets at a location consistent with the gaze of a central face compared to targets at an inconsistent location. This finding was replicated in several subsequent studies (Friesen & Kingstone, 2003; Kingstone, Friesen, & Gazzaniga, 2000; Langdon & Smith, 2005; Ristic & Kingstone, 2005). However, some of these studies did not provide strong evidence for the idea that faces are unique, typically because they did not make direct comparisons between gaze cues and other types of cue (see Langdon & Smith, 2005; Ristic & Kingstone, 2005 for exceptions). When this was done, it was found that arrow cues produced equal behavioural responses to gaze cues (Ristic, Friesen, & Kingstone, 2002; Tipples, 2002). Again, this is a finding that has been replicated in a number of studies (Brignani, Guzzon, Marzi, & Miniussi, 2009; Kuhn & Kingstone, 2009; Stevens et al., 2008; Tipper, Handy, Giesbrecht, & Kingstone, 2008; Tipples, 2008).

On the strength of this evidence, it appears that arrow cues and gaze cues are not distinguishable in terms of their orienting effects. However, perhaps the design used in these experiments did not do enough to separate the two types of cue. That is, although the studies discussed have used faces, perhaps all that has been tested is the effect of social appearance rather than relevance (Gobel, Tufft, & Richardson, 2018). If participants are given a stronger indication as to the social nature of the cue, this might produce a different effect. Wiese, Wykowska, Zwickel and Müller (2012) tested this claim by conducting a gaze cueing experiment that compared photographs of a human face and a robot in two experiments. In experiment 1 no explicit instructions were given. In experiment 2, participants were placed into one of two conditions: one group were told that the robot was controlled by a human, while the second group were told that the human was actually a mannequin. While participants did detect targets faster at the cued location regardless of the gaze cue, the benefit of cue validity was significantly stronger for agents that were believed to possess minds (humans and human-controlled robots) compared to agents that did not (robots and mannequins). Subsequent work has replicated this finding (Caruana, De Lissa, & McArthur, 2017; Gobel et al., 2018; Özdem et al., 2017; Wykowska, Wiese, Prosser, & Müller, 2014).

Gaze cues and arrow cues also appear to activate different neural substrates. Engell et al. (2010) found arrow cues initially activated the dorsal attentional system (defined here as the IPS and FEF) while gaze cues additionally activated the ventral attentional system (including the TPJ and right ventral frontal cortex). Arrow cues only activated the ventral attentional system when they were invalid, whereas gaze cues activated both systems reliably. Activation likelihood estimation meta-analyses have found the TPJ to be associated both with the orienting of attention and the ability to understand the mental states of others (Krall et al., 2015; Kubit & Jack, 2013). This suggests the TPJ may be of particular interest in the context of social attention. Özdem et al. (2017) identified greater activation (using fMRI) in the TPJ when the gaze cue was believed to be produced by a human rather than a robot. The prefrontal cortex has also found to affect gaze cues. Wiese, Abubshait, Azarian and Blumberg (2018) found no significant difference in the cueing effect between a human and a robot gaze cue at baseline (7.5ms and 8.7ms respectively). However, when TMS was applied to the left prefrontal cortex, this led to a significant difference between the cues, with an increase in the validity effect of the human gaze cue (12.3ms) and a decrease in the validity effect of the robot gaze cue (2.3ms).

Although the discussed research is of gaze cueing rather than the spatial cueing paradigm employed in the thesis experiments, there are parallels that are believed to be of application to future work looking at cueing effects for faces in dynamic displays. Thus, while the current findings of this thesis do not provide sufficient evidence to conclude that the facilitatory effects observed are unique to faces, this literature provides a basis for future spatial cueing studies that will allow a clearer picture of the distinction (if any) between faces and schematic object cueing effects. The principal ways suggested to do this are by increasing the social relevance of the faces/task employed and/or examining relevant neural substrates such as the TPJ.

6.2.6 Faces and Schematic Objects Do Not Produce Observable Location-based ICEs in Dynamic Displays

Beginning with the seminal work of Tipper et al. (1991), a diverse body of evidence has supported the notion that object-based and location-based cueing effects are distinct (Jordan & Tipper, 1998, 1999; Leek et al., 2003; McCrae & Abrams, 2001; Reppa & Leek, 2006; Possin et al., 2009; Tipper et al., 1997, 1999; Vivas et al., 2008). Indeed, this distinction contributed to the initial rationale for conducting the experiments in this thesis, as previous experiments examining cueing effects for faces had not considered the distinction between object-based and location-based cueing effects. As the experiments in this thesis found that faces did not produce observable ICEs in dynamic displays despite the consistent finding that they produced ICEs in static displays in previous work, this appeared to support the dissociation between location-based and object-based cueing effects. In addition, Experiment 8 confirmed that these faces did produce ICEs in a static display. In these experiments, typically the location and object-based cueing effects obtained were similar, with the location and object-based cueing effects being comparable in 10 of 14 comparisons (see figures 5.2 and 5.3). This may not seem a particularly noteworthy result, as dynamic cueing studies typically observe both location-based and object-based ICEs. However, it is interesting to note that both faces and schematic objects, neither of which produced observable object-based ICEs, also consistently failed to produce observable location-based ICEs.

With regard to explanations for ICEs, the best theoretical account as to why location-based ICEs were not found for faces or schematic objects appears to be the habituation hypothesis. Provided the objects in question are salient enough, it is possible that the attentional response provoked by a cue would not show habituation, which would lead to no difference in reaction time between cued and uncued stimuli and which could apply to both locations and objects. There does not seem to be a mechanism in either the reorienting hypothesis or detection cost theory to account for this result. According to the reorienting hypothesis, ICEs are present due to an attempt to reorient to a cued stimulus, which would indicate location-based ICEs regardless of the objects in a display. Similarly, detection cost theory attributes ICEs as being an attentional cost caused by the cognitive process of integrating similar cues and targets. In the thesis experiments, the relationship between cue and target was identical regardless of the stimuli employed and thus, this theory does not explain the lack of location-based ICEs specifically for faces and schematic objects.

In addition to there being no ICEs, the direction of the location-based cueing effects for schematic objects and faces tended towards facilitatory. Location-based facilitation would not be predicted by the habituation hypothesis. However, it is important to note that the observed effects are very small (schematic location cueing effect M = 3ms (d = 0.05); face location cueing effect M = 4ms (d = 0.04). Thus, there is no strong evidence that there is a location-based cueing effect for these stimuli.

6.3 Implications for Theories of Attentional Inhibition

The experiments presented in this thesis have implications for theories of attentional inhibition. The primary finding, that faces did not produce object-based ICEs, suggests they may be exempt from ICEs once dissociated from location-based cueing effects. Thus, for a theory to explain these data, it must acknowledge that ICEs may not be present for certain stimuli. This is consistent with the habituation hypothesis, as different objects may be subjected to different levels of habituation based on their salience. Thus, provided faces are of sufficient salience, they may not be habituated to and therefore may not show ICEs. The reorienting hypothesis could also explain this result if different stimuli lead to different patterns of orienting. However, the lack of ICEs for faces is not consistent with detection cost theory in its current form, as it only considers shared stimulus properties between the cue and target.

The present experiments also provide evidence that schematic objects may not produce object-based ICEs. In principle, this could be explained by the habituation hypothesis and reorienting hypothesis in the same way as the lack of cueing effects for faces: the salience of the objects prevents habituation (or reorienting away from the objects) and therefore no ICEs are found. However, currently there is no evidence that schematic objects would be of sufficient salience to achieve this effect in a simple detection task. Furthermore, it is not the case that complex objects by themselves do not produce ICEs, as photographic houses produce ICEs. Thus, neither hypothesis provides a clear mechanism to explain why a schematic house would not show habituation if a photographic house does. One possibility is that schematic houses are less familiar than photographic houses and this correspondingly reduces the habituation observed or encourages increased orienting time for the purposes of e.g. information gathering (Niimi et al., 2017). However, the effect of stimulus familiarity on ICEs has not been explicitly tested.

While the present data do not permit a conclusive statement regarding the differences in cueing effects for faces and schematic objects, the gaze cueing literature currently suggests a qualitative distinction between social and non-social cues in attentional orienting (Engell et al., 2010; Gobel et al., 2018; Wiese et al., 2018). Assuming that the neural substrates and effects identified in this literature are consistent with cueing effects, this would suggest that current theories of attentional inhibition may need expanding to explain the unique properties of cueing effects for faces. Alternatively, the habituation hypothesis may account for cueing effects for faces in conjunction with an additional attentional account (such as the reorienting hypothesis or biased-competition theory discussed). Depending on future research examining cueing effects for faces, a specific account of social orienting in spatial cueing paradigms may be necessary, but the present data does not conclusively demonstrate a distinction between faces and schematic objects at this time.

In addition to the implications for theories of ICEs from earlier experiments, Experiment 9 also provides information relevant to accounts of IOR. Just as faces did not produce ICEs and in fact produced object-based facilitation when a manual response was used, faces also did not produce IOR in a saccadic paradigm and maintained the facilitatory object-based cueing effect observed in

Experiments 2-7. Despite the clear distinction between ICEs and IOR (Hilchey et al., 2014; Sumner et al., 2004; Taylor & Klein, 2000), both were affected in a similar manner for face stimuli in a dynamic display. This suggests that the mechanism which leads to object-based facilitation for faces affects the oculomotor system as well as the perceptual system. This appears to be most consistent with the habituation hypothesis, as habituation can apply both to the perceptual and motoric responses that distinguish ICEs and IOR (Dukewich, 2009). Alternatively, the reorienting hypothesis could explain this in terms of covert orienting, with participants responding faster to cues faces because they remained oriented to them independently of their eye movements. The separation of covert attention and eye movements in endogenous attention allows for this possibility (Casteau & Smith, 2018; Gabay et al., 2010; Smith et al., 2004, 2012). It is currently unknown if schematic objects produce facilitatory cueing effects with a saccadic response: this could provide further insight with regard to the nature of the facilitation and thus, whether this facilitation is best accounted for by a specific social orienting account or a more general attentional account.

6.4 Replicability of the Presented Cueing Effects

The present experiments have demonstrated that neither IOR nor ICEs are present for faces or schematic objects in dynamic displays, whereas ICEs were found for shapes and real objects. However, questions can be raised about the replicability of these effects. This is because the effect sizes observed were small, with an average d of -0.16 for ICEs for shapes and real objects and 0.14 for the facilitatory object-based cueing effect for faces. Based on this, it might be questioned whether the cueing effects reported are genuine and replicable. To examine this, a pooled analysis of Experiments 1-7 was conducted to explore whether there was evidence overall of significant cueing effects for three categories of stimuli: shapes/real objects, schematic objects and faces. Experiment 8 used a static rather than a dynamic display and so was excluded, while Experiment 9 was excluded as it measured IOR rather than ICEs. As the 1500ms SOA was not used in the first four experiments, it was not examined in this analysis to maximise sample size. As the short SOA varied between 750ms and 900ms depending on the experiment, these were treated as a single category to maximise sample size. To account for the six comparisons made, adjusted p-values are also included using the Holm-Bonferroni correction for significant effects. This revealed a significant object-based ICE for shapes/real objects ($M = -12$ms; $t(95) = 3.071$, $p = .003$, adjusted $p = .012$, $d = -0.12$), as well as significant object-based facilitation for schematic objects ($M = 9$ms; $t(97) = 2.951$, $p = .004$, adjusted $p = .012$, $d = 0.12$) and faces ($M = 8$ms; $t(178) = 3.664$, $p < .001$, adjusted $p = .002$, $d = 0.09$). With regard to location-based cueing effects, a significant location-based ICE was found for shapes/real objects ($M = -18$ms; $t(95) = 4.787$, $p < .001$, adjusted $p < .001$, $d = -0.17$), while no location cueing effects were found for schematic objects ($M = 3$ms; $t(97) = 0.735$, $p =.464$, $d = 0.04$) or faces ($M = 4$ms; $t(178) = 1.74$, $p = .084$, $d = 0.04$). The effect sizes of these pooled values, along with the effect sizes for each experiment, are presented in figures 5.2 and 5.3. Although this pooling (and its consequent increase in statistical power) provides support for the presence of these cueing effects, it does not change the matter that the effect sizes observed were small. However, these effect sizes are comparable to the effect sizes produced by other studies examining cueing effects in dynamic displays. Although it is common to assume that an effect size of 0.2 or less is small as suggested by Cohen (1988), this guideline is arbitrary. Instead, it is more appropriate to consider the effect size relative to other results in the literature (Lakens, 2013). A summary of effect sizes of other dynamic display cueing studies is presented in figure 6.1. For example, Tipper et al. (1991) present three experiments examining object-based attention, with Experiments 2 and 3 using dynamic displays comparable to the displays used in the thesis experiments. In Experiment 2, the average ICE effect size across the two SOAs used (430ms and 695ms) was $d = -0.16$. In Experiment 3, the average ICE effect size across the two SOAs used (695ms and 959ms) was $d = -0.12$. From this summary, it is clear that the effect sizes reported in these experiments are similar to the effect sizes found in the present study, suggesting that these effects are replicable.

6.5 Summary of the Key Findings

In conclusion, the experiments presented in this thesis have provided insight into cueing effects for faces and other objects in dynamic displays and have contributed to our understanding in several ways. It was demonstrated that in dynamic displays, faces and schematic objects do not produce object-based ICEs, while shapes and real objects did produce object-based ICEs. This finding can be accounted for by both the habituation hypothesis and the reorienting hypothesis. Additionally, both faces and schematic objects produced object-based facilitation. This can be accounted for by the reorienting hypothesis and the biased-competition hypothesis. The biased-competition hypothesis proposes that activation applies simultaneously across all aspects of the attentional system (e.g. location-based, object-based, feature-based attention). Accordingly, once an object is selected, all characteristics of that object are favoured by the attentional system and the more characteristics activated, the greater the attentional effect. Thus, faces and schematic objects when cued produce greater activation because of their increased semantic and feature information compared to shapes. In this account, the fact that photographic objects produced ICEs may reflect differences in the relative contributions of semantic and feature information compared to schematic objects. While the data of the thesis experiments do not permit strong conclusions about the differences between the cueing effects for faces and schematic objects, recent studies in the gaze cueing literature support a dissociation between social and non-social cues in attentional orienting (Engell et al., 2010; Gobel et al., 2018; Wiese et al., 2018). Faces and schematic objects also did not produce location-based ICEs, a finding that appears consistent with the habituation hypothesis.

6.6 Limitations

There are limitations with regard to some of the conducted experiments that are worth mentioning. In Experiment 8, a replication of Experiment 7 using a static display, it was found that photographic

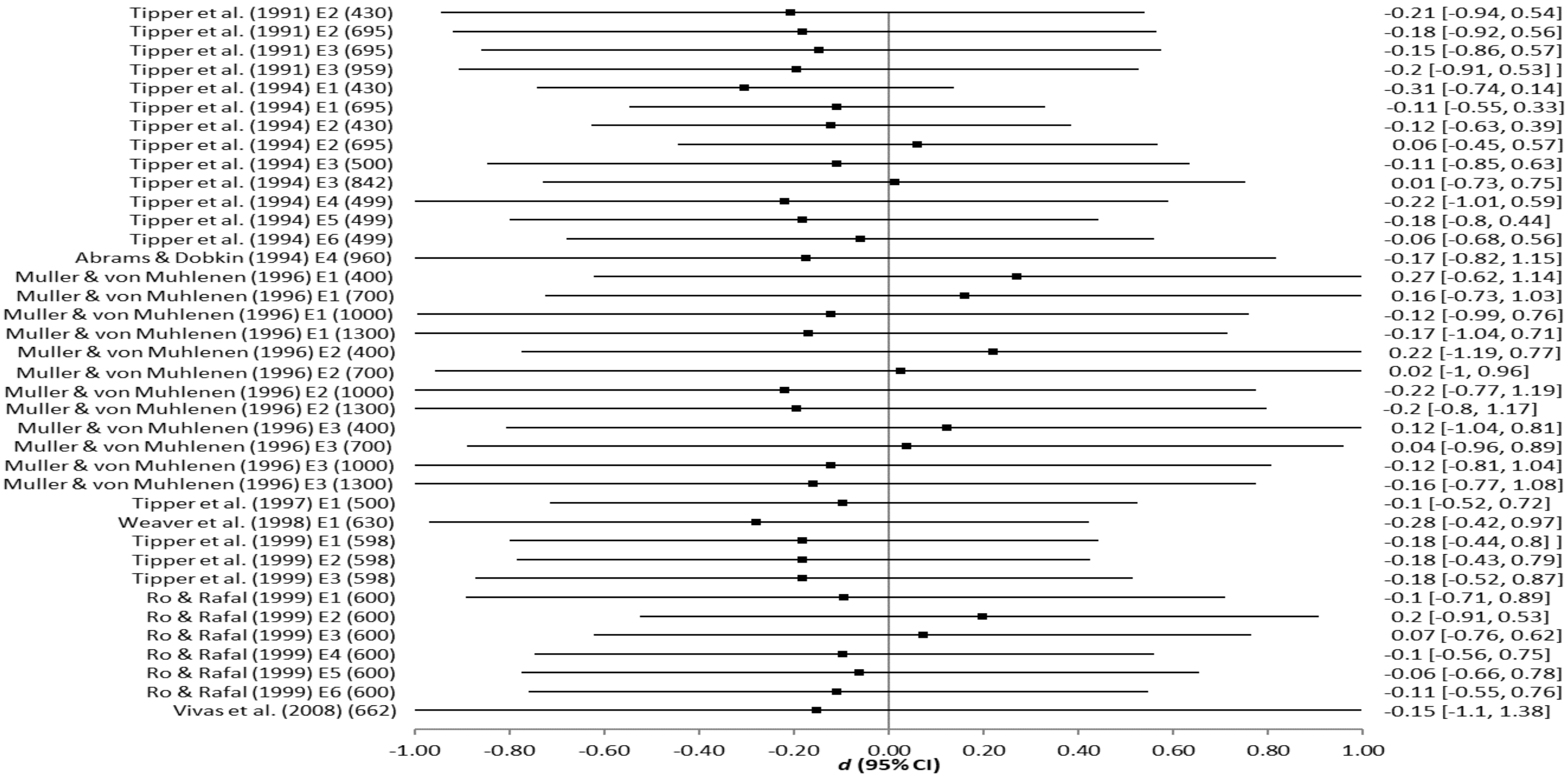


Figure 6.1: *Summary of object-based cueing effects obtained in previous work using dynamic displays. Negative values indicate an inhibitory effect, while positive values indicate a facilitatory effect. E indicates the experiment number within the cited study (e.g. E2 = Experiment 2), with the following number in brackets representing the SOA in milliseconds. As many of these studies did not provide the standard deviations necessary to calculate effect sizes and confidence intervals, where necessary standard deviations were estimated based on the standard deviations obtained in Vivas, Humphreys & Fuentes (2008), adjusted for differences in the means (i.e. if the mean reaction time was 90% of the equivalent Vivas et al. 2008 condition, the standard deviation value used was 90% of the Vivas et al. (2008) standard deviation). While this estimate will obviously contain error, it is considered sufficient to illustrate that these cueing effects are comparable to those in the thesis experiments.*

houses produced ICEs. However, photographic houses did produce ICEs in Experiment 7, while schematic objects did not produce ICEs in dynamic displays in Experiments 3, 4 and 6. Therefore, Experiment 8 would have provided greater evidence for the significance of the movement in the display if its findings were produced using a schematic rather than a photographic stimulus. However, this limitation is tempered by the fact that faces produced ICEs in this experiment, which had not been shown in any experiment using dynamic displays. This demonstrated the significance of decoupling object-based and location-based cueing effects and suggests that the schematic objects used in these experiments would show ICEs in a static display. Additionally, research has consistently demonstrated ICEs in static displays, which makes it unlikely that the schematic objects used in the thesis experiments would not (Reppa et al., 2012). Nonetheless, this was not specifically tested, so the possibility exists that certain schematic objects could show different cueing effects in a static display compared to other objects.

A second limitation relates to Experiment 9. As the cue was self-generated with a saccade in response to an arrow, there were fluctuations in the exact length of SOA in each trial depending on how quickly participants responded, as the experiment did not proceed until this was completed (or until 1000ms had passed). Similarly, the return to fixation was also recorded in the same manner and did not proceed until detected (or 1000ms had passed). The time for participants to make these saccades was recorded for each trial, with the intention being to remove trials if a response for either phase was not detected within 1000ms. Unfortunately, due to technical difficulties regarding calibration, for approximately half of the participants a significant proportion of trials exceeded this length, as at least one of these two saccades were not identified. The number of trials was great enough that it was not possible to remove these trials as this would have left insufficient data to analyse for the experiment for some combinations of the conditions. This inconsistency in timing across the SOA categories may have affected the obtained results. However, it is worth noting that despite this timing inconsistency, Experiment 9 produced the same pattern of results as Experiment 7, the experiment that served as the basis for Experiment 9. This included both experiments finding the same three-way interaction between SOA, cue validity and condition and cueing effects only being present at the short SOA and not the long SOA. Additionally, both SOA categories were equally affected as they did not differ significantly in the total time taken for both phases ($t(26) = 1.578$, $p = .127$, $d = 0.05$; 750ms SOA $M = 1014.7$ms; 1500ms SOA $M = 1024.8$ms), suggesting that the difference between these categories was generally maintained. This provides some support that this did not affect the results extensively.

While it is necessary to acknowledge these limitations, it is clear that the experiments of the thesis have provided a contribution to the cueing effects literature at large. For future eyetracking experiments using self-generated cues, it is important to ensure that the time taken for participants to respond to these cues is recorded and accounted for when interpreting the results obtained.

6.7 Future Directions

This thesis has provided evidence that faces and schematic objects produce different cueing effects compared to shapes and photographic objects. As with any research, these experiments have also identified open questions regarding aspects of the cueing effects identified.

Both schematic objects and faces did not produce ICEs in any experiment conducted and for faces, this extended as well to IOR. When cueing effects were observed, these tended to facilitation rather than inhibition. It remains unclear to what extent facilitatory cueing effects for faces are qualitatively different to those of schematic objects. Findings from the gaze cueing literature can be used as a model to identify if these effects can be differentiated. For example, when the social relevance of the gaze cue is emphasised (such as when participants believe a cue is generated by a fellow participant compared to a computer; Gobel et al., 2018), stronger cueing effects are found. A spatial cueing task could test this by having participants believe aspects of the display are socially relevant (such as under human control or associating responses to certain stimuli with social rewards) and examining if this leads to greater facilitatory cueing effects. It may also be possible to distinguish these effects through their neural substrates. In gaze cueing, this has been done by assessing activation for social and non-social cues with fMRI (Özdem et al., 2017) and by stimulating the prefrontal cortex with TMS, which led to an increase in social cueing effects and a decrease in non-social cueing effects (Wiese et al., 2018). Examining the neural basis for these cueing effects will give an indication as to whether faces produce unique cueing effects or not.

In contexts outside of the laboratory, faces are important typically because of their unique identities rather than their status as faces. In the present experiments, three objects were presented but each object was identical to the other display objects. This was the case not only for the objects but also for both the schematic and photographic faces. Future experiments could consider the effect of using distinct objects in a display. As Kravitz and Behrmann (2011) observed that cueing effects applied to different objects that shared properties with the cued object, the use of distinct objects could increase the cueing effects observed. This may also serve to explore further the similarities and differences between the cueing effects for faces and schematic objects. For example, faces that differ with regard to properties such as their facial expressions may lead to cueing effects not found when a display comprises different types of other objects, as differing facial expressions may be a more salient difference than other object properties. More detailed displays may also increase the cueing effects obtained (Samuel & Kat, 2003) and provide useful information regarding cueing effects for faces and schematic objects.

Just as the present experiments found that faces did not produce ICEs in dynamic displays, several studies have identified a lack of ICEs for emotional faces in static displays (Fox et al., 2002; Park et al., 2012; Perez-Duenas et al., 2014; Rutherford & Raymond, 2010; Silvert & Funes, 2016; Verkuil et al., 2009). However, the absence of ICEs appears to be associated with specific task demands and participant characteristics, as most of these experiments also found ICEs for emotional faces for certain tasks and participant groups. Additionally, other experiments have found ICEs for emotional faces (Lange et al., 2008; Stoyanova et al., 2007). These findings align with the present experiments as this inconsistency in static displays can be attributed to the conflation of location-based and object-based ICEs, effects that were separated in the current experiments. However, the differences in the cueing effects between emotional and non-emotional faces in static displays could be clarified further using dynamic displays. For example, one possibility is that faces produce an object-based facilitatory cueing effect in static displays as well as dynamic displays and that this facilitatory effect is stronger for emotional faces than for non-emotional faces. Assuming there is also a location-based ICE and that this is competing with the object-based cueing effect, this would explain why static displays consistently produce ICEs for non-emotional faces, but produce differing results for emotional faces. However, it is also possible that emotional faces reduce the magnitude of the location-based ICE, a notion consistent with the lack of location-based ICEs for faces in the present experiments. A comparison of the facilitatory cueing effects for non-emotional and emotional faces in dynamic displays may provide insight into the observations in static displays. Considering task and participant characteristics that have had an effect in studies using static displays and applying them to dynamic displays, such as participant anxiety and the use of discrimination tasks instead of detection tasks, could also extend our knowledge of cueing effects for faces across static and dynamic displays. However, this may partially be mitigated by the fact that cueing effects in static and dynamic displays may be qualitatively different (e.g. Christ et al., 2002). Nonetheless, the application of other characteristics to faces in dynamic displays would at the least provide further knowledge of the cueing effects for faces in dynamic displays. There are also characteristics of faces that have not been explored in cueing effects studies that may lead to differences in the effects obtained, such as face familiarity or perceived personality characteristics of the faces in the display.

In addition to extending our knowledge of face cueing effects for dynamic displays, the present work could also inform future static display experiments. It is possible to investigate object-based cueing effects for faces by comparing displays with faces to displays without objects. Future work could examine the difference in cueing effects between these conditions. While experiment 8 found faces in static displays to produce ICEs, and to produce ICEs smaller than those for houses, an object-absent condition could provide further evidence as to the extent of the facilitatory cueing effects observed for particular objects.

The present studies also found a clear distinction between schematic and photographic stimuli, with schematic houses producing object-based facilitation and photographic houses producing ICEs. One suggested explanation for this difference is that of familiarity, as attentional facilitation may be of greater benefit if more information is required about an object. Niimi et al. (2017) proposed that familiarity may affect the time course of ICEs, but only compared using real objects versus squares as cues and did not specifically control levels of familiarity. This could be tested directly by comparing learned and novel stimuli.

6.8 Summary

The research presented in this thesis has demonstrated that in dynamic displays faces do not generate object-based ICEs. This novel finding was achieved by decoupling location-based and object-based cueing effects in these experiments. Additionally, it appeared to be the case that schematic objects did not produce ICEs as well, whereas shapes and photographic objects did. The fact that ICEs were not found for faces and schematic objects is consistent with the habituation hypothesis (Dukewich, 2009) and the reorienting hypothesis. Additionally, faces and schematic objects tended to produce facilitatory object-based cueing effects. Suggested explanations for this include the reorienting hypothesis and the biased-competition account. It is not possible to distinguish from these data whether the cueing effects for faces and schematic objects are qualitatively different, but it is proposed that this could be done by increasing the social relevance of face stimuli and/or examining neural substrates. This approach has helped to differentiate gaze and arrow cues in the gaze cueing literature (e.g. Özdem et al., 2017; Wiese et al., 2018). Although object-based cueing effects were the primary focus of the thesis, it was also found that faces and schematic objects did not produce location-based ICEs. These findings place limitations on theories of ICEs as they clearly demonstrate that ICEs are not found for particular stimuli, an observation incompatible with the detection cost theory. Although the cueing effects observed did not consistently show statistical significance across the experiments, a pooled analysis of seven experiments did reveal significant object-based cueing effects for each category of object (ICEs for shapes/real objects, facilitation for schematic objects and faces). Additionally, while the effect sizes observed were in the range that is typically considered small, these cueing effects are comparable to other studies that have used dynamic displays, suggesting that they are replicable and genuine effects. These findings extend our knowledge of the study of cueing effects in dynamic displays and have significant implications with regard to theories of cueing effects. However, there is still a need for future research to elucidate the facilitatory cueing effects observed. For example, it is currently not apparent whether the facilitatory cueing effect observed for schematic objects has the same basis as the facilitatory cueing effect seen in faces or if these effects are qualitatively different. This can be explored by further emphasising the social relevance of the stimuli used and examining potential neural substrates for social orienting such as the TPJ and prefrontal cortex. Another factor that could be considered in future work is the use of a variety of objects and faces in a display, as this may highlight differences between faces and schematic objects and may also increase the magnitude of the cueing effects observed. Examining characteristics manipulated by studies of cueing effects for faces using static displays in more detail by applying them to dynamic displays could also help bridge studies of static and dynamic displays and clarify the cueing effects for faces obtained. Although emotional faces have not been found to produce ICEs in static displays in several studies, this observation may indicate either an increased object-based facilitation for these faces or a reduced location-based ICE. By examining the cueing effects obtained for emotional faces in dynamic displays, this could be addressed. There are also facial characteristics that have not yet been examined in any study of cueing effects, such as face familiarity or perceived personality, which may have an impact on the observed cueing effects. Although there are still many aspects of these cueing effects to be uncovered, this thesis has demonstrated a novel facilitatory object-based cueing effect for faces and schematic objects in dynamic displays and so has expanded on the current knowledge of cueing effects.

Appendix A – Information Sheet and Consent Form (Experiment 1)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by myself and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre and should move your eyes from this point as little as possible. To prevent your head from moving, you will use the chin rest in front of this monitor. At the start of each trial, one of the three objects will change from black to white and then return to normal. Then, a black square will appear around the cross in the centre and then disappear. Then, the three objects will move. After they have moved, a grey probe will appear on one of the objects. As soon as you see this probe, press 1. There is an equal chance that it will be any of the three objects that changes in each trial. In some trials, no probe will appear after the objects move. In this case, press 2. Speed is essential, so press 1 as quickly as possible when you see the probe appear. There will be one block of practice trials and then two blocks of experimental trials and the experiment should take no longer than 20 minutes.

Contact Details:

Robert Swalwell (PhD student) (r.b.swalwell@dur.ac.uk)

Dan Smith (supervisor) (daniel.smith2@dur.ac.uk)

Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Who have you spoken to? ....

Do you consent to participate in the study? YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

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

(NAME IN BLOCK LETTERS) ....………............

Appendix B – Information Sheet and Consent Form (Experiments 2-4)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by myself and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre and should move your eyes from this point as little as possible. To prevent your head from moving, you will use the chin rest in front of this monitor. At the start of each trial, the outline of one of the three objects will turn to black and then return to normal. Then, a black square will appear around the cross in the centre and then disappear. Then, the three objects will move. After they have moved, one of the objects will turn grey. As soon as you see the object change, press 1. There is an equal chance that it will be any of the three objects that changes in each trial. There is a 4% chance that after the objects move, no object will change. In this case, press 2. Speed is essential, so press 1 as quickly as possible when you see the object has changed. There will be one block of practice trials and then two blocks of experimental trials and the experiment should take no longer than 20 minutes.

Contact Details:

Robert Swalwell (PhD student) (r.b.swalwell@dur.ac.uk)

Dan Smith (supervisor) (daniel.smith2@dur.ac.uk)

Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Who have you spoken to? ....

Do you consent to participate in the study? YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

Signed .... **Date** ....

(NAME IN BLOCK LETTERS) ....

Appendix C – Information Sheet and Consent Form (Experiment 5)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by myself and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre and should move your eyes from this point as little as possible. To prevent your head from moving, you will use the chin rest in front of this monitor. At the start of each trial, the outline of one of the three objects will turn to black and then return to normal. Then, a black square will appear around the cross in the centre and then disappear. Then, the three objects will move. After they have moved, one of the objects will turn grey. As soon as you see the object change, press 1. There is an equal chance that it will be any of the three objects that changes in each trial. There is a 4% chance that after the objects move, no object will change. In this case, wait until the trial ends or press 2. The time from when the object finishes moving to it changing to grey can be 150, 300 or 900 milliseconds, so do not press 2 immediately after the objects finish moving, but only if you are sure enough time has passed. Speed is essential, so press 1 as quickly as possible when you see the object has changed. There will be one block of practice trials and then two blocks of experimental trials and the experiment should take no longer than 30 minutes.

Contact Details:

Robert Swalwell (PhD student) (r.b.swalwell@dur.ac.uk)

Dan Smith (supervisor) (daniel.smith2@dur.ac.uk)

Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Who have you spoken to? ....

Do you consent to participate in the study? YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

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

(NAME IN BLOCK LETTERS) ....……….........

Appendix D – Information Sheet and Consent Form (Experiments 6-7)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by myself and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre and should move your eyes from this point as little as possible. To prevent your head from moving, you will use the chin rest in front of this monitor. At the start of each trial, the outline of one of the three objects will turn to black and then return to normal. Then, a black square will appear around the cross in the centre and then disappear. Then, the three objects will move. After they have moved, one of the objects will turn grey. As soon as you see the object change, press 1. There is an equal chance that it will be any of the three objects that changes in each trial. There is a 4% chance that after the objects move, no object will change. In this case, wait until the trial ends or press 2. The time from when the object finishes moving to it changing to grey can be 150 or 900 milliseconds, so do not press 2 immediately after the objects finish moving, but only if you are sure enough time has passed. Speed is essential, so press 1 as quickly as possible when you see the object has changed. There will be one block of practice trials and then two blocks of experimental trials and the experiment should take no longer than 30 minutes.

Contact Details:

Robert Swalwell (PhD student) (r.b.swalwell@dur.ac.uk)

Dan Smith (supervisor) (daniel.smith2@dur.ac.uk)

Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet?	YES / NO
Have you had an opportunity to ask questions and to discuss the study?	YES / NO
Have you received satisfactory answers to all of your questions?	YES / NO
Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply?	YES / NO
Were you given enough time to consider whether you want to participate?	YES / NO

Who have you spoken to? ....

Do you consent to participate in the study?	YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

Signed .... **Date** ....

(NAME IN BLOCK LETTERS) ....

Appendix E – Information Sheet and Consent Form (Experiment 8)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by me and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre and should move your eyes from this point as little as possible. To prevent your head from moving, you will use the chin rest in front of this monitor. At the start of each trial, the outline of one of the three objects will turn to black and then return to normal. This is the cue. Then, a black square will appear around the cross in the centre and then disappear. The three objects will stay in place, but one of the three will become darker after a period of time. As soon as you see the object change, press 1. There is an equal chance that it will be any of the three objects that changes in each trial. In 4% of trials, no object will darken. In this case, wait until the trial ends or press 2. The time from the cue appearing to one of the objects becoming darker can be 350 or 1100 milliseconds, so do not press 2 immediately after the objects finish moving, but only if you are sure enough time has passed. Speed is essential, so press 1 as quickly as possible when you see the object has changed. There will be one block of practice trials and then two blocks of experimental trials and the experiment should take no longer than 30 minutes.

Contact Details:

Robert Swalwell (PhD student) (r.b.swalwell@dur.ac.uk)

Dan Smith (supervisor) (daniel.smith2@dur.ac.uk)

Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Who have you spoken to? ....

Do you consent to participate in the study? YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

Signed .... **Date** ....

(NAME IN BLOCK LETTERS) ....

Appendix F – Information Sheet and Consent Form (Experiment 9)

- The data produced by this study is kept confidential.
- The data produced by this study can only be accessed by me and my supervisors (Dr. Dan Smith and Dr. Tony Atkinson).
- The data produced by this study is kept anonymous (cannot be linked to specific individuals).
- The data produced will be used only in the context of my research, specifically my PhD thesis and possibly publications in academic journals.
- You have the right to withdraw from the study at any time without penalty.
- You have the right to withdraw your data from the study after taking part.

Instructions:

Setup / Eyetracking Info:

Adjust the chair and/or chinrest until you are comfortable. Once you are happy with your position, the eyetracker will be placed on your head and adjusted until it can detect your eye position. It must be fitted tightly for the purposes of the experiment. Before the experiment begins, the eyetracker must be calibrated. For this stage, dots will appear at one of nine points on the screen and you have to look at each dot until it disappears. Once this stage is done successfully, the experiment will begin. It may be necessary to do this procedure again during the experiment if the eyetracker fails to detect your eye position: the experimenter will inform you if this is the case.

Experimental Procedure:

At the start of each trial, a black oval with a white dot will appear at the centre of the screen. You should look at this dot. Once the eyetracker has detected you are looking at the dot, the trial will begin. On the monitor you will see three objects in a triangular arrangement and a cross in the centre. You should keep your gaze on the cross in the centre unless instructed to look elsewhere. After a second has passed from the beginning of the trial, the cross in the centre will be replaced with an arrow which points at one of the objects. Look at the object the arrow is pointing at, then return to the cross in the centre. Once this is done, the objects will move. Once the objects have moved, one of the objects will darken. As soon as you detect this change, look at the object that has darkened. There is an equal chance that it will be any of the three objects that changes in each trial. In 4% of trials, no object will darken. In this case, keep looking at the cross in the centre until the trial ends. Once one of the objects is looked at or 2500ms passes, the screen will go black and the next trial will begin. The time from the objects moving to one of the objects becoming darker can be 150 or 900 milliseconds, so be aware that the change may not be immediate. Speed is essential, so look at the darkened object as soon as you detect a change. There will be 10 practice trials and then two blocks of experimental trials. Three breaks will be offered during the experiment: one break in the middle of each experimental block and one break once the first block has been completed. The experiment can be paused at any time if you require another break.

Contact Details:

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Tony Atkinson (supervisor) (a.p.atkinson@dur.ac.uk)

CONSENT FORM

(The participant should complete the whole of this sheet himself/herself)

Please cross out as necessary

Have you read the Participant Information Sheet? YES / NO

Have you had an opportunity to ask questions and to discuss the study? YES / NO

Have you received satisfactory answers to all of your questions? YES / NO

Have you received enough information about the study and the Intended uses of, and access arrangements to, any data which you supply? YES / NO

Were you given enough time to consider whether you want to participate? YES / NO

Who have you spoken to? ....

Do you consent to participate in the study? YES / NO

Do you understand that you are free to withdraw from the study:

* at any time and
* without having to give a reason for withdrawing and
* without any adverse result of any kind? YES / NO

Signed .... **Date** ....

(NAME IN BLOCK LETTERS) ....

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