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**Object- and location-based forms of representation in inhibition of return.**

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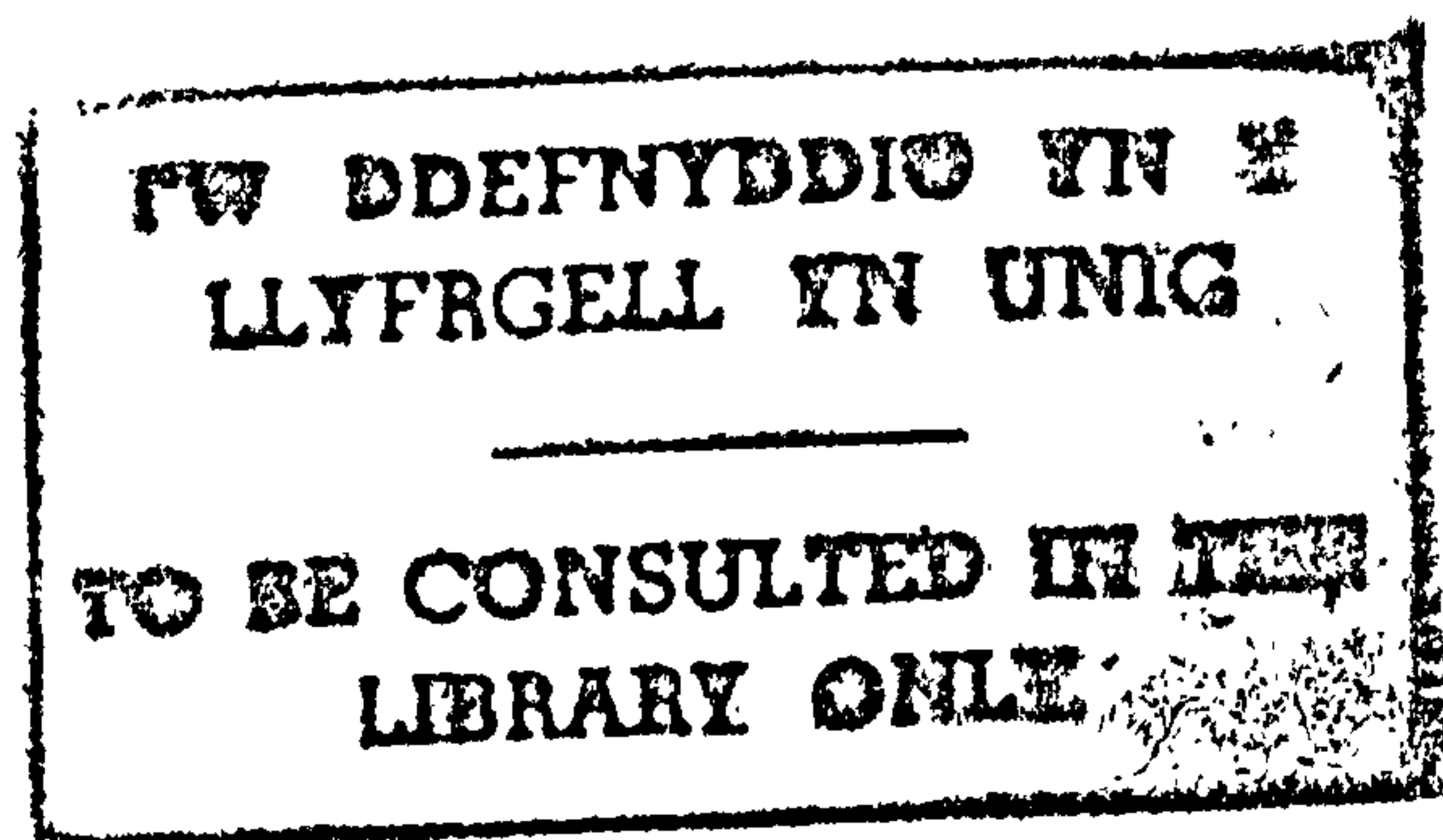
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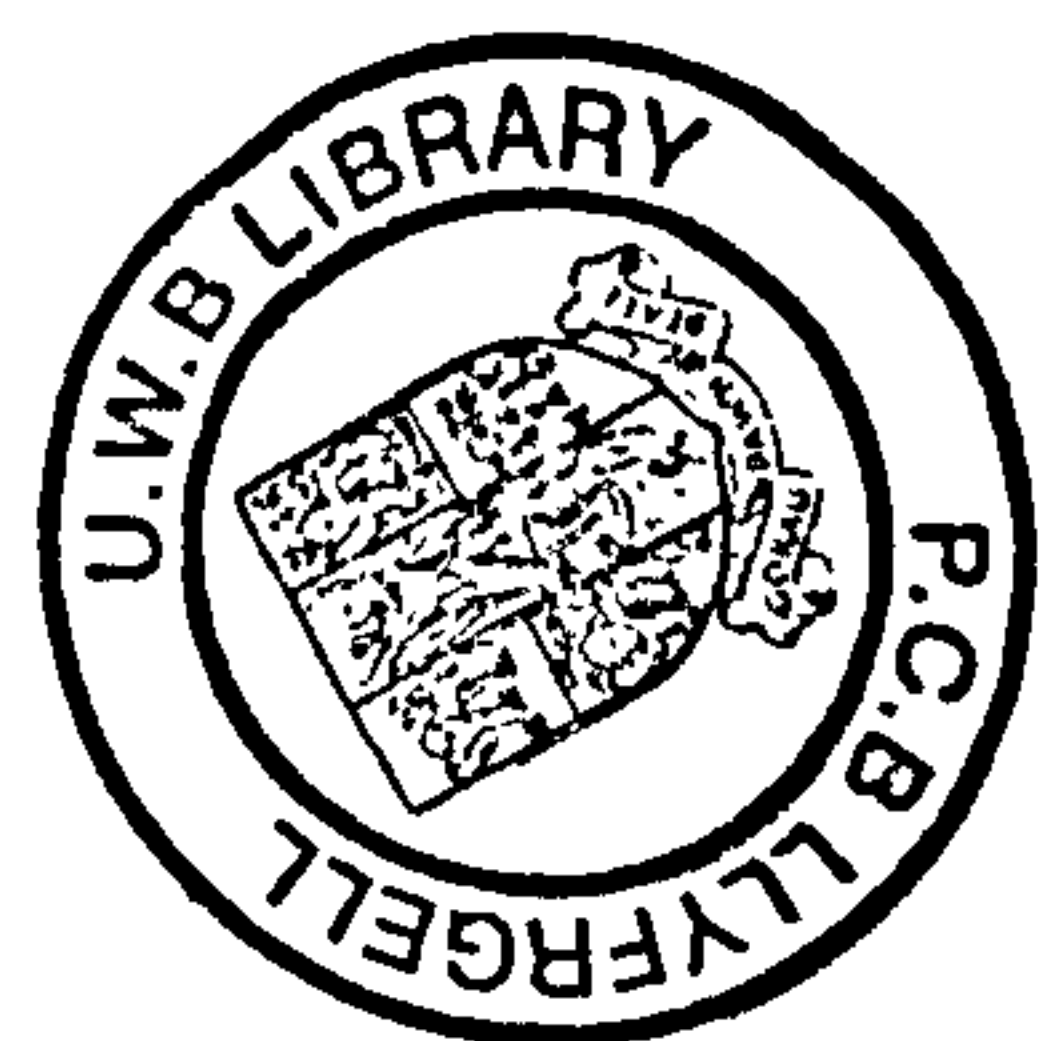
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# Object- and Location-based Forms of Representation in Inhibition of Return

Heather Jordan B.Sc., M.Sc.



A thesis submitted for the degree of Doctor of Philosophy  
at the University of Wales, Bangor  
August 1998



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# Object- and Location-based Forms of Representations in Inhibition of Return

Heather Jordan

A thesis submitted for the Degree of Doctor of Philosophy in the University of Wales, Bangor, August 1998.

Orienting processing resources towards a peripheral region of a display, by means of an exogenous cue, produces a biphasic effect on subsequent target detection. Initially response latency is facilitated, but increasing the SOA to 300 ms or greater results in slower detection, and this is known as the inhibition of return (IOR) effect. Initially this inhibitory effect was thought to bias attention against returning to a previously attended location but subsequent work demonstrated that it can also be associated with an object when motion is utilised to dissociate the two effects. This thesis re-examined the generality and utility of the object-based IOR effect.

Chapter 3 demonstrated that presenting an (apparent) object at the cue-target location is sufficient to trigger the object-based IOR effect. The observation that inhibition can spread across the surface of an object (Chapter 4) confirmed that pure object-based IOR is observed in static displays. Together these chapters provided a complete dissociation of the two independent IOR effects and suggests that they operate additively in the typical IOR procedure.

Chapter 5 demonstrated that the separate inhibitory mechanisms have characteristic boundary conditions. Orienting attention within-objects abolishes the location-based IOR effect, but does not effect the object-based effect. In sharp contrast, increasing object salience modulates the object-based effect, but has no effect on location-based inhibition.

Finally, there was no evidence of a retinotectal pathway involvement in the location-based IOR effect under monocular conditions. Rather, both effects appear to be generated by cortical regions, with an exclusively left visual field bias for the object-based IOR effect.

It was concluded that object-based IOR effects generalise to static procedures, which seriously questions the interpretation that IOR effects observed in static displays are mediated purely by a spatial frame of reference. This conclusion may generalise to all static precueing procedures. The boundary conditions of the object-based IOR effect are consistent with a mechanism that serves to guide efficient visual processing.



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# Chapter 1

## *Forms of Representation in Visual Attention: Literature Review*

Increasingly, vision is being understood as a dynamic, holistic processing system - an approach that has been termed "post-reconstructionist". The reconstruction approach emphasised the process of "translating" information from the "external" visual scene into a series of internal representations (e.g. Marr, 1982). Post-reconstructionists acknowledge that vision cannot be decoupled from behaviour as it is task-oriented, survival-supportive, purpose-directed and motor-coupled i.e. "perception for action" (for discussion see Stiehl, 1996; Tipper & Weaver, in press). Vision is an active process supporting basic behaviours (e.g. navigation, prey catching, obstacle and enemy avoidance, reproductive partner finding) in the real-world space-time continuum. Assuming perception is an active process, according to Stiehl (1996) this implies several aspects:

1. Active agents with instinctive (or conscious) awareness and subject to ego-motion.
2. The existence of distal environmental visual triggers.
3. Efficient pre-attentive visual processes within the retino-cortical pathway acting on compact, error-tolerant representations of the visual world.
4. The capability to master exorbitant quantities of visual data efficiently (selective visual attention).

Post-reconstructivists have been challenged with the cry:

"Perceptual activity is exploratory, probing, searching: percepts do not simply fall onto sensors as rain falls on the ground. We do not just see, we look."  
(Bajcsy, 1985, p. 55).

The post-reconstructivist approach to computer vision has led to the "re-



discovery” of early seminal work by the Gestaltists (Wertheimer, 1912; Wertheimer, 1923), ecological (or direct) perception (Gibson, 1950), neurobiology (e.g. Hubel & Wiesel, 1977; Livingstone & Hubel, 1988) and cognitive psychology. In turn, computer vision allows these disciplines to test and refine their theories of vision. In some cases, attempted implementations of machine vision systems highlight problems which were previously not considered by those studying biological vision systems (for example, see section 2.3.2).

Consideration is given to both the processes and the representations involved in extracting “what is where by looking” (Marr, 1982, p. 103). As we move around, and interact with our environment, our sensory systems are bombarded with vast quantities of information about the scene. Mammals have evolved highly efficient visual systems, which are very successful at producing accurate internal representations of the external environment. However, the sheer complexity of the visual input creates a problem in itself. Consider the problem faced by a primate foraging in a forest for food. The visual environment of a forest is very complex and rich in information. The challenge to the foraging primate is to select the food (ripe fruit) which it is seeking, from all the other visual information. Watching monkeys foraging in their natural setting gives the viewer a sense that this is accomplished with apparent ease. However, it is the extraordinary sophistication of the visual perception system, rather than the ease of the task, which is responsible for this illusion.

Searching for a target in a complex visual scene is not a trivial task. In cognitive science terms, the visual processing system has to extract viewer-centred information about task-relevant objects, from all of the visual information that is available in the scene. This information must be compared with the task-defined symbolic model (representation) of the target object in order to complete the task. It is generally agreed that visual attention plays a role in the “matching” of complex visual stimuli to the high level mental model of the target. Although there has been extensive discussion on how this “matching” process is performed (e.g. Treisman & Gelade, 1980; Treisman & Sato, 1990; Treisman & Schmidt, 1982) there has been much less about how movements of attention itself are controlled in search tasks. Survival requires that visual processing is done in such a way as to locate the target (fruit) quickly, before competitors (other monkeys) find it. There are two ways to achieve this -

increasing processing power/capacity of the visual system or increasing the efficiency of visual search. Obviously, evolution has directed higher order animals to increase the processing power available to achieve this end. Higher order animals have larger brains with increased visual capacity compared to those of lower order species. However, this approach obviously reached an end point as most primates have a similar brain/body ratio, with approximately similar amounts dedicated to visual perception (about 40%). To improve visual search efficiency further, cognitive mechanisms including those involving visual attention have also evolved. Visual attention allows certain retinal inputs to have priority access to processing and directs appropriate motor action to it. Attending to an object in the visual scene helps us to locate, identify and interact with it via either other perceptual modalities or motor movements. Attention is required to “decide as quickly as possible” whether a target is present in a visual scene. If attention can be controlled efficiently, then visual search can be carried out efficiently.

It is relatively straight-forward to program eye-movements across a visual scene, e.g. from left to right. However, although easy to implement, it is probably not the most efficient strategy to use in order to accomplish a particular task. If you are searching for an object e.g. a pencil, you are probably going to give priority to the most likely places and continue until you find it. As you search unsuccessfully, you will look in new places. Visual attention also tends to go to the “most interesting” region in the visual scene first and this is known as visual capture (for recent review see Yantis, 1998; e.g. Yantis & Jonides, 1990). We know that selection of (saccadic) fixation targets when searching a visual scene is influenced by several factors. In general these factors can be divided into:

- low-level factors which automatically draw computational processing resources e.g. moving patterns or salient image features like texture discontinuities or colour blobs - sometimes called “pre-attentive”.
- high-level (overt) factors where resources are strategically directed in a sequential manner to likely (target) candidates - sometimes called attentive.

A second factor also constrains where you are likely to look next when performing a conscious search. You “know” where you have already looked. Once you have looked in a certain place, and failed to find your pencil, you are



likely to bias your search towards new locations. It is more efficient to search everywhere once, rather than the same location repeatedly. Similarly, once visual attention has been “captured” by features in a particular location, and the visual system “knows” that the target object is not to be found there, it needs to move its search to other (novel) locations. If visual attention could “remember” where it has been recently, then it could actively avoid previously attended locations and search others for the target (Posner & Cohen, 1984; Maylor, 1985; Maylor & Hockey, 1985). Several authors have argued in greater detail that the inhibition of return (IOR) effect is the product of mechanisms that serve this function (e.g. Posner & Cohen, 1984; Jordan, under review). Inhibitory mechanisms, that have access to a “perceptual working memory”, actively bias perceptual resources away from previously attended regions of the visual scene.

This thesis will be chiefly concerned with the forms of representations that mediate inhibitory mechanisms. The first chapter reviews the literature on the types of representations which visual attention appears to have access to. Evidence from psychometric studies with normal populations and the deficits which are observed with various types of insults in patient groups suggest that visual attention is mediated by representations of both location and object information about the visual scene. Location and object information can be coded from various viewpoints (frames of reference) i.e. viewer-centred (or egocentric): body-, hand-, trunk-centred etc. and object-centred (or allocentric): feature-to-feature, feature-to-reference (Hummel, 1994). Although the role of particular frames of reference are interesting, the use of a simple target detection task throughout this thesis means that this issue is not explored in great detail. In chapter 2 the literature that shows evidence for inhibitory mechanisms, and the representations which mediate them will be considered.

### 1.1 The medium of attention

The question of whether visual attention is mediated by location- and/or object-based representations has become a hotly debated topic in the visual cognition literature (for reviews see Egly, Driver & Rafal, 1994; Kanwisher & Driver, 1992; Kramer & Jacobson, 1991; Driver, 1998). Evidence from a variety of paradigms that examine focal and divided attention will be briefly considered.

### 1.1.1 Location-based models of attention

Implicit in many theories of visual attention is the assumption that it acts on an internal representation of space. The contents of a visual scene are arrayed in physical space, and optics preserve this spatial array when it projects onto the retinae. Retinotopic projections from the retinae to the cortex preserve the spatial arrangement on maps throughout the visual cortex. Although the coding becomes progressively coarser, adjacent points in physical space continue to be coded adjacently in the various areas of the visual cortex and this is interpreted as a location-based representation. An Euclidean metric is assumed to code the distance between objects and demonstrations that spatial separation between elements modulates attentional effects are the primary support cited for these location-based models of attention.

Traditionally, theorists have used the “spotlight metaphor” (Posner, 1980) to describe covert visual attention. The spotlight metaphor, in its original formulation, allocates processing to one spatially defined region of an array representation, to the exclusion of other. This region is considered a unitary and compact locus of focused attention (as defined by Yantis, 1993a). The boundary between the attended and unattended space is presumed to be relatively abrupt and the diameter of the spotlight beam fixed at approximately 1 degree. A variant of the spotlight metaphor, the “zoom-lens” model (Eriksen & St. James, 1986), proposes a less distinct boundary between attended and unattended regions and a variable rather than fixed diameter. This model suggests that the attended area has high clarity at the centre of the attended region which gradually decreases with distance. The diameter of the attended region varies with the ‘power setting’ of attention. A high power setting gives greater resolution to the centre of the region with an abrupt decrease in resolution towards the periphery while relatively easy discriminations could be performed with attention distributed across the visual field (see Duncan & Humphreys, 1989; Treisman & Gormican, 1988 for additional discussion of the dynamic nature of visual attention). Similarly, “gradient model” variants suggest that processing efficiency varies across the visual field, decreasing in a continuous fashion from the focus of attention towards the periphery (Downing, 1988; Downing & Pinker, 1985; Hughes & Zimba, 1985). The critical prediction from this class of model is that all signals arising from the attended region of the array are processed to some degree.



### 1.1.1.1 Characteristics of Location-based Models of Attention

All spatial models of attention share several common characteristics. The most important is that the medium of selection is a topographic representation of the visual scene. This representation contains basic visual-feature information coded in two-dimensions, for example colour, locally oriented contrast etc. Higher-level information, for example recognised objects, are not encoded at this level. Neurobiological data suggests that an “attentional working map” (Figure 1.1) may be found at early stages of visual processing (pre-V4) which have retinotopically structured neuronal populations (Felleman & Van Essen, 1991). There may be more than one submap of features, consistent with the modular organisation of early visual processing.

“Spotlight” and associated models also share the feature of a secondary map that controls the selection process. This map, often called the salience map (e.g. Koch & Ullman, 1985), also contains only location information. The open area of the salience map in Figure 1.1 represents an area of activation of processing on the attentional working map (the “spotlight”). The salience map is sometimes equated with the thalamic pulvinar nucleus (e.g. LaBerge & Brown, 1989) which has been shown to demonstrate increased activation during the selection process in PET studies (LaBerge, 1990).

When the area of activation on the salience map projects on to a portion of the working map, visual information becomes available for position-based prioritised processing. The “activation” can take the form of (a) increased processing or (b) decreased inhibition of the selected area relative to the surrounding area or (c) processing in the activated region and inhibition of the surrounding region. Spatial models are often neutral on this point and the fate of the non-selected visual information depends on the characteristics of the particular models (LaBerge, 1990). Capacity-limited models (e.g. Koch & Ullman, 1985; Treisman, 1988) would assume that only selected information becomes available for further processing. Other models (e.g. Van der Heijden, 1992) assume that higher-level processes proceed for all objects on the visual field in parallel, with priority for selected “attended” information.

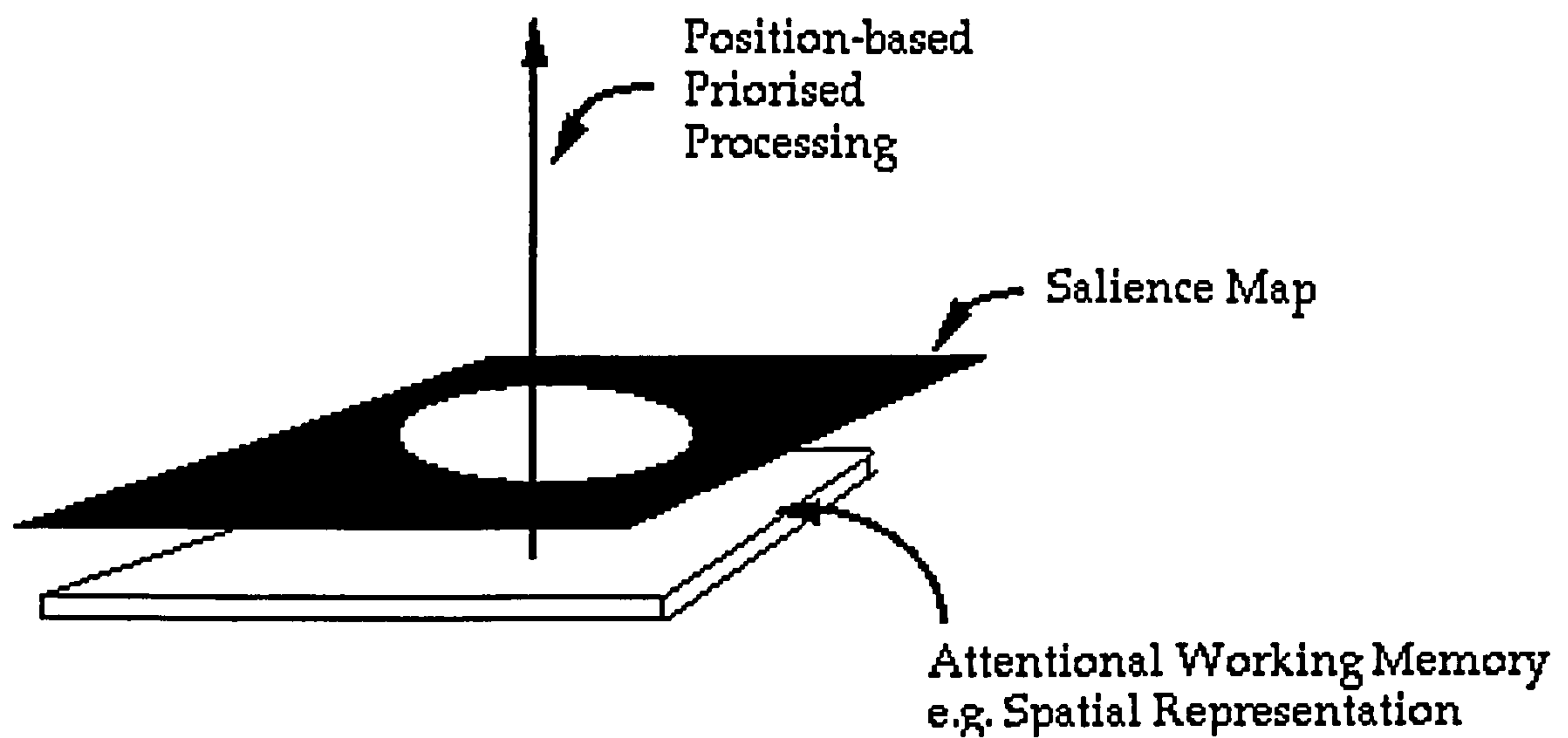


Figure 1.1 Typical components of spatial models of attention, illustrated using Posner's (1980) Spotlight model of attention. The Saliience Attribute Map moves the 'Spotlight' across the Spatial representation of the visual scene. Visual information in the "beam" of the Spotlight is available for further processing.

Various forms of “Spotlight” models of selective visual attention vary in their details e.g. whether movements of attention across a representation are analogue or discrete; whether attention moves at a constant or variable rate across the representation; whether the focus of the beam is fixed or variable; whether the beam is separable or indivisible etc. Evidence for location-based attentional selection has been found using a variety of techniques (PET: Corbetta, Miezin, Shulman & Petersen, 1993; ERPs: Mangun, 1995; Mangun & Hillyard, 1995). The spatial cueing paradigm has been a particularly influential tool in exploring the parameters of attentional selection.

#### 1.1.1.2 Evidence for Location-based attention: Spatial Precueing Paradigm

Posner and his colleagues developed an experimental procedure which made it possible to non-invasively examine covert orienting of attention in a visual scene using a very simple procedure (Posner, 1980). In the original spatial precueing procedure, participants were asked to detect the onset of a target in a peripheral location and respond, using a simple reaction time (RT) key pressing response (Posner, Nissen & Ogden, 1978). Participants viewed a display consisting of several place-markers and were instructed to fixate on the centre of this display box (Figure 1.2). The target was preceded by an abrupt luminance increment (brightening of the peripheral box) which automatically directed attention to the target location (cued), to the alternative location (uncued) or had only an alerting value, providing no predictive spatial information (neutral). Participants were faster to detect the target when it occurred in the cued location and slower in the uncued location, relative to the neutral cueing condition. Other measures including accuracy, saccade latency or discrimination efficiency measured in RT or accuracy have subsequently shown the same effects. It is now well established that directing covert attention to a location aids detection of the target (Bashinski & Bacharach, 1980; Eriksen & Hoffman, 1973; Eriksen & Yeh, 1985; Jonides, 1981; Posner, 1980; Posner et al., 1978; Yantis & Jonides, 1990) due to increases in perceptual efficiency, as well as a change in response bias (Luck et al., 1994; Müller & Findlay, 1987; Shaw, 1984). Later work has

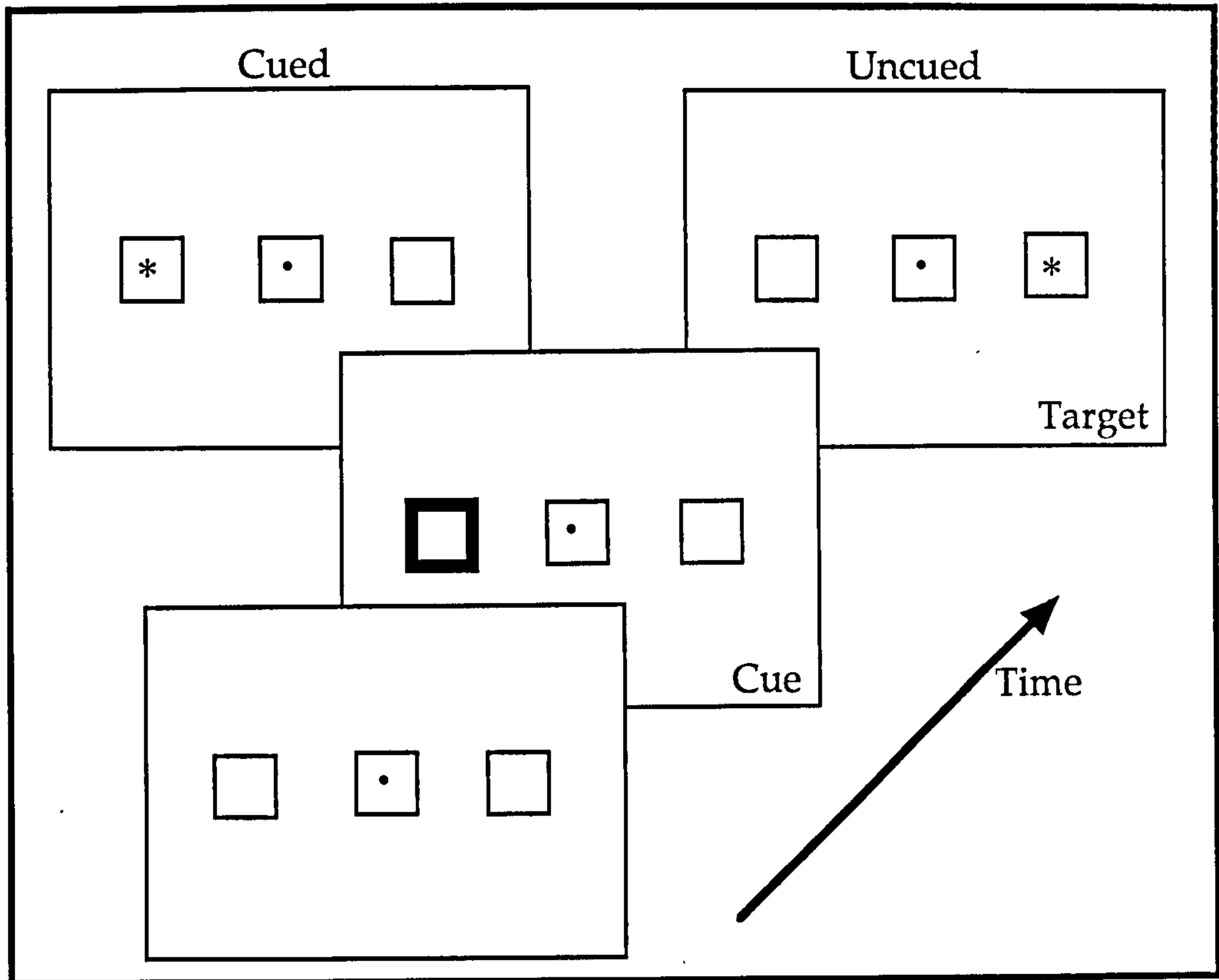


Figure 1.2 Illustration of Posner and Cohen's (1984) exogenous precueing paradigm showing cued (left) and uncued (right) conditions.



shown that a centrally presented symbolic cue (e.g. arrow) produced cueing effects (Posner, 1980). However, exogenous and endogenous cues produce distinct cueing effects (Jonides, 1981) and are thought to reflect different attentional systems (e.g. Briand & Klein, 1987).

Peripheral (exogenous) cues, e.g. an abrupt luminance increment, produce cueing effects: (a) which asymptote at approximately 100 ms, (b) regardless of their informativeness, (c) which cannot be ignored, even when participants are explicitly instructed to and (d) which are unaffected by dual-task requirements. Posner (1980) interpreted the shorter response latency in reacting to targets which appeared in the same location as the cue as the benefit gained by not having to reorient the “spotlight of attention” across the visual display. The need to shift attention from the previously cued location to a new location in the invalidly cued trials, before a voluntary action can be emitted, results in a cost i.e. increased response latency. These results have been replicated in a variety of experimental conditions including supra-threshold luminance changes (brightening or dimming; Posner, 1984), signal detection studies of near threshold stimuli (Bashinski & Bacharach, 1980; Downing, 1988) and discrimination tasks (Egly & Homa, 1991). Exogenous cueing effects are thought to reflect the operation of a spatial reflexive attentional system which is driven by the physical properties of the peripheral cue and is immune to higher-level cognitive influences (e.g. Briand & Klein, 1987; Posner, 1980). When the movements of attention are manipulated, modifications are observed in P1 (80 to 120 ms) and N1 (160 to 200 ms) amplitudes without changes in latency or scalp topography (Luck et al., 1994; Mangun & Hillyard, 1991). Exogenous orienting is thought to be controlled by the posterior attention system that consists of the posterior parietal cortex (PPC), the superior colliculus (SC) and the pulvinar of the thalamus (Posner, Cohen & Rafal, 1982; Posner & Peterson, 1990; Rafal, Calabresi, Brennan & Sciolto, 1989).

In contrast to exogenous cueing effects, endogenous (central, symbolic) cues produce cueing effects that are sensitive to predictive probabilities and the demands of the task. Participants voluntarily orient their attention in response to the central cue. Attentional costs/benefits are observed as participants endogenously orient and maintain their locus of attention in the cued region. Endogenous orienting appears to be controlled by the posterior attentional

system, with the additional influence of the anterior system, consisting of the cingulate gyrus and the supplementary motor area, which is capable of executive functions e.g. developing and maintaining expectancies (Carr, 1992). This thesis is concerned only with the exogenous cueing procedure.

Posner's spatial precueing paradigm provides the strongest support for purely spatial selection by visual attention. His original interpretation of the cueing effects were motivated by his theoretical model of visual attention as a spotlight moving across a spatial representation of the visual scene. Although evidence from other procedures suggests that attention is not mediated by a purely spatial representation (section 1.3), there have been few attempts to examine the form of representation which mediates the cueing effects in Posner's procedure.

### 1.2 Objects and attentional effects

It has been proposed that attentional selection occurs at levels of representation which are more elaborate than elementary features or location maps (e.g. Baylis & Driver, 1992; 1993; Duncan, 1984; 1993; Egly et al., 1994; Humphreys, Olson, Romani & Riddoch, 1996; Kramer & Jacobson, 1991; Kramer & Watson, 1996; Neisser, 1967). Such theories suggest that representations of surfaces (Nakayama, He & Shimojo, 1995), objects (Duncan, 1984) and object-files (Kahneman, Treisman & Gibbs, 1992), produced through prior segmentation of the visual scene, serve as candidate entities for selection and resultant further processing and action. These representations are related and probably constitute a continuum, with surfaces segmented and thus available early in visual processing, while completely identified objects occur much later in the system and provide access to extra-visual knowledge (e.g. He & Nakayama, 1995)

Object-based theories predict that processing costs and benefits depend on whether relevant and irrelevant visual information is located within an object or perceptual group. In divided attention tasks, object-based models predict optimum performance when the critical information is contained within a single object (e.g. Duncan, 1984). In contrast, performance should be maximised in focal attention tasks (i.e. where costs are associated with ignoring irrelevant information) when task-irrelevant information is located on a separate object. Location-based theories of attention predict that costs and benefits, in both



divided and focused attention, depend solely on the spatial separation between relevant and irrelevant information. In many situations, object- and location-based models make identical predictions, as the properties of a single object are more proximal than those of two separate objects. Location- and object-based theories are not mutually exclusive (Duncan, 1984). Only the most extreme versions of object-based theories suggest that spatial factors do not indirectly modulate selection (e.g. Vecera & Farah, 1994).

It is possible, in many procedures, that location- and object-based effects of attention are confounded, unless either overlapping or moving objects are presented or by ensuring that task-relevant and irrelevant properties have equivalent spatial separations, regardless of whether they occur on the same or different objects. An alternative strategy is to explicitly vary spatial separation and observe its effects on object-based attentional effects. In these ways, it is possible to observe the relationship between location- and object-based attentional effects.

The following sections will briefly review the evidence for spatial- and object-based representations as the medium of attention in; (1) focal and (2) divided attention tasks. One of the biggest problems in considering the literature is the lack of consistency in the use of the terms surrounding the possible forms of representation of segmented visual information. For the purpose of this thesis, the term "object-based" will be used to refer to effects that are associated with chunks of information which are segmented as belonging to an object. This approach acknowledges that objects occupy regions of space, but that visual information is segmented and processing resources are allocated on the basis of Gestalt grouping or other similar "strategies", rather than on any specifically spatial parameter. Spatial factors may therefore indirectly affect selection of objects via their contribution to grouping strength (Baylis & Driver, 1992; Duncan, 1984; Neisser, 1967). In contrast, the term "object-centred" (Marr, 1982) will be used exclusively for spatially invariant representations, which deny a role for spatial factors in modulating object attentional effects (see also Humphreys et al, 1996; Umiltà, 1988; Vecera, 1994; Vecera & Farah, 1994). This reflects the notion of objects being coded from an object- rather than viewer-centred frame of reference. An object-based representation of an outspread human hand would reflect the distance between each finger. In contrast, an object-centred

representation would code that the fingers are part of the hand, but not the distance between each. Hummel (1994) has proposed this contrast can also be thought of as the dichotomy between feature-to-feature (object-based) and feature-to-reference (object-centred) representations.

### 1.2.1 Evidence for Location- versus Object-based Effects in Visual Attention in Normals

#### 1.2.1.1. Focal Attention

##### 1.2.1.1.1 Response Competition

Flanker interference in letter identification tasks provided early evidence that selection in vision is mediated by location (Eriksen & Eriksen, 1974). Interference from response incompatible distractors was dependent on spatial separation. As long as the target-flanker separation remained within one degree, the flankers could not be ignored. Eriksen and Eriksen's findings were consistent with the suggestion that an attentional 'beam' acts on a spatial map which subtends approximately one visual degree and is not affected by the "objects" present in the scene.

Driver and Baylis (1989) suggested that interference from distractors may arise because targets and flankers perceptually grouped on the basis of proximity, rather than simply because they were close together. Using grouping by motion, they attempted to unconfound proximity/spatial distance effects in the response competition paradigm. They observed that distractors which were located spatially distant from, but congruent in motion to, the target produced more interference effects, than spatially closer but motion incongruent flankers. They interpreted these findings as evidence that grouping by common fate (Wertheimer, 1912; Wertheimer, 1923) could override the effect of grouping by proximity. They suggested that proximity (relative location) may be only one of many Gestalt grouping factors which influence the distribution of attention, producing object-based effect.

Driver and Baylis (1989) pitted motion and proximity against one another, and in their procedure, motion was dominant. However, Kramer, Tham and Yeh (1994) made minor changes to the procedure and stimuli and reversed the dominance relationship. The most parsimonious explanation is that when proximity and motion are pitted against one another, either grouping factor may dominate, depending on the experimental circumstances (Driver & Baylis, in



press). Evidence that other Gestalt grouping factors can also modulate attentional effects have come from subsequent studies e.g. connectedness (Kramer & Jacobson, 1991) colour (Baylis & Driver, 1992 experiment 1 & 2) and good continuation (Baylis & Driver, 1992 experiments 5 & 6). In addition to motion, colour-grouping has been shown to over-ride proximity in appropriate experimental conditions (Baylis & Driver, 1992 experiment 2). Baylis and Driver (1992) interpret these findings as attention being directed to groups which are parsed on the basis of Gestalt principles of perceptual organisation, rather than a pure location-based representation (see also Neisser, 1967). They speculate that perceptual grouping is based on parsing which occurs early in the visual processing stream (e.g. Marr, 1982).

#### 1.2.1.2 Divided Attention Tasks

Another early illustration that attention can be directed to objects, rather than spatial locations, comes from the work reported by Duncan (1984). Duncan presented participants with brief presentations of an outline box superimposed by a diagonal line, so that they occupied the same spatial region (Figure 1.3). Each of the objects varied in two different features. The box could either be tall or short and have a gap on the left or right. The line could be oriented clockwise or anticlockwise from vertical and be either dotted or dashed. Subjects were required to report two decisions about the appearance of the features in the display. The two target features could both belong to the same object (e.g. size and gap location on the box) or to each of the two items (e.g. line texture and box size). Subjects were more accurate in reporting these features if they belonged to the same object than if one feature belonged to each object. Indeed, Duncan (1985; 1993) showed that participants could identify two properties of a single item as accurately as one property, in appropriate conditions. He interpreted this as attention being directed selectively to one object which facilitates the processing of its features (see also Neisser, 1967). Reduced accuracy in reporting features of two separate objects was interpreted as the cost of

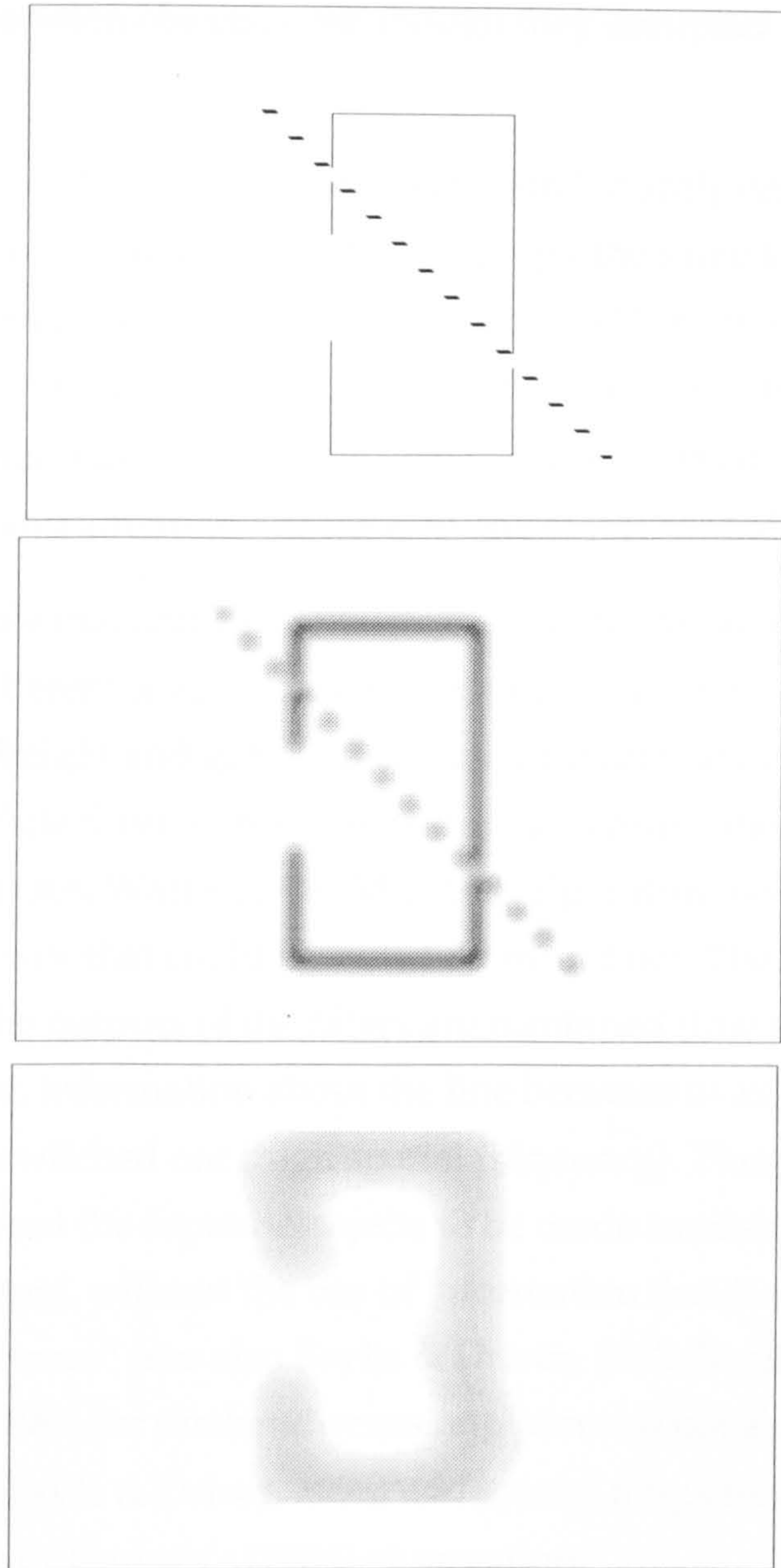


Figure 1.3 An example of Duncan's (1984) stimuli showing a gap to the left of a tall box and an anticlockwise dotted line (Top). The lower pictures illustrate the result of applying a high (Middle) and low (Bottom) spatial filter to the image. In the former case it is possible to pick out the line clearly. The box and its gap can be observed in the output of the low spatial frequency filter. (Based on Watt, 1988)



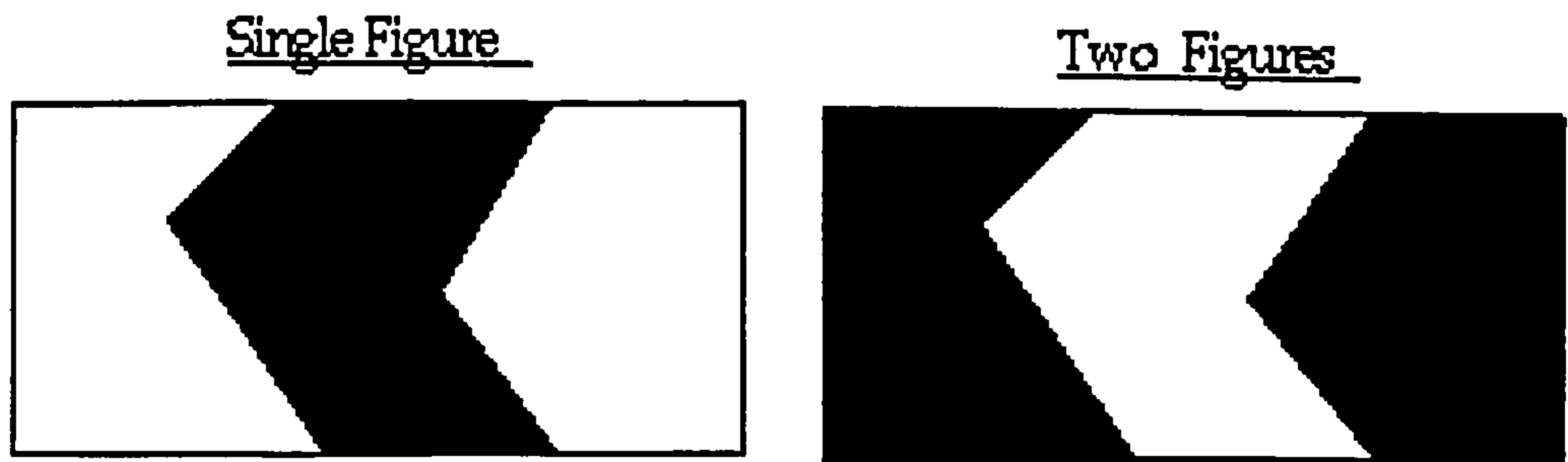
switching attention between objects, even though they occupied the same spatial location.

Spatial models of attention, which select stimuli purely on a location basis, cannot account for selection when two objects occupy the same location. However, there are several alternative explanations for Duncan's (1984) findings. Posner (see footnote 3, Duncan, 1984) suggested that if the attentional spotlight operates in three- rather than two-dimensional space, objects could be separated on the basis of depth and attention allocated to one object spatially in depth.

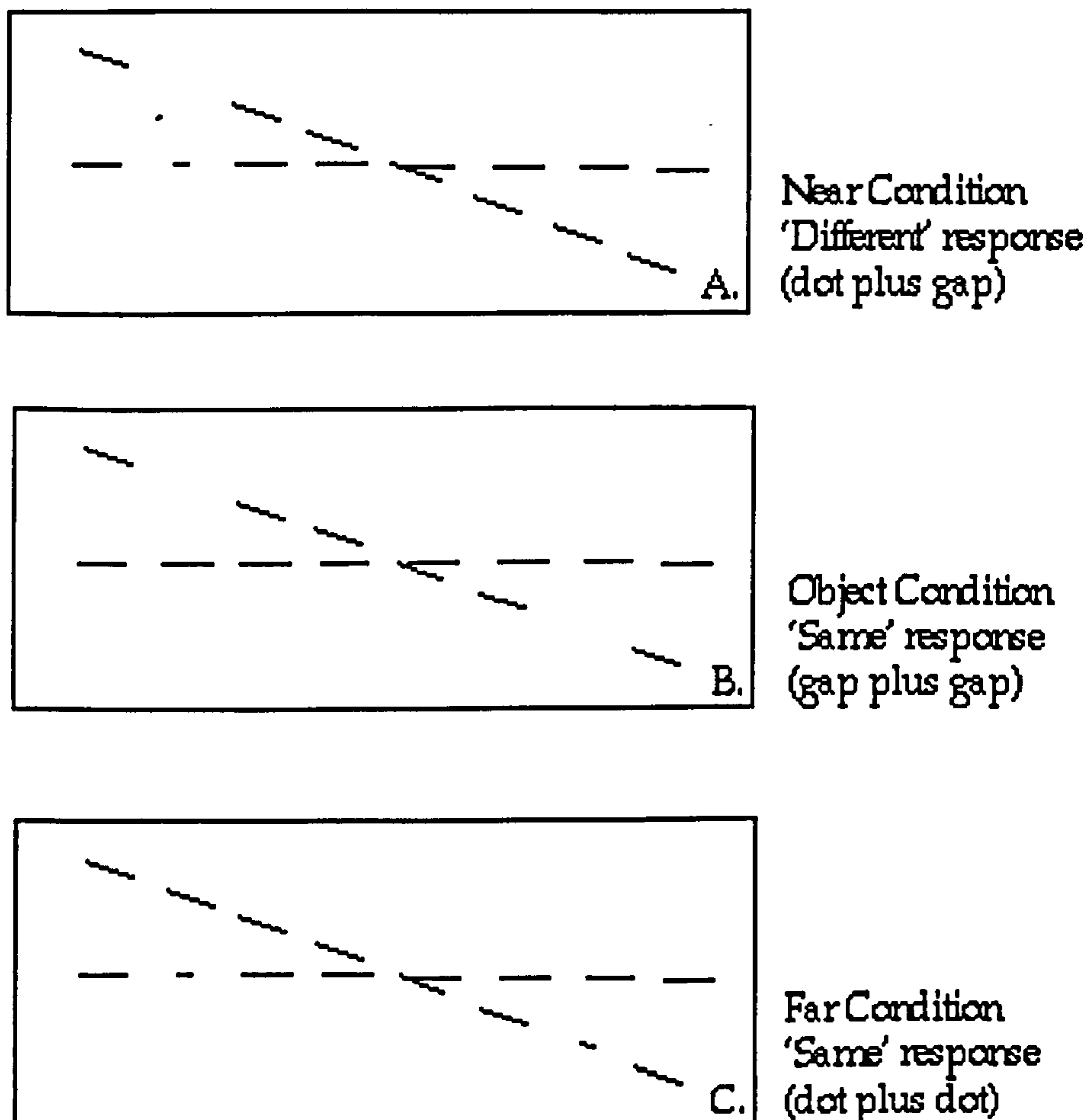
It is also possible that Duncan's findings could be explained by a cost in switching between different spatial frequencies, rather than different objects. The attributes of the box (height and gap location) are primarily available at low spatial frequencies, while those of the line (texture and orientation) are available at high spatial frequencies. Watt's (1988) MIRAGE algorithm models filters of varying spatial frequency that could be switched in and out. The box can be picked out when all the outputs of the filters are combined (low spatial frequencies). However, information about the line becomes available only after the coarser filters are switched out (high spatial frequency). Thus, it is possible for the information about the separate objects to be made available through appropriate spatial filters, without the use of information that is explicitly associated with "objectness" (see also Baylis & Driver, 1992; Baylis & Driver, 1993; Lavie & Driver, 1996 for further discussion). More recent experiments have excluded both depth (Lavie & Driver, 1996) and spatial frequency (Baylis & Driver, 1993) accounts of Duncan's (1984) observation.

Baylis and Driver (1993) directly compared within- and between-object effects for judgements about physically identical attributes (Figure 1.4). They produced a series of ambiguous figure-ground displays, similar to the face-vase illusion (Rubin, 1915). By manipulating the participants' perceptual set, they could reliably ensure that an identical ambiguous figure would be interpreted as a single or two separate figures against a ground by different groups of participants. The task was to compare the height of the apices of the dividing contours and report the side with the lower apex (i.e. right in Figure 1.4). Consistent with Duncan (1984), they reliably observed an increase in both RT's





**Figure 1.4** Example of ambiguous displays used by Baylis and Driver (1993) to examine the relative costs in making a within- versus between-object judgement of contour apices height. The areas in black represent the figure colour and the ground is shown in white. In the actual study the perceptual set of participants was manipulated so that individuals interpreted either red or green as the figure colour. Thus, the same physical stimuli could be used to examine one- and two-object effects in a between subjects design.



**Figure 1.5** Example of stimuli used by Lavie and Driver (1996) to examine the effect of spatial extent on object judgements.

and error rates when the contours appeared to belong to separate objects compared to a single object. This observation has been replicated in several other studies that controlled for the possible effects of convexity and concavity (Baylis, 1994; Driver & Baylis, 1995; Gibson, 1994). These studies show that judgements about two separate edges are more difficult than one. However, the influence of figure/ground segmentation may be specific to edge assignment, rather than a general effect on attention (Lavie & Driver, 1996).

Lavie and Driver (1996) reported a more carefully controlled study of the interaction between spatial effects and objects in a divided attention task. The participants were required to make judgements about stimuli that were never superimposed which ensured that there were no masking effects. They were presented with a display containing two intersecting lines that incorporated dots or gaps in peripheral regions (Figure 1.5). Participants were asked to respond with a judgement of either 'same' or 'different' depending on whether the two object features matched (e.g. two dots or two gaps) or not (one dot and one gap). The elements (and therefore spatial frequency) and spatial distance between them (spatial proximity and eccentricity effects) were equivalent in the within- and between-object conditions. They observed a benefit in both RTs and accuracy for decisions about features on the same line compared to different lines, even though they were separated by more than 8 degrees. They also observed that manipulating the probability of the elements appearing in the same Vs different side of the display did not modulate the object-based effect. This suggests that the object-based effect is non-strategic and as lines were clearly two-dimensional in appearance, these experiments also exclude the depth account.

In their final experiment, Lavie and Driver (1996) provided participants with a precue (luminance increment) that was 70% predictive of the spatial position (left/right) of the elements. No object-based attentional effects were observed and they argued that participants could use the cue to narrow the focus of spatial attention to the cued side of the display. Vecera and Farah (1994) observed a similar contrast using Duncan's (1984) procedure. They replicated Duncan's stimuli, but presented them in either the same location (together condition) or spatially separated. Consistent with Duncan's report, participants were more accurate at responding when the response dimensions were shared by a single object compared to trials which required between-object shifts of

attention, regardless of spatial separation. The findings from this task could be accommodated within the spatially invariant object-centred interpretation of Duncan's effects. When they changed the task to a pre-cued target detection task, they observed an absence of object-based attentional effects in the together condition and spatial attentional effects in the separate condition. This suggests that the representations utilised in the task may vary with behavioural goals and/or processing load; the discrimination task showed no evidence of spatial effects (only an object-centred representation mediated behaviour) while detection was mediated by a spatial form of representation.

**Table 1.1**

Summary of the studies in which pure object-based attentional effects have been observed in divided attention tasks.

Study	Task	Spatial Effects	Object Effects
Duncan (1984)	Discrimination		✓
Baylis and Driver (1993)	Discrimination		✓
Lavie and Driver (1996)	Discrimination	✓	✓
Vecera & Farah (1994)	Discrimination	✓	✓
	Detection	✓	✗
Kramer, Weber & Watson (1997)	Post-display Probe	✓	✓

Object-based facilitatory have been reported by Egly, Driver and Rafal (1994) effects in a variation of Posner's pre-cueing procedure (section 1.1.1.2) where participants were instructed to simply detect the onset of a target. They used a predictive luminance increment to direct attention to one end of an object. RTs to a subsequent target which appeared at the uncued end of the same object (cued object) were faster than to those which appeared at a location on a second object (uncued). By ensuring that the spatial separation between the object and uncued conditions were identical they showed evidence for an object-based cueing effect. (This procedure is illustrated in Figure 4.1 and described in detail in section 4.2) However, the use of a predictive cue, which probably activates the anterior in addition to the posterior attentional system, makes it difficult to interpret this result. Although an "exogenous" cue is used, participants will voluntarily orient/maintain their attention to the cued region. It is unclear



whether object-based effects would be observed if a non-predictive cue was used. There is currently little evidence for object-based attentional effects using a more typical pre-cueing procedure, as described in section 1.1.1.2.

Duncan (1984) and Vecera and Farah (1994) are examples of studies which have used overlapping stimuli i.e. where different objects occupied the same spatial location in 2-D space, to control for spatial effects. Object-based theorists acknowledge the obvious fact that objects occupy different sets of points in space, but assert that “the chunk of information dealt with by focal attention is determined by Gestalt grouping, not by anything specifically spatial” (Duncan, 1984, p. 515). Indeed, there is ample evidence that attention can select one of two objects which overlap in space (Rock & Guttman, 1981; Tipper, 1985). Location-based theorists postulate a flexible attentional “spotlight” which conforms to the precise shape of the selected object (e.g. Castiello & Umiltà, 1992; Stuart, Maruff & Currie, 1997). However, this explanation would imply an object-based account, as selection takes account of the boundary of an object.

### 1.2.1.3 Conclusion from Normal Studies

The literature reviewed in section 1.2 suggests that neither a location- nor object-based medium of attentional selection is sufficient to explain the effects observed in a variety of tasks. Driver (1998) has suggested that the location-versus object-based accounts of attentional selection is merely a new variation of the early versus late selection arguments. (Allport, 1980; Allport, 1993; Deutsche & Deutsch, 1963). He claims that the argument hinges on how much perceptual processing occurs before attentional selection. However, some object-based theorists (e.g. Vecera & Farah, 1994) would claim that spatial factors, including proximity, have an indirect effect on selection, and thus the debate is one of the relative importance of this factor. Location-based theories of attention can be assimilated into more general, object-based frameworks. “Multiple sites of selection” or “hybrid” (Driver, 1998) models of attention are difficult to develop due to the lack of understanding of the relative contributions of various factors in particular conditions. One attempt is the CODE theory of attention (Logan, 1996) which operates within a spatial medium of attention with an attentional working map, but object information is represented as changes in the spatial distribution. Thus, spatial information still has a special role in mediating covert attention (Tsal & Lavie, 1993), but is modulated by object segmentation. Although Duncan

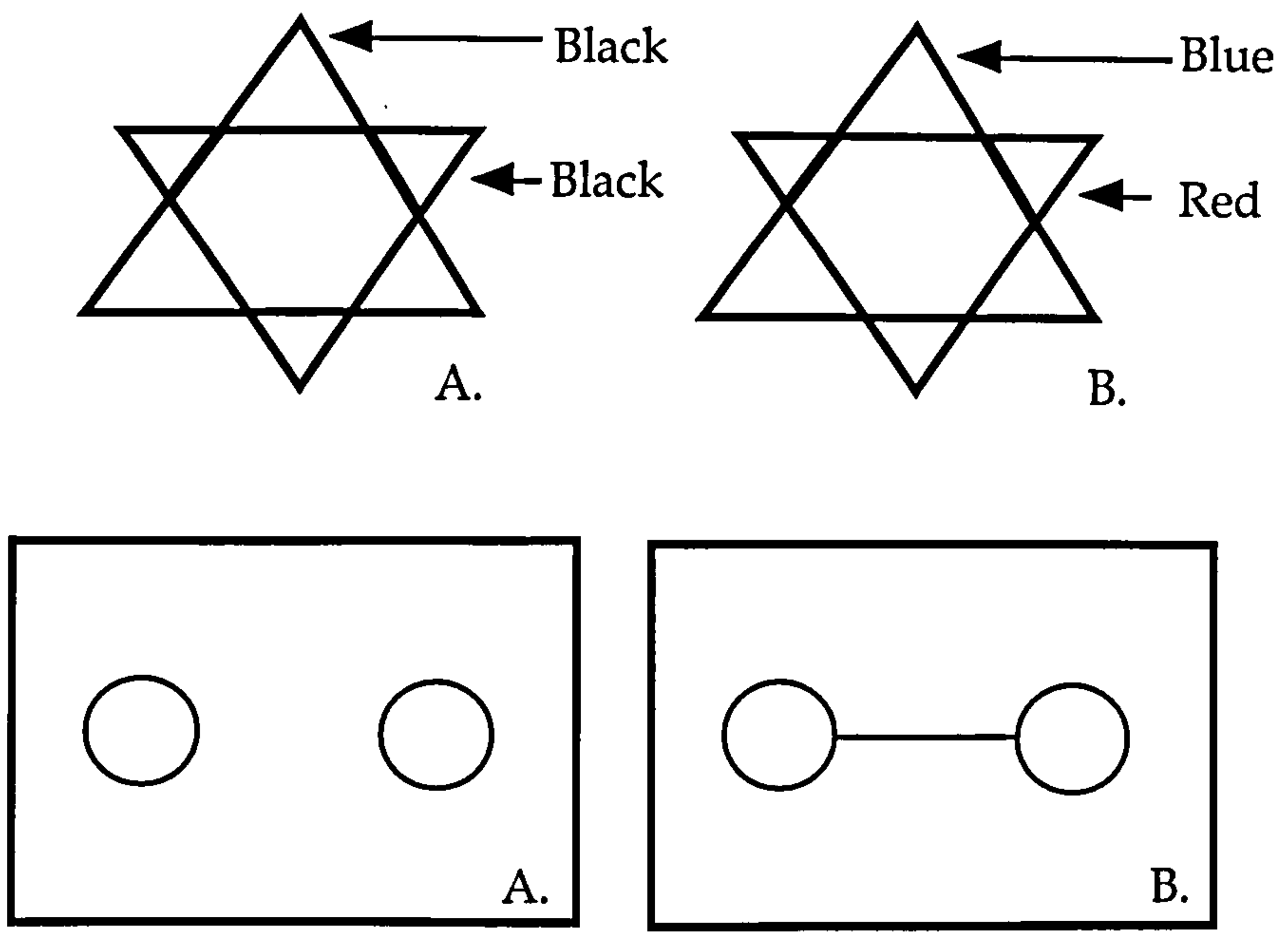
(1984) suggested that space- and object-based forms of representation modulate visual attention independently, fifteen years later the true relationship between them appears to be much less clear.

## 1.2.2 Evidence for Location- and Object-based Attentional Effects in Patients.

### 1.2.2.1 Balint's syndrome

Perhaps the most dramatic evidence for object-based attentional selection is seen in patients who manifest simultanagnosia (Farah, 1990) associated with Balint's syndrome. This deficit is the result of bilateral lesions of the posterior parietal lobes or parietal-occipital junction (Holmes & Horrax, 1919). These patients have great difficulty in making comparative judgements between two objects, although they can clearly perceive and describe one object at a time. The syndrome has been described as a bilateral disengage deficit where they are impaired at disengaging and moving attention in any direction (Farah, 1990). However, a spatial explanation cannot account for simultanagnosia as patients are unable to attend to more than one object, although they occupy the same spatial location. Thus, if shown a six-pointed Star of David made up of two triangles that are the same colour, they observe a Star of David (Figure 1.6; Panel A). However if the triangles are differently coloured, they can only see one or other triangle, but never both simultaneously (Figure 1.6, Panel B) (Luria, 1959). No purely location-based account of attention can accommodate this phenomenon.

The attentional deficit suffered by these patients is clearly object-based. Luria (1959) demonstrated that if two separate adjacent circles are shown to a patient they only report one. However, once the circles are re-ordered into a single object by the addition of a line, the patient reported perceiving a barbell or a pair of spectacles. Humphreys and Riddoch (1993) extended this observation by providing two patients with Balint syndrome with displays that contained thirty-two circles that were either a single colour (red or green) or equal proportions



**Figure 1.6** Examples of the stimuli used by Luria (1959) to demonstrate that simultaneous agnosics have object-based attentional deficits. These patients are more likely to perceive multiple shapes if they are grouped into a single object. This can be achieved by presenting component triangles in the same colour (top panel, A) rather than different colours (top panel, B) or explicitly connecting separate component objects (bottom panel, A) into a single hierarchical object (bottom panel, B).



of red and green. The patients were asked to report whether the display contained circles of a single colour or two colours. All of the displays contained black lines that were either randomly placed or arranged so that they connected up pairs of circles. The critical condition was the displays that contained two colours. In some trials the lines joined two same-colour circles together, and in others two different-coloured circles. Both patients correctly reported the presence of two colours in the display when the lines joined different coloured circles together. However, if the connected circles were a single colour they experienced great difficulty in disengaging their attention from a single barbell to examine others.

#### 1.2.2.2 Unilateral Neglect

Patients who suffer a unilateral lesion, commonly of the right inferior parietal lobule and/or the posterior associative cortex, commonly show the condition termed unilateral neglect (for review see Bisiach & Vallar, 1988). Visual neglect is also (less commonly) associated with an insult to other cortical or subcortical structures (Bisiach & Vallar, 1988; Heilman & Valenstein, 1985; Mesulam, 1981). Neglect is characterised by the “ignoring” of visual, auditory and tactile stimuli located in extrapersonal contralesional space, even when the information is in an imagined internal representation (Bisiach & Luzzatti, 1978). The condition can be distinguished from the behaviour associated with primary sensory and motor deficits (hemianopia and hemiplegia), although this may be difficult in the acute phase (Heilman & Valenstein, 1985). Many patients do have visual field cuts and hemiplegia but severe neglect is seen in cases that do not show signs of these deficits (Halligan, Marshall & Wade, 1990). Patients often appear to be unaware that they ignore contralesional space (anosognosia) but it can be demonstrated with many simple tasks including line cancellation, line bisection, picture copying and copying from memory where items in the contralesional field are ignored.

The precise mechanism which underlies the neglect phenomenon is unclear, but there is generally agreed to be some disruption of selective attention (Bisiach, 1993). One view suggests that patients may develop difficulties in disengaging attention in order to move it and engage with a new location (Posner, 1988; Posner & Peterson, 1990; Rafal, 1996). Alternatively, attention may be directed optimally to the ipsilesional compared to the contralesional side of

space (Robertson, 1992). There are a number of potential frames of reference which can be used to code left and right space (Feldman, 1985). Neglect can be considered environmentally based, with a reference frame which is defined by gravity and the position of visual landmarks in the scene. Alternatively, neglect may be viewer-centred, defined by the position of the head or trunk (Calvanio, Petrone & Levine, 1987; Farah, Brunn, Wong, Wallace & Carpenter, 1990; Ladavas, 1987). Indeed, there is evidence that when patients with right hemisphere lesions are rotated into different orientations, both viewer- and environmentally-centred left space is neglected (Calvanio et al., 1987; Ladavas, 1987).

Although neglect has been considered a spatial deficit, more recent studies have shown that the neglect of space is modulated by the presence of objects. As in the normal population, these object-based effects appear to be mediated by perceptual grouping, figure-ground and object segmentation processes (for review see Driver, 1996; Driver, 1998). Driver and Halligan (1991) found evidence of object-based neglect, in a discrimination task. The patient was asked to make a same-different judgement, about pairs of vertically elongated nonsense shapes. A decrement in accuracy was observed when the distinguishing information appeared on the left side of the object in environment- or viewer-based coordinates. This decrease in accuracy was found even when the objects were rotated 45 degrees so that the relevant information now appeared in the patient's egocentric intact field. This suggests that neglect can be observed for information appearing in the contralesional side of both space and objects independently (see also Behrmann & Moscovitch, 1994).

Young, Hellaway and Welch (1992) demonstrated that object-based neglect that may be mediated by more abstract descriptions of objects. They presented a left hemifield patient with upright chimerical faces. She failed to recognise any of the chimeras on the left. Rotating the display by 90 degrees did not improve her performance significantly, even though the left chimeras now appeared in the right side of egocentric space. In contrast, she performed correctly on all right side of face chimeras. A similar effect has been found with words (Brunn & Farah, 1991; Caramazza & Hillis, 1990).

Behrmann and Tipper (1994) tested the idea that visual neglect is associated with an object-based form of representation using stimuli similar to

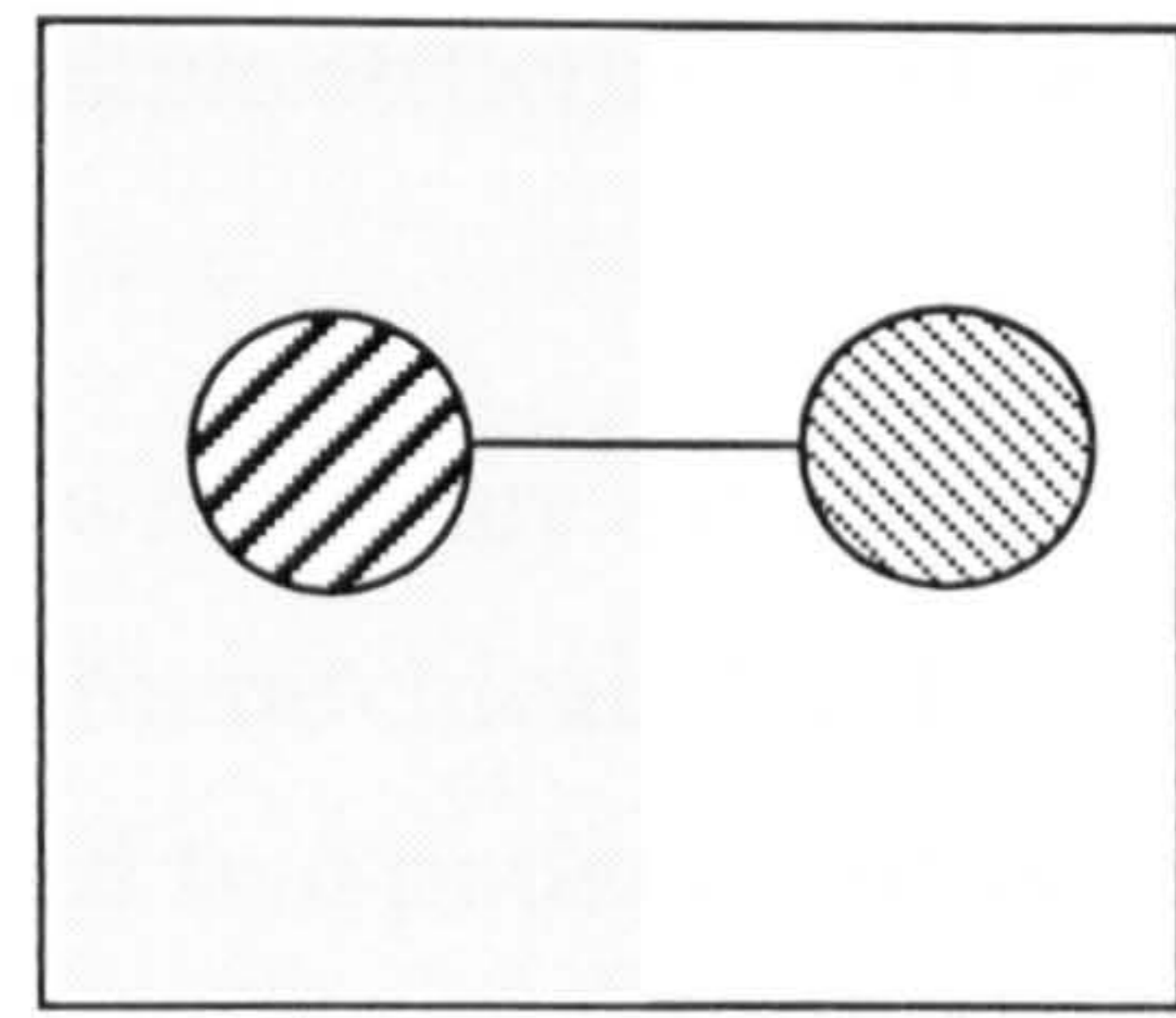
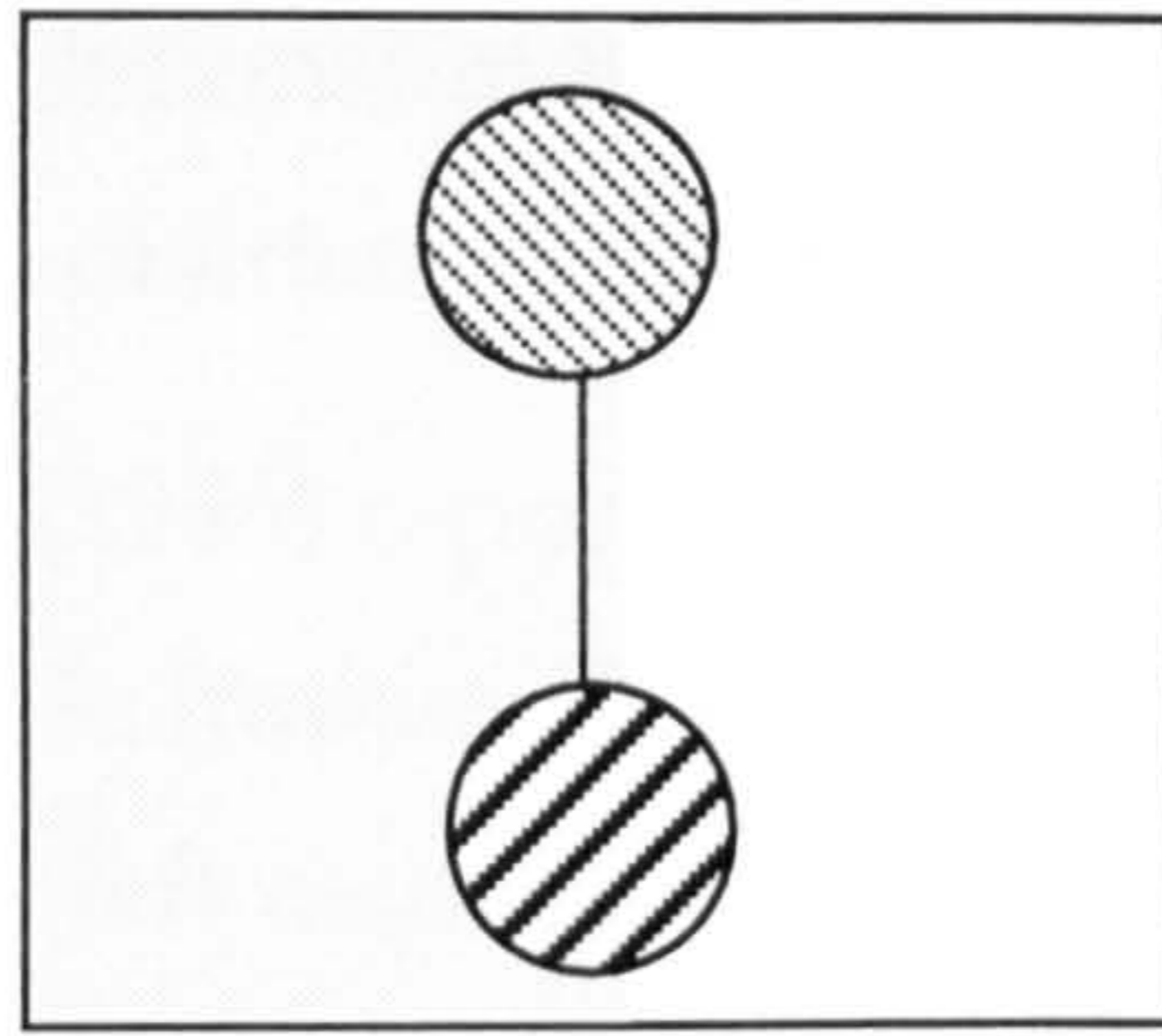
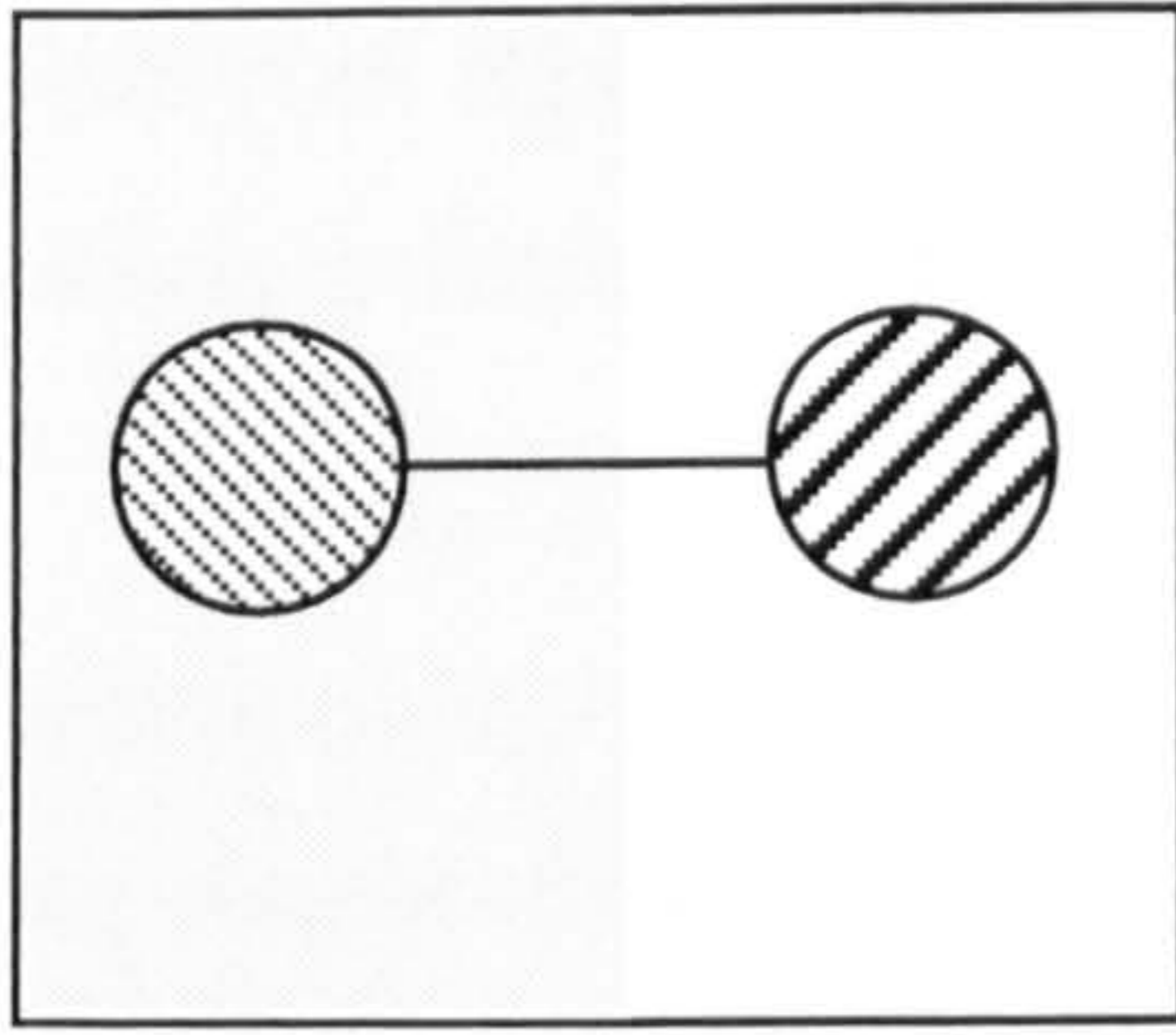
that of Humphreys and Riddoch (1993). They used a target detection task, presenting the patient with a stimulus that consisted of a blue circle and a red circle (Figure 1.7). These circles could be grouped together into a single object (barbell) by the addition of a line. They found that patients with lesions in the right parietal lobe had severe difficulties detecting targets presented in the left side of space. In contrast, when the barbell was rotated 180° there was a complete reversal of neglect from the left to the right side of space. The left side of the moving object took the neglect with it as it rotated in space. Thus, there is evidence that visual neglect is associated with an object-based form of representation (Figure 1.7). However, subsequent work (Tipper & Behrmann, 1996) found that the original result does not generalise to all patients. Some patients show neglect effects that appear to act in both object- and location-based forms of representations. This is similar to the finding in normals that both of these representations can be active simultaneously (section 1.2).

Buxbaum, Coslett, Montgomery and Farah (1996) have suggested that apparent object-based neglect is the product of viewer- or environmental neglect after the patient had mentally rotated the objects back to their upright position. Thus, the viewer or environmental and object-based frames of reference become aligned. This explanation of "object-based" neglect does not require anything other than a spatial representation. Thus, it would be useful to replicate Behrmann and Tipper's study, incorporating it with a second task e.g. counting backwards, which would disrupt mental rotation is a simple way to exclude this explanation.

Halligan and Marshall (1993) report a single-case study where the parsing of a perceptual object influences the extent of visual neglect in a copying task. P.B. was a 54 year old man who had suffered a sustained infarction in the area served by the right middle cerebral artery. One of the stimuli consisted of a hypercomplex figure (a potted flower). The second figure was identical although the pot and stem was deleted. The material was intrinsically controlled for lateral extent and position although the two figures were perceptually parsed as either a single object, or two separate objects. The patient failed to copy the entire half of



A. Location-based Neglect



B. Object-based Neglect

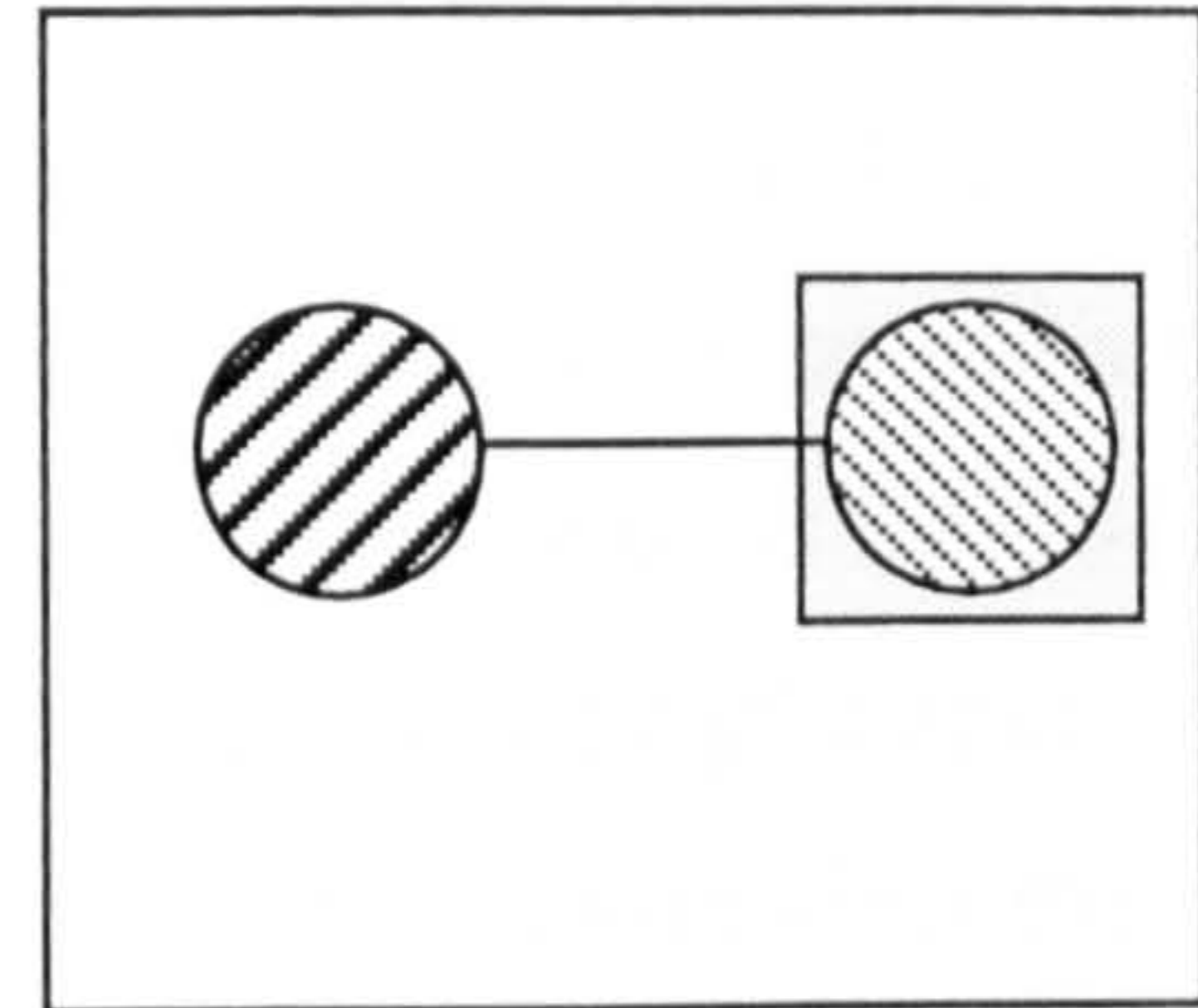
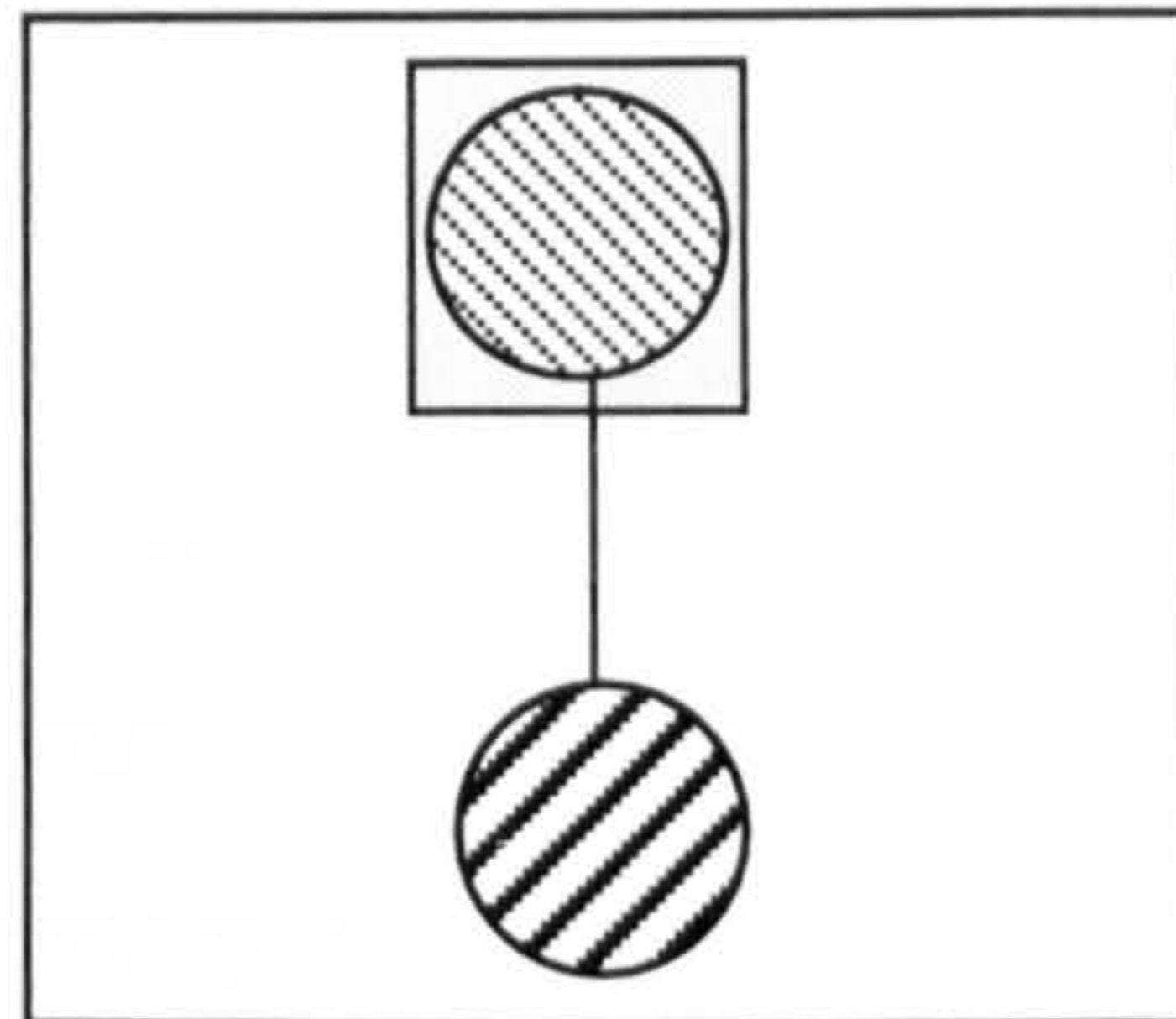
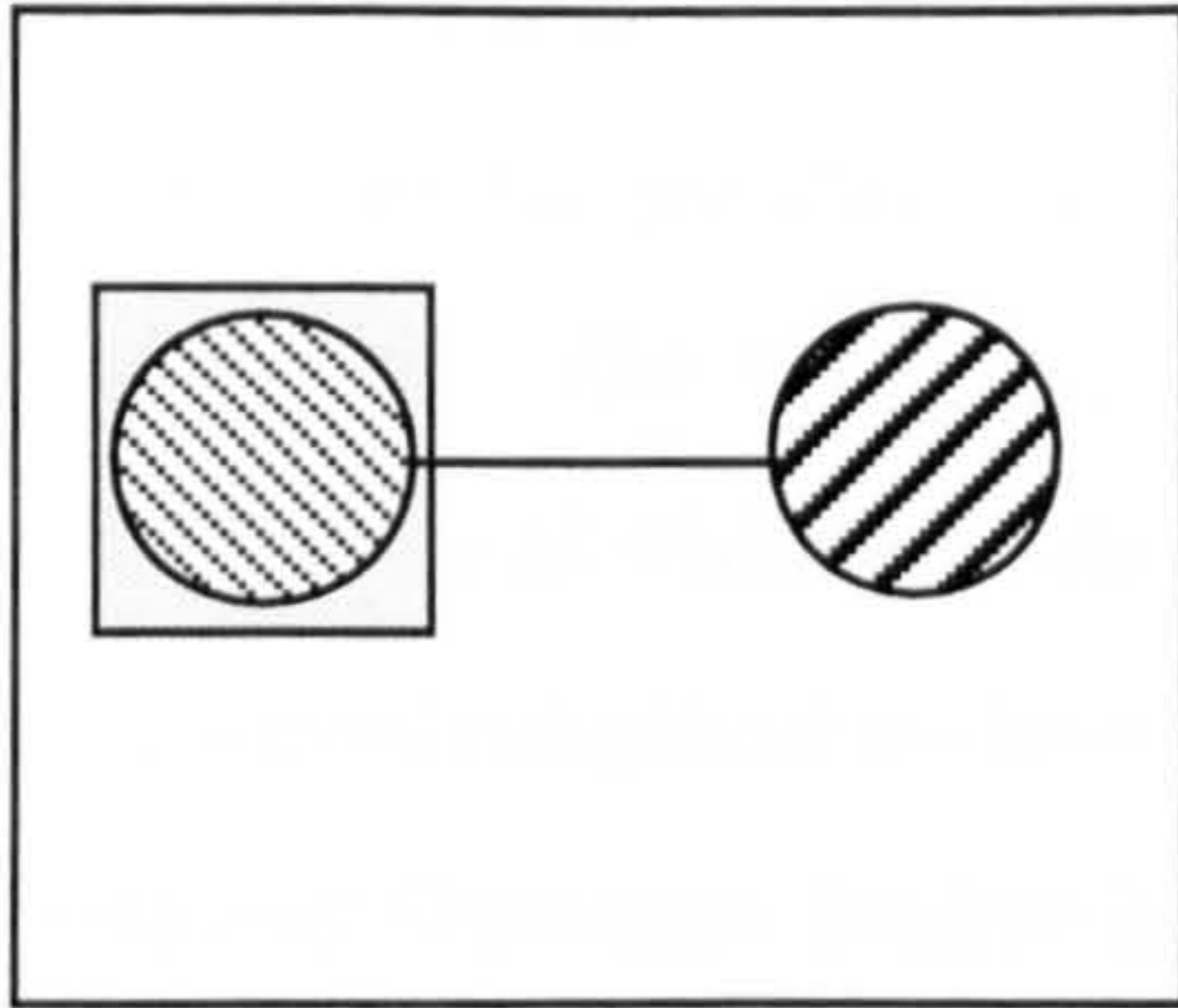


Figure 1.7 An illustration of the movement of the neglected field with the rotating barbell.

the hypercomplex figure despite omitting only the left half of each of the complex figures. Thus the relationship between the various structures of the object influenced the spread of attention across it.

Plaut and Behrmann (1996) reported a study in which they explored the relationship between multiple frames of reference and hierarchical object representations in unilateral left neglect. They presented two patients suffering with moderate left neglect with a simple line drawing of a flower in pot (Figure 1.8, Left Panel). The flower could be presented rotated in each of four orientations so that the principal axis was upright, downward, leftward or rightward. By rotating the picture in this way it is possible to dissociate object-centred and viewer-centred frames of reference. Both patients showed evidence of a combination of both frames of reference when copying the upright and rotated flowers. More interestingly, Plaut and Behrmann (1996) extended the study to observe the way in which the relative contributions of the two frames of reference interact with object hierarchies while copying a single flower and more complex stimuli (Marshall & Halligan, 1993). As patients complete a copying task, an object-centred frame of reference is assigned to each object sequentially, and subsequently, to each sub-object feature. This frame of reference is not typically aligned with the patient's egocentric axes, uncoupling the object-centred frame of reference from a viewer-centred frame. This would allow patients to succeed in copying the right sides of objects which are positioned to the left of objects whose left sides are neglected (e.g. Driver & Halligan, 1991; Gianotti, Messerli & Tissot, 1972) or the entire element of an object if it is presented as an isolated object, but only the left side of the same part when the object is presented with other objects (Driver & Halligan, 1991).

Ho, Behrmann and Plaut (1995) have proposed a model where each feature ("child") of an object ("parent") can be considered as an object with its own object-centred frame of reference. The object-centred frame of a child is defined in relation to its position and orientation to the parent. This produces a hierarchical representation that is traversed when drawing from memory (Figure 1.8). The probability of drawing a "child" is the weighed average of the probabilities of drawing it in the viewer-centred (defined by the page and fixed) and object-centred (defined by the parent) frames of reference and then multiplying the result by the probability of its parent being drawn. If the parent

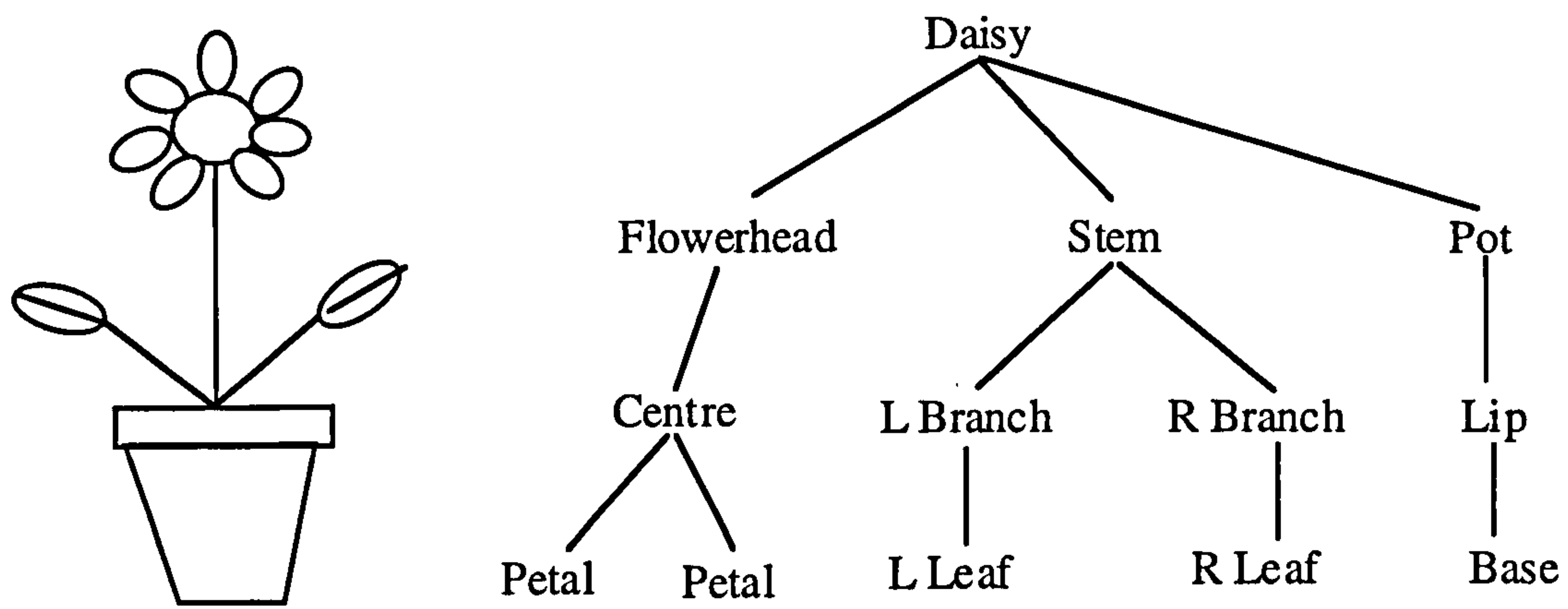


isn't drawn, none of its children are drawn. Figure 1.9 illustrates the computational model's predictions of the probability of drawing each part of a left-facing daisy according to whether copying is mediated by an entirely viewer- or object-centred frame of reference. In each case, the computational model (Ho et al., 1995) provided fairly good matches for the varying performances between patients providing an accurate account of how the relative contributions of the two frames of reference interact with object structures.

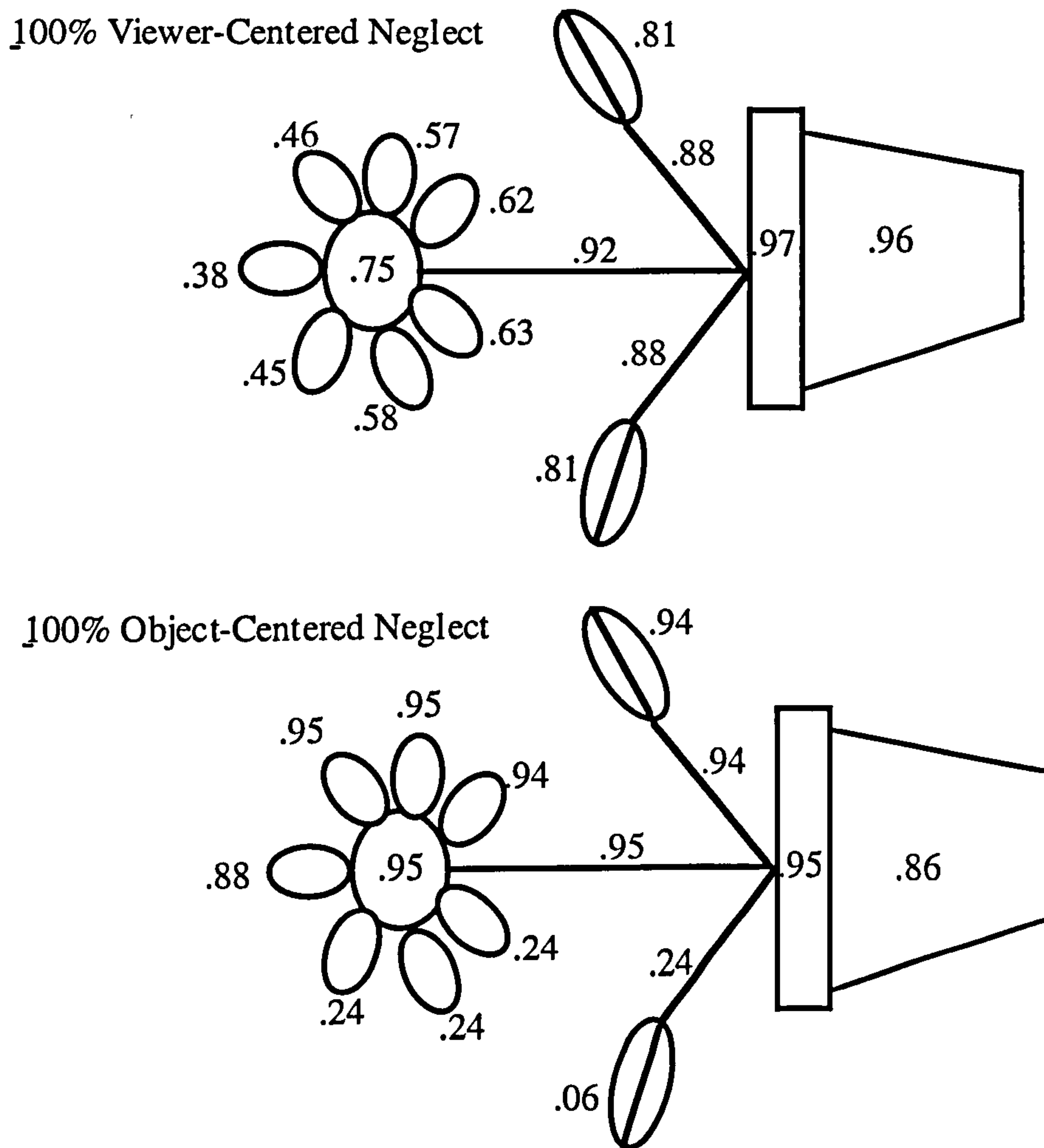
At the level of neural wetware there is evidence that the left hemisphere is preferentially specialised for local and the right for global processing (Robertson & Lamb, 1991; Sergent, 1982), perhaps via spatial frequency filter asymmetries (Ivry & Robertson, 1998). For example, Figure 1.10 shows cases of stimuli which patients with right (centre panel) and left hemisphere lesions (right panel) were asked to reproduce. Damaging the right tempo-parietal junction produces deficits in the perception of global configurations of objects. In contrast, patients with insults of the left hemisphere are unable to perceive local features of objects although they do appear to see global configurations. Taken together, these patients show a double dissociation of global and local perception, which is consistent with the notion that (1) the visual system represents visual information at different spatial scales in separate representations and (2) identifying information at one hierarchical level is not dependent on processing at a different level. It has been suggested that object-based neglect is the result of an impaired attentional "control" system. Although the visual scene is parsed into appropriate (global) objects, focal attention is not guided to the left side of the object (Halligan & Marshall, 1993; 1994).

Humphreys and Riddoch (1994) also found evidence for two forms of internal representations, one for perceptual parts of an object (within-object) and one for whole objects (between-objects). They reported data from two neuropsychological cases who showed unilateral neglect of one hemifield if the stimuli were coded as parts of a single perceptual object and neglect of the opposite hemifield if the stimuli were coded as separate objects. Attentional cueing effects to the left and right were found to be specific to the form of





**Figure 1.8** The hierarchical representation (right) of the simple daisy flower (left) which two unilateral left neglect patients were given to draw in a study reported by Plaut and Behrmann (1996, exp. 1)



**Figure 1.9** The probabilities of drawing each part of a left-facing daisy if copying is mediated exclusively via a viewer- or object-centred frame of reference (from Plaut & Behrmann, 1996).

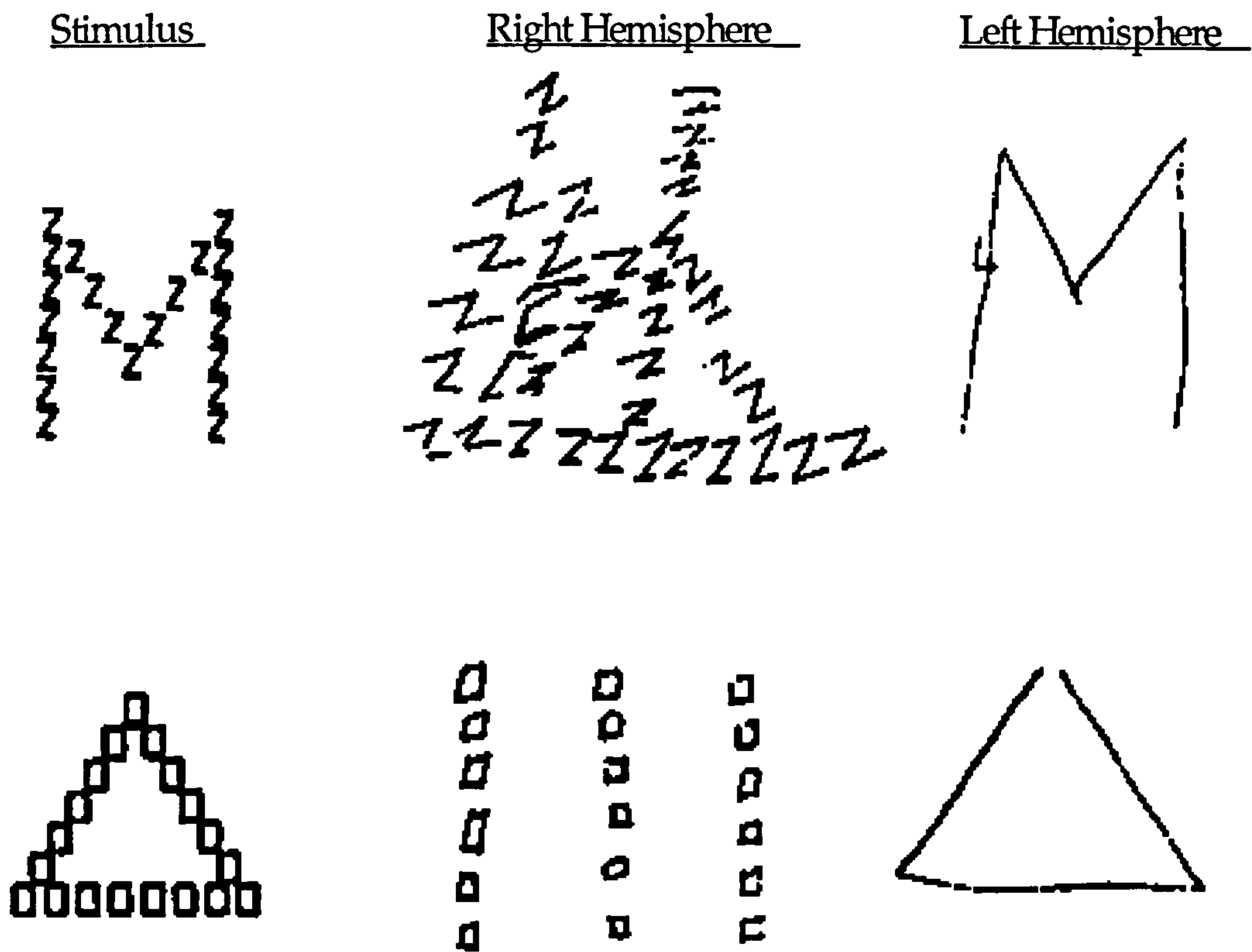


Figure 1.10 Patients with left and right hemisphere lesions were asked to reproduce the stimuli on the left. The patient with a right hemisphere lesion drew repetitions of the correct elements, but failed to reproduce the global configurations. In contrast, the patient with the left hemisphere lesion drew the overall global shape correctly, but failed to include the correct local elements.  
 (Taken from Ivry & Robertson, 1998, p. 34.)

representation utilised. The two types of representation appeared to be coded in parallel and visual selection operated independently on both. They speculated that the within-objects and between-object representations are encoded in contrasting forms. The within-object representation, which was associated with left-neglect, was found to be visual in that it was improved with visual cues. Motor cues were found to improve right-neglect which was associated with the between-objects representation.

### 1.2.3 Conclusion: Location- versus object-based medium of attention?

In this review, the role of location- versus object-based representations on visual attention in a range of experimental paradigms has been considered. In no single case, other than spatial pre-cueing which we will return to (but see Egly, Driver & Rafal, 1994), has the evidence been convincingly in favour of a pure location-based attentional effect in the absence of an object-based effect. Rather, the evidence suggests that selective attention is sensitive to 'what' is in the visual field as well as 'where' it is located. As Driver and Baylis (in press) have succinctly pointed out:

*"A naive version of the spotlight metaphor might ... be held to characterise human vision as the blind application of tunnel vision to successive locations, in a desperate search for anything 'out there'."*  
(p. 3).

In contrast, the experimental evidence suggests that the visual system is capable of selecting objects, even in the absence of differentiating spatial information i.e. overlapping shapes.

Secondly, we have seen that there is evidence for more than one type of segmentation by the visual system. Roles have been proposed for spatial frequency, figure/ground segmentation and perceptual (Gestalt) grouping as the basis of object-based attentional effects. Additionally, we have observed that within-object structures can also influence the spread of attention. There may be different representations that code separate objects and the structural relationships between components of a single object. The pattern of neglect may differ across the different representations in the same patient. The relationship between these processes remains a topic of debate.



### 1.3 Dual Pathways for location- and object-processing

A variety of evidence suggests that the primate visual system processes object and location properties separately. The dual pathway model of visual processing asserts that there are two mutually-exclusive hierarchically organised visual pathways which emanate from V1 (Ungerleider, 1983; Ungerleider & Mishkin, 1982). This model is derived from observations of the different effects of lesions in the parietal and inferior cortex and the knowledge that two major fibre bundles emerge from the occipital cortex and project rostrally in the brain (Flechsig, 1896; 1920). The ventral stream (inferior longitudinal fasciculus nerve bundle), lying ventrally and terminating in the temporal lobe, was thought to be responsible for computing and collating object visual attributes e.g. shape, colour, orientation etc. The second, the dorsal pathway (superior longitudinal fasciculus nerve bundle), terminates in the parietal cortex and is specialised for spatial vision. Livingstone and Hubel's (1988) more detailed account elaborated on Ungerleider and Mishkin's distinction but translated it into magno/parvo channels.

Ungerleider and Mishkin (1982; Ungerleider, 1983) conceived of the dorsal/ventral streams as a simple portioning of labour of the analysis of "what" and "where" in visual input. Rueckl, Cave and Kosslyn (1989) investigated the differences in computational demand between a single system that represents both form and location and a system where the two types of information are represented separately e.g. the primate visual system. They built two three layer models which were designed to simultaneously classify and locate shapes that could appear in multiple locations in the matrix. One of the networks were designed so that all the units in the hidden layer projected to all of the nodes in the output layer. This was considered a simulation of a single pathway visual processing model. The performance of this network was compared with a variation in which the hidden nodes were split into two groups, with some projecting to nodes in the output layer which registered shape identity and the remainder to other output nodes which registered location. They found that the split network showed a better performance in encoding the location and identity of a shape, but only if the proportion of nodes dedicated to computing identity and location were allocated optimally. The representation of the identity of a shape was shown to be considerably more difficult than the "where" classification. The performance in computation of both identity and location was

systematically related to the number of nodes dedicated to each. Thus, if there were sufficient numbers of hidden nodes dedicated to both “what” and “where” processing the split network outperformed the unsplit model. The split network developed two separate internal representations, one for location and the other for identity. The unsplit network was forced to represent both location and identity using one representation as all of the hidden units are connected to the all of the output layer units.

While the receptive and projective fields of “split” and “unsplit” models adopt quite different solutions, these are clearly useful responses to the task under the relevant constraints. While the “unsplit” model does manage to perform these computations simultaneously, the “split” model performs more effectively. The main advantage of the latter model is the computation of identity independently of location. Location information has a significantly stronger influence on both models, but the allocation of the independent tasks to separate networks reduces the influence of location on the feature detectors. This makes identification of form more efficient. Rueckle, Cave and Kosslyn (1989) pointed out that, in the primate visual system, reducing the interference between location and object information is even more important as the two types of information guide behaviour in different ways. In the absence of two cortical systems, and therefore identity and location information tied together, it would be necessary to filter out extraneous information, at a large computational expense. The model also indicates that computing identity is much more computationally demanding than computing location and may explain why many more cells are devoted to this process in the primate temporal lobe (Van Essen, Anderson & Felleman, 1992).

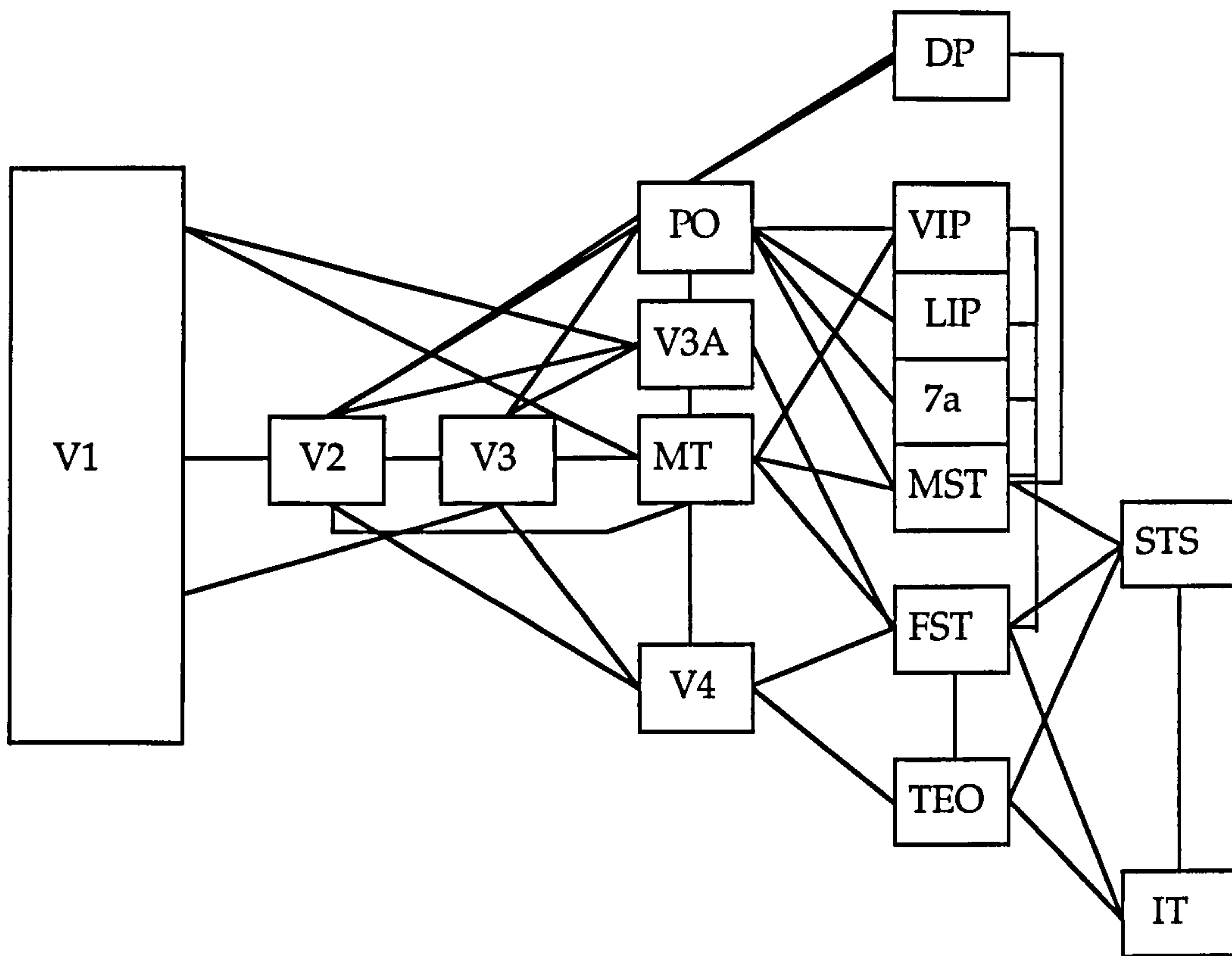
Ungerleider and Mishkin’s (1982) scheme is based on the observations of the results of lesioning relatively gross portions of monkey cortex. This has produced difficulties in interpreting their data as it is difficult to identify the critical areas within the monkey pathways and the homologous structures in the human visual system (Ungerleider & Haxby, 1994; for a review see Turnbull, Carey and McCarthy, 1997). Indeed, Zeki (1993) argues that the two pathways cannot be mutually exclusive as neurophysiology has shown that there are many connections between the two pathways. The proposition that there are only two pathways emanating from V1 is incorrect (Figure 1.11). V1 has direct as well as



indirect connections to areas V3, V4 and V5 (Zeki, 1993). Area V3 sends much of its output to the parietal cortex rather than the temporal cortex as the dual pathway model would suggest (Zeki, 1993). Area V4 has a heavy output to the temporal cortex (for review see Zeki & Shipp, 1988). Thus, both V3 and V4 process form, although in keeping with their different derivations, V3 is involved with dynamic form and V4 in form associated with colour. This is consistent with the absence of a case in the neurophysiological literature that reports a patient with a total and specific loss of form vision alone.

Milner and Goodale (1993; 1996) agree with the notion of dual pathways in the brain (Ungerleider & Mishkin, 1982). However, they suggest that the division of labour between the pathways is not consistent with the differences in function between them. They agree that the ventral stream is associated with object recognition, but argue that the dorsal stream is more directly related to visuo-motor processes than simply coding the spatial locations of objects. Most of the supporting evidence for this idea comes from reviews of the neuropsychological literature (Goodale & Milner, 1992; Milner & Goodale, 1993). A patient with visual form agnosia (D.F.) is unable to describe the shape, size and orientation of visual objects, but can use the same information to guide motor responses. In contrast, the opposite pattern of deficits was found in a patient with Balint syndrome (R.F.) who could describe the appearance of objects but cannot reach for them accurately (Goodale et al., 1994). This dissociation cannot be accommodated within the original dual pathway account (Ungerleider & Mishkin, 1982) and Milner and Goodale (1996) suggest that different forms of representation are accessed by object recognition and visuomotor systems. They suggest that the ventral stream mediates object-centred ("location-blind") representations for object recognition while the visuomotor system accesses viewer-centred ("location-aware") object representations in the dorsal stream. The superior parietal region (SPT) was proposed to code the viewer-centred object information (Milner & Goodale, 1996). (This is precisely the situation which Ruckelshaus, Cave and Kosslyn's (1989) model suggests is non-optimal. However, their model was designed to simply identify objects, not act upon them, which is the function of the





**Figure 1.11** A schematic illustration of the major projections of the dorsal and ventral streams. Not all of the known connections are shown and those within the PP area are omitted. Area AIP is also omitted from the drawing. V1-4 visual areas 1-4; V3A visual area 3A; PO, parietal-occipital area; MT, middle temporal area; DP, dorsal prestriate area; VIP, ventral interparietal sulcus area; LIP, lateral intraparietal sulcus area; 7a, parietal area 7a; MST; medial superior temporal area, FST, fundus of the superior temporal sulcus; PP, posterior parietal complex; STS, anterior complex within the superior temporal sulcus; IT, inferotemporal complex.

(Taken from Milner & Goodale, 1995, p. 40)

human visual system.) The dual-stream system that Milner and Goodale (1996) propose is not so much a 'what' and 'where' as a "location-blind" and "location-aware" dichotomy.

The suggestion that superior parietal lobule represents "location-aware" object information is interesting as this region is also implicated in the movements of attention. Bushnell, Goldberg and Robinson (1981) found single cells in area 7a, which is within the superior parietal region, whose activity was enhanced when the macaque attended to a particular spatial location, prior to both eye or hand movements. Corbetta, Miezin, Shulman and Petersen (1993) have shown that blood flow is enhanced in this area when participants perform a visuospatial selective attention task. Finally, Posner et al (1984) have shown that patients with damage to this parietal region showed the greatest disruption in shifts of attention to the neglected field using the pre-cueing paradigm. Thus, there is converging evidence from single cell recording, imaging and patient studies that selective visual attention is mediated by a region that represents object information within a spatial representation. This is precisely the form of representation described by hybrid models of attention (e.g. Logan, 1996) and one in which spatial and object-based effects could not be dissociated in a behavioural task as they would be mediated by a single representation.

#### 1.4 The spatial cueing paradigm and location- and object-based representations

In section 1.1.1.2 the pre-cueing paradigm was described as evidence for a location-based representation as the medium of selective attention. Posner (1980) explicitly claimed that attention was a "Spotlight" which moved across a location-based representation. However, more recent evidence suggests that spatial attention is aware of objects that occupy a location. Re-examining Figure 1.2 (Top Panel) shows that attention was directed to regions of the display which were marked by outline boxes, which were described as placeholders. This introduces an inherent confound in the spatial cueing paradigm. If there is more than one type of representation in visual attention e.g. location- and object-based, cueing a location using the spatial cueing paradigm also may have the effect of cueing the object which occupies the space.

Relatively little attention has been given to examining the role of object-based attentional effects in the pre-cueing procedure. Initially, Posner's spotlight

metaphor of visual attention moving across a pure spatial representation precluded consideration of the influence of the place-markers on the cueing effects observed. More recently, authors (e.g. Farah, 1990) have questioned whether the place-markers in the display are sufficient to evoke object-based effects in this procedure. As already noted, Egly, Driver and Rafal (1994) have reported facilitatory attentional effects that spread across objects. However, the design of this procedure is unusual and their result needs to be generalised to more common pre-cueing procedures (see Chapter 4).

It is very difficult to examine this issue directly. Simply removing the outline objects from the display and comparing the resulting effects introduces to problems. The place-markers themselves may produce masking effects that arise both as a result of the perceptual interaction between the peripheral cue and target themselves and also between them and any other changes in the display. Additionally, removing the place-markers would make it more difficult to localise/remember where the peripheral cue appeared before the onset of the target. This would be expected to influence the control of movements of attention around the display. These possible confounds would produce opposite effects, potentially making it difficult to observe the role of the place-marker objects in the pre-cueing procedure. A possible alternative method would be to move the place-marker objects in the time period between the onset of the cue and target. Thus, the influence of the object- and spatial representations would be de-coupled. However, there is insufficient time to do this as the facilitatory effect peaks at approximately with a 100-150 ms stimulus onset asynchrony. Thus, a variation on of the spatial pre-cueing paradigm will be used to examine the role of task-irrelevant objects in the display.

Inhibition of return (IOR) is observed using the pre-cueing paradigm, with nonpredictive peripheral cues and a long temporal interval between the cue and target. The long temporal delay has allowed Tipper and his colleagues (e.g. Tipper, Driver & Weaver, 1991; Tipper, Weaver, Jerreat & Burak, 1994b; Weaver, Lupiáñez & Watson, in press) and others to move the stimuli between the onset of the peripheral cue and target. By de-coupling the location and object identity of the previously attended stimuli, it is possible to examine the influence of location- and object-based representations in this type of procedure. Observations that inhibitory attentional effects can be associated with previously



attended objects in dynamic displays suggest that location- and object-based forms of reference may be confounded in the pre-cueing procedure. This thesis examines the issue more systematically, confirming that location- and object-based IOR effects are the product of independent mechanisms, are confounded in static displays and investigates the boundary conditions of each of these effects.

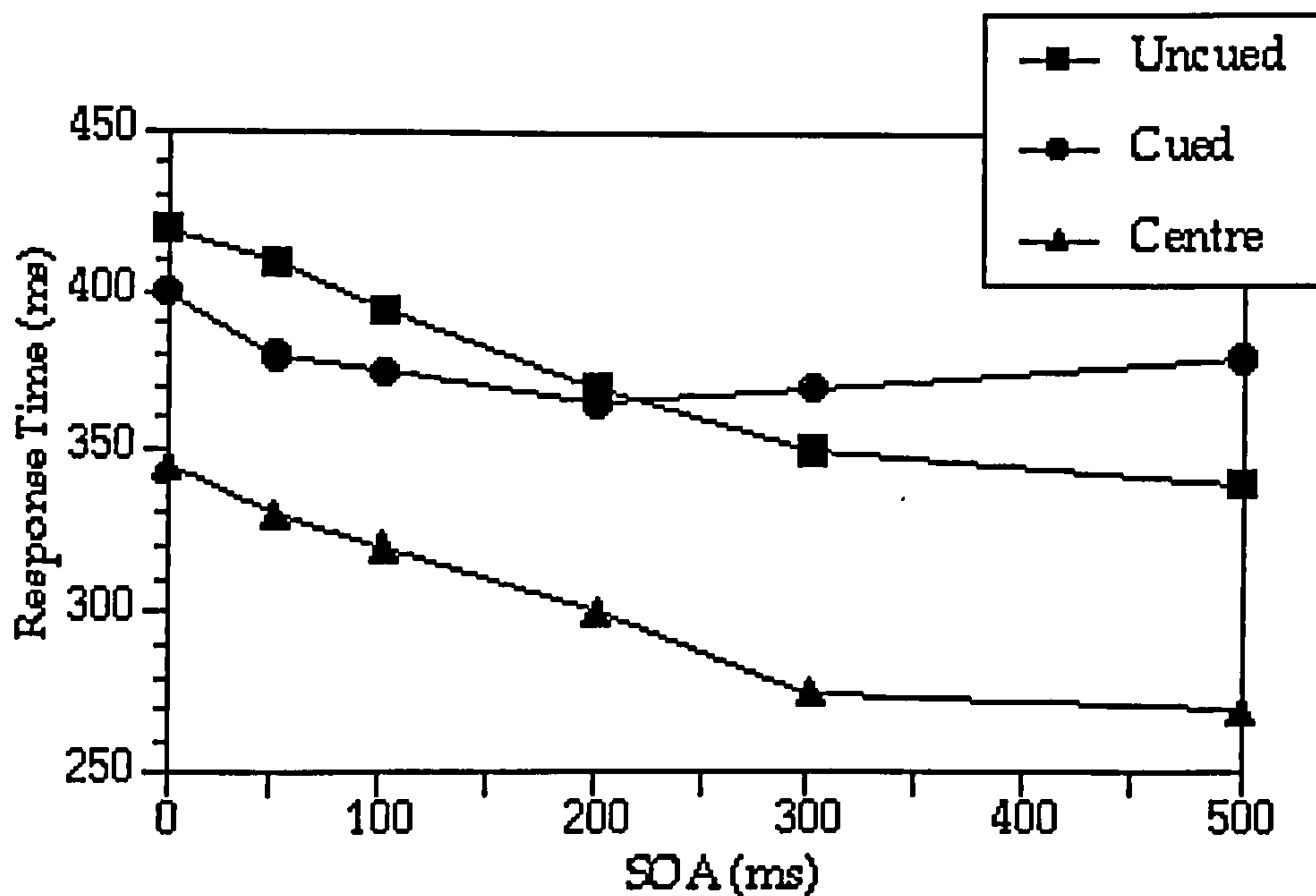
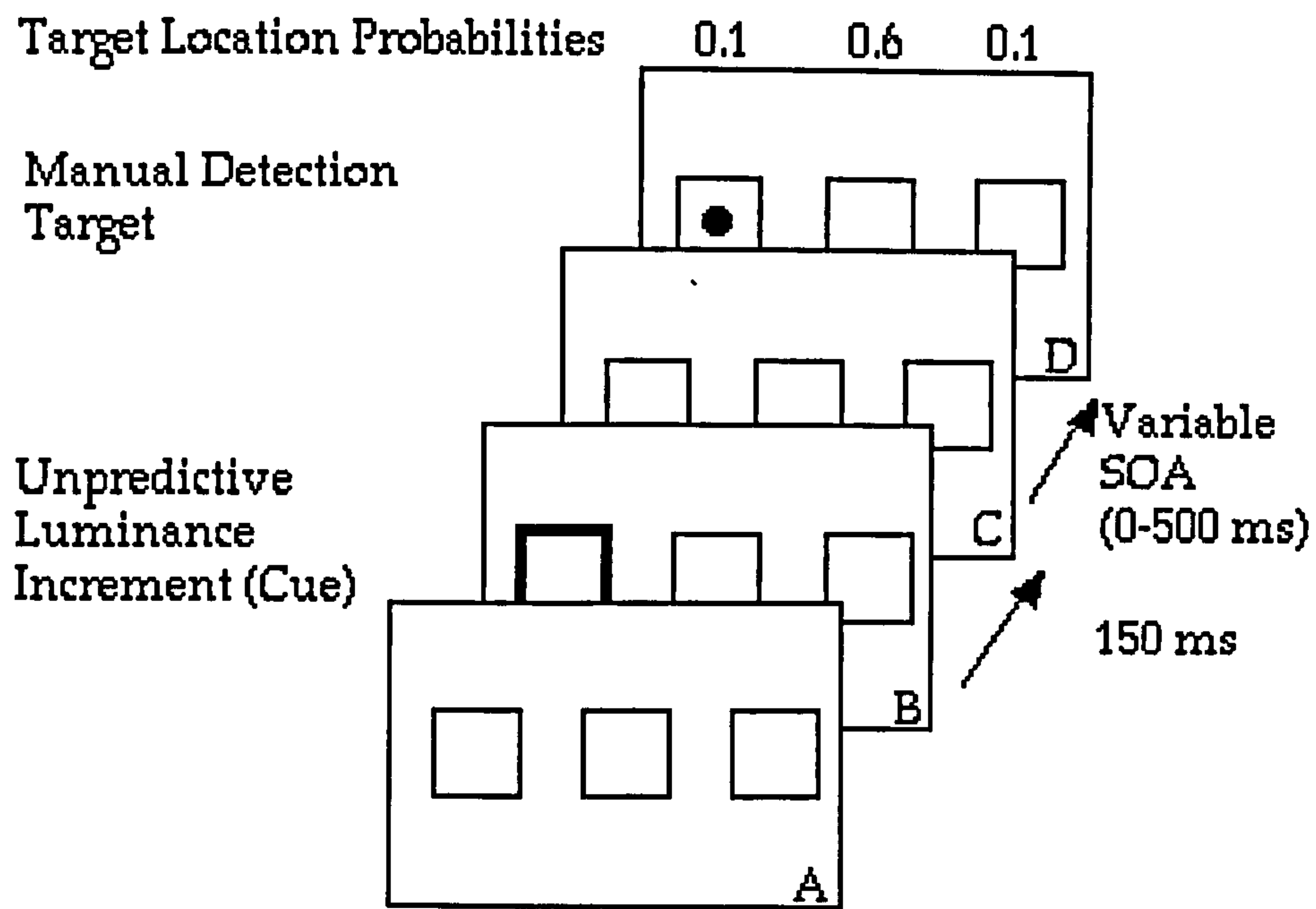
## Chapter 2

### *Space and Object-based Representations and Inhibition of Return*

In Chapter 1 the evidence for space- and object-based representations as the medium of visual attention was reviewed. Although object- and location-based attentional effects have been observed in both focused and divided attentional tasks, there are few reports of object-based attentional effects in the spatial pre-cueing paradigm (see section 1.1.1.2 Posner, 1978; Posner et al., 1978; Egly, Driver & Rafal, 1994). The focus of this thesis is a special case of the spatial precueing paradigm; the inhibition of return (IOR) effect (Figure 2.1; Top Panel). Generally, responses to targets appearing in cued regions of the display are facilitated. However, when (a) the stimulus onset asynchrony (SOA) between the peripheral cue and target is greater than 300 ms, and (b) the peripheral cue is non-predictive, responses are slower to targets appearing in cued regions (Figure 2.1; Bottom Panel).

#### 2.1 The Inhibition of Return Procedure

Posner & Cohen (1984) originally demonstrated that responses to a previously cued peripheral location are significantly slower than those to an uncued peripheral location using the procedure illustrated in (Figure 2.1; Top Panel). Three boxes (subtending 1 degree each) were presented on a cathode ray tube. One box occupied the centre of the display (fixation box) and the remaining two flanked it 8 degrees away. The trial commenced with the brightening of the outline of one of the two peripheral boxes for 150 ms. After an interval varying from 0 to 500 ms the target (filled square subtending 0.1 degrees square) appeared in the centre of one of the boxes. In 60% of the trials the target appeared in the central fixation box. The target appeared, with 10% probability, in either one of the peripheral boxes. The participants responded to the onset of the target



**Figure 2.1** Top Panel; Illustration of Posner and Cohen's (1984) procedure in the original report of the "inhibition of return" (IOR) effect. Bottom Panel; The biphasic effect of an exogenous cue on target detection response times, as reported by Posner and Cohen (1984). Initially, target detection is facilitated at the cued location. After 300 ms this effect is reversed, so that RT's to cued targets are slower compared to uncued targets. This increase in response latencies is known as the IOR effect.



by pressing a single key (target detection) as quickly as possible. The remaining 20% of trials were catch-trials where no target appeared and the subjects were instructed to withhold a response. It was assumed that subjects would maintain attention in the fixation box as the target appeared in this location in the majority of trials. Eye movements were monitored using EOG electrodes to ensure that the subjects fixated on the centre of the display. Trials in which the subjects made detectable eye movements were excluded from the subsequent analyses.

The time course of the exogenous cueing effect (Figure 2.1, Bottom Panel) was explained by Posner and Cohen (1984) in the following way. The peripheral cue automatically attracts (“pulls”) attention to its spatial location (see also Yantis, 1993b). Targets, appearing in the same location shortly after the cue, are detected relatively quickly because insufficient time has elapsed for the re-alignment of attention to the centre of the display. This facilitation effect on target detection (decreased response latency) does not occur at longer cue-target SOA’s as attention has sufficient time to reorient to the centre of the display and is actively inhibited from returning to the previously attended (cued) region of space. This inhibitory effect was later termed the “inhibition of return” (IOR) effect (Posner, Rafal, Choate & Vaughn, 1985) and has been shown to last for several seconds after the onset of the cue (e.g. Cohen, 1981; Tassinari, Aglioti, Chelazzi, Marzi & Berlucchi, 1987). The IOR effect is not confined to the visual domain as has it has been observed for ipsilateral cues and targets within and across visual, auditory and somatosensory modalities (Reuter-Lorenz & Rosenquist, 1996; Reuter-Lorenz, Jha & Rosenquist, 1996; Schmidt, 1996; Spence & Driver, 1998a; Spence & Driver, 1998b; Tassinari & Berlucchi, 1995).

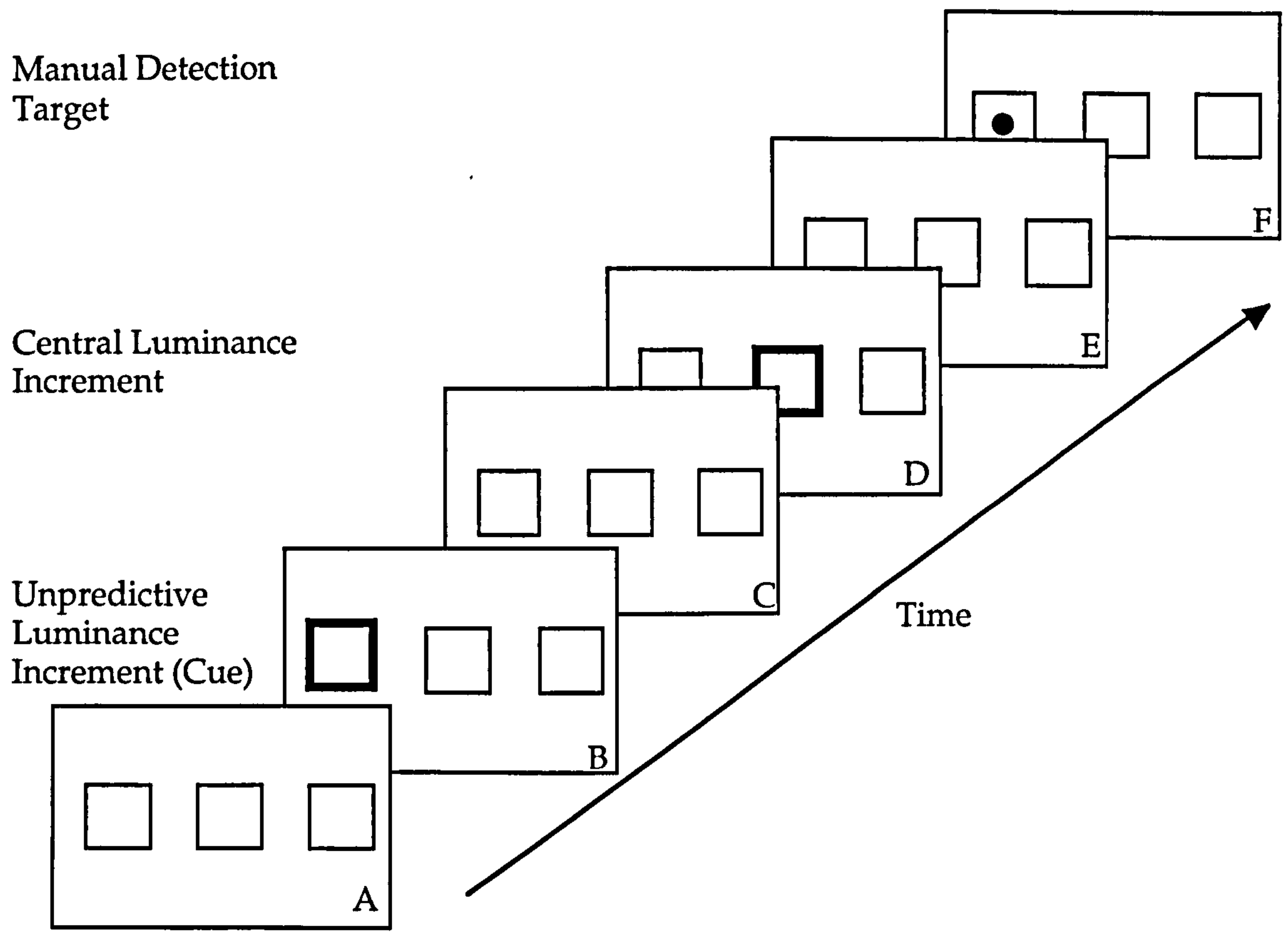
Posner and Cohen’s (1984) original studies relied on the participants to maintain attentional resources endogenously on the centre of the display in the absence of an incentive to re-allocate it elsewhere (e.g. Possamai, 1986) and/or the use of a central cue at fixation to explicitly summon the return of exogenous attention to the centre (e.g. Cohen, 1981). A central fixation event is usually included in the displays which make up the typical static IOR procedure in contemporary IOR studies. This ensures that attention is oriented away from the cued region. Figure 2.2 illustrates the typical IOR procedure commonly used, and this will be referred to as the prototypical static IOR procedure for the remainder of this thesis. Only variants on this procedure will be described in detail.

### 2.1.1 IOR as an sensorial artifact?

The IOR effect is not the product of low-level sensory artefacts. One possibility is that IOR is the result of metacontrast forward masking effects (Breitmeyer & Ganz, 1976) in which the stimulation associated with the onset of the peripheral cue interferes with processing of the subsequent target occurring at the same location. However, IOR occurs at cue-target SOA's which are outside the typical (100 ms) range of masking effects (e.g. Foley & Boynton, 1993). Furthermore, metacontrast masking has been found to have no effect on RT's (e.g. Fehrer & Raab, 1962), the dependent variable typically used to study IOR. The sensorial explanation is also inconsistent with the evidence that IOR; survives eye movements (Maylor & Hockey, 1985; Posner & Cohen, 1984); can be associated an object which has moved to a new location (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b; Tipper et al., 1991; Tipper, Jordan & Weaver, in press; Tipper et al., 1994b; Weaver et al., in press) can be observed at regions which are remote from the cue (Maylor, 1985) and survives inter-ocular transfer under dichoptic viewing conditions (see also Maylor, 1993 cited in Maylor, 1985; Tassinari & Berlucchi, 1993). Thus, the IOR effect is generated by perceptual-motor processes in the human visual system.

### 2.2 The relationship between facilitation and inhibition in the precueing paradigm.

Posner and Cohen (1984) argued that the appearance of a visual stimulus at a peripheral location automatically summons attention to the cued location, resulting in the facilitatory effect. They suggested that facilitatory effects on the detection of cued targets are due to a short-lived orienting response. Evidence for the IOR effect was found only after attention had been re-oriented away from the cued location. According to Posner and Cohen, "if attention is not drawn away from the cued location, no net inhibition is found" (p. 541). The relationship between facilitatory and inhibitory mechanisms was thought to be reciprocal and this interaction would prevent the over-commitment of sensory processing resources to the attended location. Facilitatory effects tend to control the orientation of attention in the fixed visual field, while inhibition biases the systems to novel locations in the environment. "Once eyes move away from the target location, events that occur at that environment location are inhibited with respect to other locations" (Posner & Cohen, 1984, p. 550, emphasis added).



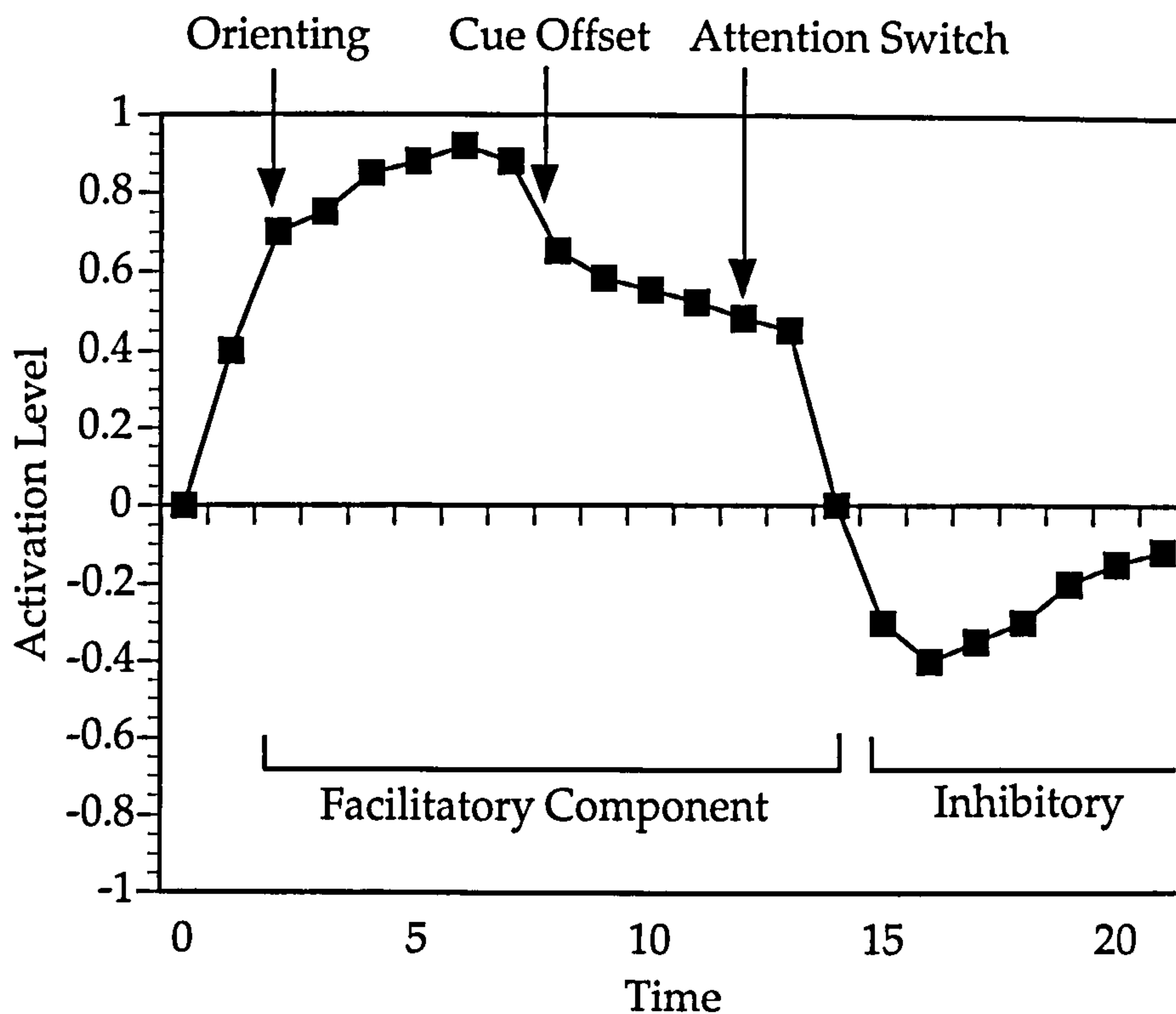
**Figure 2.2** An illustration of the typical static inhibition of return procedure in which the peripheral cue is unpredictable and a central cue is presented to ensure that attention is aligned with the centre of the display prior to the onset of the target. This procedure is taken as the prototypical static IOR procedure for the remainder of this thesis.



Maylor (1985) on the other hand suggested that the facilitatory and inhibitory effects are not independent, both reflecting different aspects of the orienting response. She noted that the facilitation effect was completely abolished if the participant made an overt orienting response to another stimulus at the moment the cue appeared. IOR also disappeared, and this was due to the orienting response (and thus facilitation) (Maylor, 1985 Experiment 2). In addition she found that the magnitude of both the facilitatory and inhibitory effects were reduced by approximately one-half by the simultaneous cueing of two locations (Experiment 3). She concluded that both the facilitatory and inhibitory components were "dependent on externally controlled orienting" and acted in tandem. However, Posner and Cohen (1984) reported the abolition of the IOR effect with simultaneous cueing, which is consistent with the inability to attend to non-contiguous regions (Posner et al., 1978). Klein and Taylor (1994) reported that their attempts to replicate the simultaneous double-cueing procedure produced mixed results, and the issue remains unclear.

Houghton and Tipper (1994) have proposed a model of selective attention where a gain-control mechanism, driven by facilitatory and inhibitory imbalances, plays a central role in the selection of targets in the perception-action interface. In essence, their model consisted of (1) an object field, consisting of externally-driven units which coded the input, (2) the target field, which represented the properties of an internally generated target (or template) and (3) a match/mismatch field (MMF) which received signals from both of the previous representations, compared them and generated a feedback signal. The signal from the MMF fed into the gain-control system which formed the basis of the selection mechanism. A match led to an excitatory imbalance in the gain-control feedback, activating all other properties of the target object including a response. A mismatch signal corresponding to a distractor had an inhibitory effect, which dampened object properties below those of the target, but above resting level. Once the stimuli is removed, the representation of the target object decays to its resting equilibrium level. The representation of the distractor also returns to its resting level, but via a different route, which results in an inhibitory rebound effect. The post-offset rebound is achieved by the same mechanism which performs selection.

When they incorporated their opponent-based selection mechanism with orienting subsystems, they were able to examine the relationship between facilitatory and inhibitory components in the precueing paradigm. When the cue and internal target match in their location properties the MMF generated a match signal causing overall facilitation. Subsequent re-orienting of attention was modeled by quenching the activation of the previous externally driven orienting target (the peripheral cue) and is replaced by a new target e.g. the location of the fixation marker. The activation associated with the previous cue persists (due to the facilitation) and now generates a mismatch signal from the MMF, due to the change in internal target (Houghton & Tipper, 1994). This mismatch instigates an inhibitory rebound in the representation of the cued input, including its spatial location. Thus, re-orienting of attention away from the location of the peripheral cue, and not the offset of the cue itself, sets up inhibition for that region resulting in the IOR effect (Figure 2.3). This is consistent with Posner and Cohen's (1984) proposal. Additionally, the facilitatory and inhibitory components are independent, but there is a functional coupling as the facilitatory component drives the inhibitory one.



**Figure 2.3** The facilitatory and inhibitory components of Houghton and Tipper's (1994) simulation of IOR. The curve represents the activation of a single node representing the location of the peripheral cue. Orienting is realised as the establishment of the internal target, and occurs at  $t = 2$ . Attention switching at  $t = 12$  removes the facilitation and initiates inhibitory rebound in the location opponent circuit. This suppresses activation of the previously facilitated location (taken from Houghton & Tipper, 1994, p. 104).

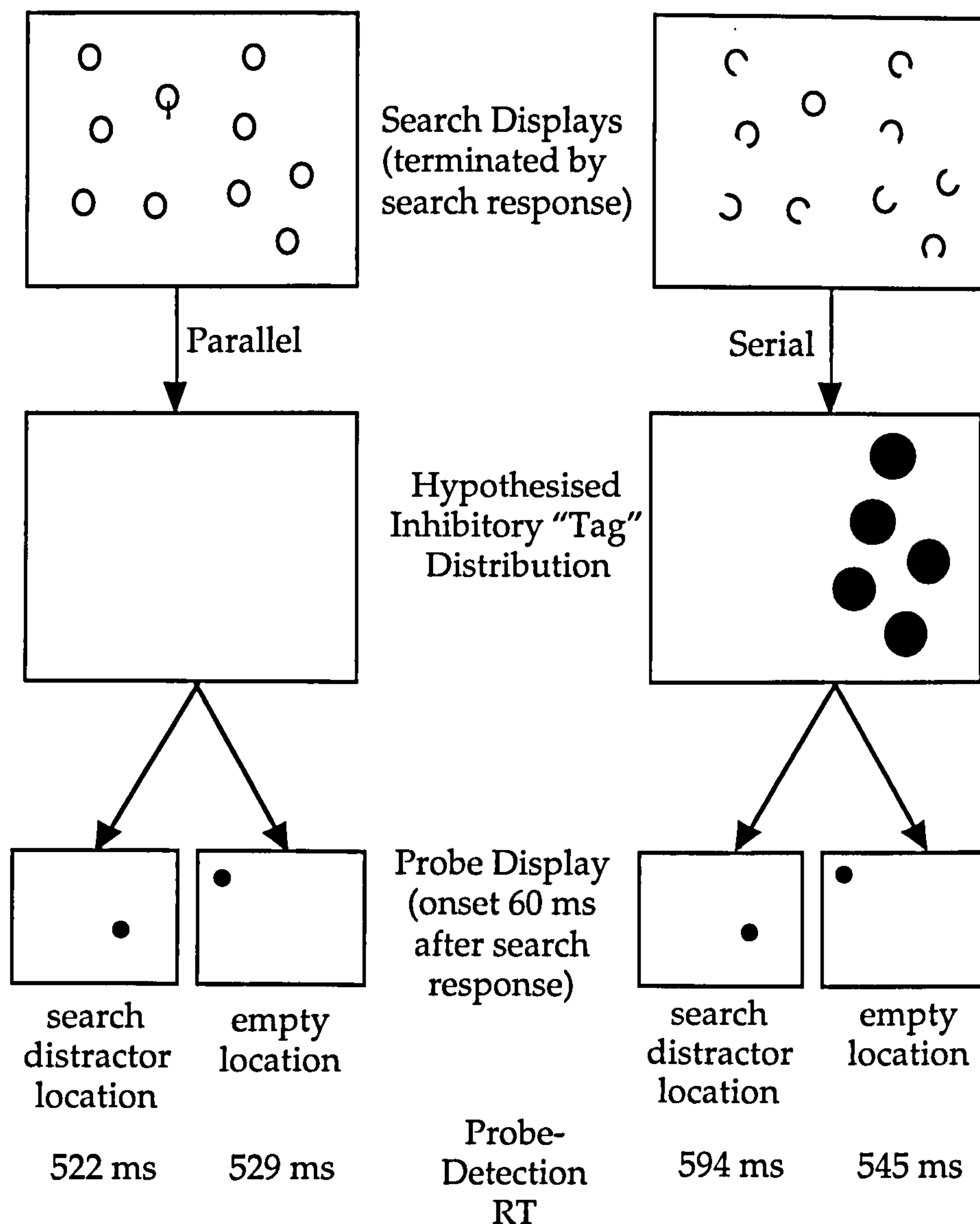


## 2.3 The Function of Inhibition of Return

### 2.3.1 Guiding Efficient Visual Search

Intuitively, an inhibitory mechanism which biases processing resources away from previously attention regions of the visual scene is precisely what is needed to guide efficient search in complex visual scenes (Posner & Cohen, 1984). Each possible target region needs to be examined once, and if a target is not present, processing resources should be directed to a novel location and inhibited from returning to the previously attended one (see Chapter 1). The inhibitory mechanism which underlies the empirical IOR effect appears to act in this way, enabling past behaviour to influence future behaviour, at a pre-conscious level. The observation that multiple (up to four) locations are inhibited when successive peripheral cues are presented is consistent with the idea the inhibitory mechanisms help to guide efficient search (Abrams & Pratt, 1996; Danzinger, Kingstone & Snyder, in press; Tipper, Weaver & Watson, 1996).

Klein (1988) explicitly tested the notion that the purpose of IOR may be to bias the movement of processing resources in search tasks. He reasoned that inhibitory "tagging" of distractors in a serial search task should prevent attention returning to the rejected items (Figure 2.4). This inhibitory tag was indirectly measured using a probe-detection task, where RTs to a luminance increment appearing in a rejected search item location were compared to those occurring in an empty region of the display. Consistent with Klein's prediction, probe-detection RTs were consistent with inhibition at rejected distractor locations in the serial search task. A parallel search condition served as a control for extraneous factors, including masking and expectancies, that were almost identical in the two search tasks. This experiment provided support for the intuitive notion that the function of IOR was to promote efficient visual search and many authors continued to describe this as the function of IOR although attempts to replicate Klein's (1988) findings failed (Klein & Taylor, 1994; Wolfe & Pokorny, 1990). Very recently, several independent laboratories have claimed to replicate Klein's (1988) observation of inhibitory effects in serial visual search tasks (Takeda & Yagi, 1998 from Klein, personal communication July 1998; Müller, personal



**Figure 2.4** The relationship between the search display conditions and the proposal that inhibition of return is associated with attended search items in Klein's (1988) study. In the serial search condition (right), presumed allocation of attention to each item is followed by inhibitory "tagging" of the location of the search distractor item. These inhibited regions are represented by filled black circles. The parallel search condition (left) in which search-target detection was assumed to be carried out without the involvement of attention served as a control condition. No region is inhibited as attention was not allocated to any of the search items.

The search display was terminated by a two-alternative forced choice response (target present/absent) and 60 ms elapsed before the onset of the detection-probe. As predicted, RT's for the probe detection task were slower in the serial search condition when the probe appeared in a previously occupied location compared to the other three conditions (bottom row).

communication July 1998). Although the boundary conditions are not completely clear, it appears that the temporal gap between the removal of the search display and the onset of the detection-probe is critical.

### 2.3.2 Guiding efficient allocation of processing resources

An instructive and interesting observation has recently arisen from the machine vision literature which suggests that the role of an inhibitory mechanism which produces a bias in favour of novelty has a more general and fundamental function than simply guiding visual search. Janßen (1996) implemented a saccadic camera on an autonomous vehicle and “set it free” in a real world environment. The system consisted of a camera under autonomous control and a recognition system that processed the camera input recognising complex visual scenes and directing camera fixations (Figure 2.5). The system consisted of a peripheral feature detection system that “preattentively” extracted “salient” (i.e. interesting) points in the periphery of the camera image. A “higher-level” scene recognition system developed hypotheses about the scene and suggested “interesting” locations for the next saccade. The data-driven ‘bottom-up’ and hypothesised ‘top-down’ suggestion were registered on an egocentric “interest map” which determined the movements of the camera. The critical point for this discussion is that: “ “inhibition of return” must be incorporated... [to ensure that the scan-path of the camera] ... does not simply oscillate between the two most salient positions.” Janßen (1996, p. 303.). Janßen’s work suggests that inhibition in the oculo-motor system is necessary to control, and a consequence of the ability to produce, saccadic eye movements.

Janßen (1996) termed the mechanism that biases his saccadic camera away from previously fixated locations “inhibition of return” but he does not appear to be aware of the IOR effect in the human visual system (HVS). However, there are several interesting comparisons between Janßen’s “inhibition of return” and the empirical IOR effect that is the focus of this thesis. The “inhibition of return” mechanism in this machine vision system “memorizes the locations already gazed at” (Janßen, 1996, p. 303) and



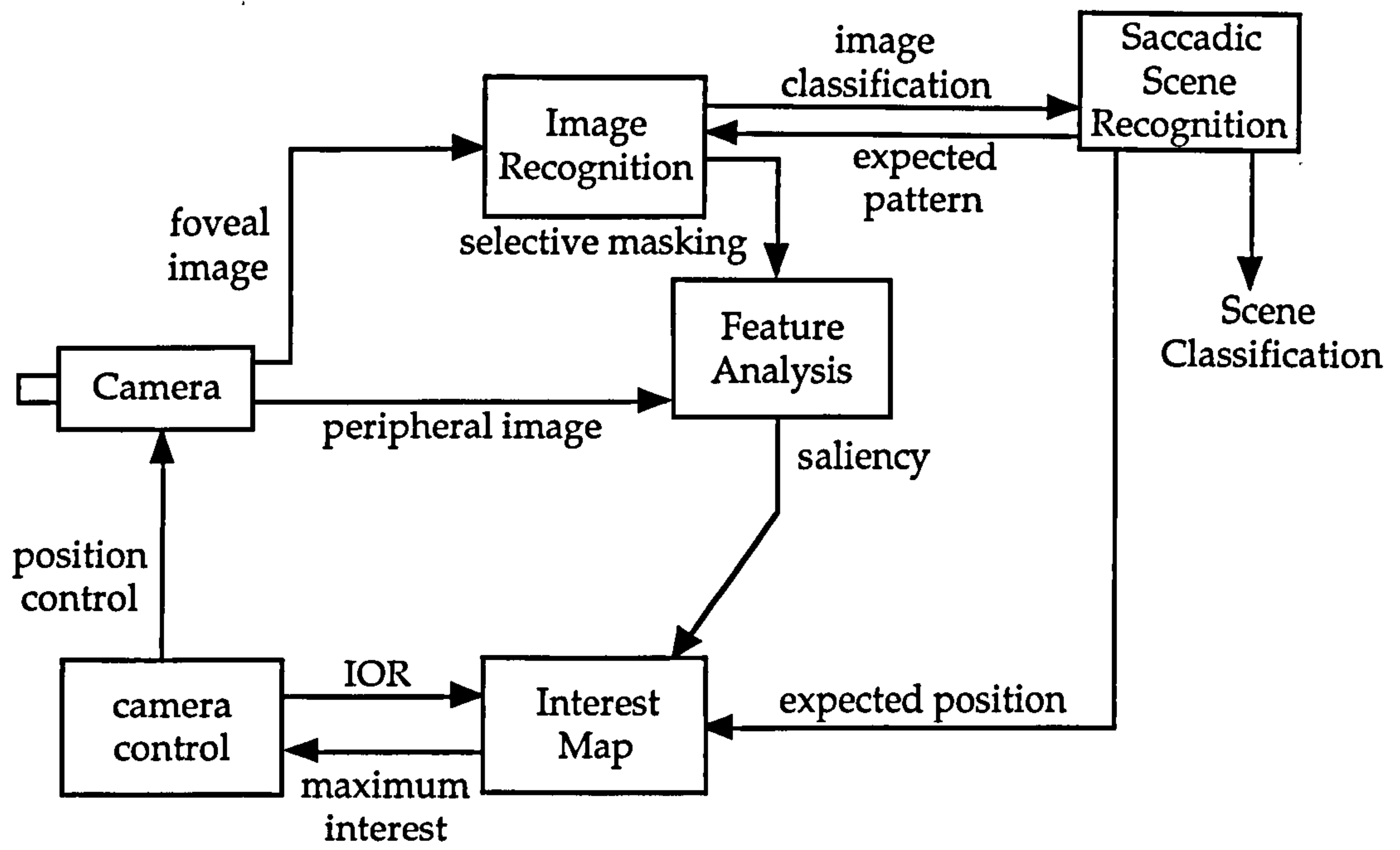


Figure 2.5 Overview of the saccadic recognition system proposed by Janßen (1996).

previously fixated locations are only registered on the inhibition map in the interest module once the camera saccades to a new location. This is consistent with both Posner and Cohen's (1984) and Houghton and Tipper's (1996) notion that IOR of a spatial location is triggered by orienting away from it. The "inhibition of return" mechanism in Janßen's camera system is separate, but complimentary to the "excitatory" (labelled maximum interest in Figure 2.5) mechanism which reflects the levels of high activation on the interest map. This is consistent with Houghton and Tipper's dual process model of the consequences of an exogenous cue in the pre-cueing paradigm (see section 2.2).

The interest map which registers regions of maximum interest, modulated by a 'memory trace' that the camera has recently fixated there, is aware of the visual features which are stimulating activity (for more details see Appendix 1.2). In Janßen's model, the feature analysis module, which is the data-driven input to the interest module, does not have the capacity to perform complex processing e.g. form processing. Rather, it simply extracts regions of local distinctiveness (e.g. a region of high luminance or discontinuities at the edges of objects) using a series of Gaussian filters of varying spatial frequency (for more details see Appendix 1.1). The interest map is a purely space-based egocentric representation i.e. coding locations relative to the present position of the camera. Both the role and characteristics of the interest map in the saccadic camera system are similar to the superior colliculus (SC) which is a subcortical region of the brain which has both visual and motor functions (Wurtz & Albano, 1980). SC is topographically organised (Meredith & Stein, 1990) and contains cells that show an increase in firing rate immediately prior to a saccadic eye movement (Goldberg & Wurtz, 1972; Schiller & Koerner, 1971). It receives visual input from the retina via the retinotectal pathway and from several cortical visual areas (Schiller, 1977) and has indirect outputs to the motor areas which produce eye movements (Stein, Goldberg & Clamann, 1976). Thus, the SC and the interest map occupy equivalent functional positions in the human and Janßen's camera saccadic systems. Additionally, the SC is known to represent visual information in a non-retinotopic frame of reference (Mays & Sparks, 1980; Mays & Sparks, 1981; Sparks, 1988) and does not have the ability to code complex form information (Goldberg & Wurtz, 1972). Thus, the interest module in the saccadic camera system and the SC and associated structures in the human visual system (HVS) appear to be fairly homologous.

Converging evidence suggests that IOR is generated via midbrain visuomotor circuitry including the SC. The magnitude of the IOR effect is larger in the temporal compared to the nasal hemifield in normal adults (Rafal, Henik & Smith, 1991) and infants (Simion, Valenza, Umiltà & Dalla Barba, 1995) which is a classic marker of retinotectal pathway involvement in orienting (Rafal et al., 1991). Indeed, the observation of IOR in newborns (Simion et al., 1995) and in the absence of a functioning geniculostriate circuitry in hemianopia (Danziger, Fendrich & Rafal, 1997) suggests that this effect can be mediated by purely subcortical structures. Empirical evidence suggests that IOR relies specifically on an intact SC. Patients suffering from progressive supranuclear palsy (PSP), which affects all of the structures of the midbrain pathway, but in particular the superior colliculus (SC) show disrupted eye movements (Rafal, 1992) and deficits in moving covert attention (Rafal, Posner, Friedman, Inhoff & Bernstein, 1988). Uniquely, these patients show no evidence for IOR, although Parkinson's patients who have insults to adjacent structures show the normal pattern of effects (Posner et al., 1985). However, it should be noted that insults to the SC also cause hypermetabolism of the frontal eye fields (FEFs) which is probably not present in the patients with Parkinson's disease. Thus, it may be more correct to conclude that normal oculomotor functioning, rather than intact SC, are necessary to observe IOR.

There are strong links between the IOR effect and the oculomotor system. For example, IOR affects both the direction (Posner et al., 1985) and latency (Abrams & Dobkin, 1994; Rafal et al., 1989) of saccades. The introduction of a second oculomotor task which requires the programming and execution of small saccadic eye movements (pursuit eye tracking of an unpredictable spot) abolishes the IOR effect, but it is not affected by smooth-pursuit eye-tracking (Maylor, 1985). The observation of IOR in pro- but not anti-saccade tasks excludes the possibility that IOR is simply an alternation bias (Rafal, Egly & Rhodes, 1994). Direct evidence that IOR is related to the saccadic system comes from experiments in which inhibition was activated by an endogenously generated eye movement, in the absence of a peripheral visual signal (Posner et al., 1982; Rafal et al., 1989; Vaughn, 1984). In contrast, covert endogenous orienting of attention in key press tasks, in which participants are instructed not to make eye movements, does not produce IOR (Rafal, Ro, Ingle & Machado, 1998). Rafal et al (1989) argued that saccade preparation was necessary and sufficient to generate



the IOR effect. Tassinari and colleagues proposed that IOR is the product of oculomotor suppression of saccades towards a peripheral cue in the traditional cue-target (C-T) IOR procedure (Berlucchi, Tassinari, Marzi & Di Stefano, 1989; see also Rizzolatti, Riggio, Dascola & Umiltà, 1987; Rizzolatti, Riggio & Sheliga, 1994; Tassinari et al., 1987; Tassinari, Biscaldi, Marzi & Berlucchi, 1989). However, IOR is observed in conditions where participants were required to orient their eyes to a cue and return their gaze to a central fixation point (Abrams & Dobkin, 1994; Rafal et al., 1989) and in procedures in which participants respond to all visual events (target-target T-T procedures; Maylor & Hockey, 1985; Maylor & Hockey, 1987). Maylor and Hockey (1987) directly compared the size of the IOR effect in C-T (ignore cue-target) and T-T procedures and although they did observe IOR in both situations, the IOR effect was larger in the C-T manipulation. This suggests that although there may be some inhibition in the response component, it is not an adequate explanation for the IOR effect observed.

There is ample evidence that suggests that the IOR effect is mediated by midbrain structures and is generated within the oculomotor system. This is consistent with the implementation of the "inhibition of return" mechanism in Janßen's (1996) saccadic camera system. However, there is a major problem with the notion that IOR is purely mediated by the SC and associated structures. Originally, IOR was thought only to be associated with spatial locations in a visual scenes (Maylor, 1985; Maylor & Hockey, 1985; Posner & Cohen, 1984), but there is now evidence for a separate object-based IOR effect (Tipper et al., 1991; Tipper et al., 1994b). Tipper, Driver and Weaver (1991) reasoned that a location-based inhibitory mechanisms would be sufficient to guide visual search in a static visual scene e.g. primates gathering fruit. However, when search is being carried out for mobile objects e.g. a weak gazelle amongst a moving herd of animals, inhibition of a previously attended location is unlikely to be an efficient strategy. Objects that have been previously attended to may move into an uninhibited location, resulting in repeated processing. Alternatively, a previously unattended target object may move into an inhibited spatial location. An IOR effect which is based on an object-based representation, rather than a spatial one, would be more useful and consistent with the observation that attentional effects are commonly observed to be mediated by object-based representations (Chapter 1).

## 2.4 Object-based IOR

Originally, Tipper, Weaver and Driver (1991) presented participants with a typical IOR display (Figure 2.2, Panel A) and cued one of the two peripheral placemarkers (Figure 2.2, Panel B). Prior to the onset of the target, the peripheral placemarkers rotated either 90° or 180° degrees in polar co-ordinates to occupy a new location in the display. Both of these conditions produced results that were consistent with inhibition of a previously attended object that had moved to a new location. They argued that inhibition associated with a cued object was sufficient to explain the empirical IOR effect. Subsequently, Tipper, Weaver, Jerreat and Burak (1994b) re-examined this issue and found evidence for both location- and object-based IOR effects in a single display. Initially they replicated Tipper et al (1991, Experiment 2), manipulating the amount of rotation of objects in the display as a within-subject variable. Essentially they replicated the original findings but found an interaction between the amount of rotation in the moving display (90° and 180°) and cueing. This finding supports the simultaneous existence of two separate object- and location-based inhibitory mechanisms. Additionally, in the static condition of this experiment they found evidence that inhibition is associated with both a static object and the location it occupies, and suggests that the resultant effects in this task are due to these two mechanisms acting additively.

A review of the literature suggests that midbrain structures do not have the ability to encode complex motion of objects or perform any type of feature analysis which would be needed for an object-based attentional system without support from cortical structures (Goldberg & Wurtz, 1972; Gross, 1991; Schiller, 1972). Tipper and Weaver (in press) suggested that object-based IOR in dynamic displays (Tipper et al., 1991; Tipper et al., 1994b) is mediated by cortical structures. In order to examine this issue Tipper, Rafal, Reuter-Lorenz, Starrveldt, Ro, Egly, Danzinger and Weaver (1997) reported a study in which two split-brain patients were presented with two objects in a display, which rotated such that the boxes either remained in the visual field, or crossed the midline. It was predicted that if the object-based IOR effect was mediated by cortical structures, which communicate via the corpus collosum, inhibition should be observed as long as the object remained within the visual field. However, as inhibition in one hemisphere is not available to the other, once the object rotated across the midline, no cueing effect should be observed. The results were consistent with a

cortical involvement in object-based IOR, as the normal effect was observed when the object remained in the same hemifield, but was abolished when it crossed the midline. More surprisingly, the between-field object-based IOR effect was replaced with a facilitatory effect. This suggests that the facilitatory effect is mediated by subcortical structures while the inhibitory mechanism is generated in cortical regions of the brain. Both object-based facilitatory and inhibitory effects are associated with a previously cued object, but the larger inhibitory effect normally masks the smaller excitatory one (see also section 0).

Consistent with notion that the location- and object-based IOR effects are independent effects, empirical evidence suggests that they are mediated by different neural structures. The object-based IOR effect requires cortical processing (Tipper et al., 1997). As an inhibitory effect is observed in the absence of a functional geniculostriate pathway (Danziger et al., 1997) the location-based IOR effect is presumably generated by midbrain structures and requires an intact SC (Posner et al., 1985). The location- and object-based IOR effects also appear to have individual characteristics. Firstly, the object must be visible at the time of cueing in order to observe object-based IOR (Tipper et al., 1994b). There is also some preliminary evidence that the object must also be visible when the target occurs to observe the object-based IOR effect (Lupiáñez, unpublished data). Secondly, manipulating SOA between the peripheral cue and the target in the dynamic IOR procedure suggests that the location-based inhibition is associated with a region over a long period while the object-based effect decays more rapidly (Tipper & Weaver, in press; see Table 2.1). As the location- and object-based IOR effects appear to be mediated by different regions of the brain, which have separate visual inputs, it raises the question of whether the inhibitory influence of these effects occur at the same level in the perceptual-attention-motor system.



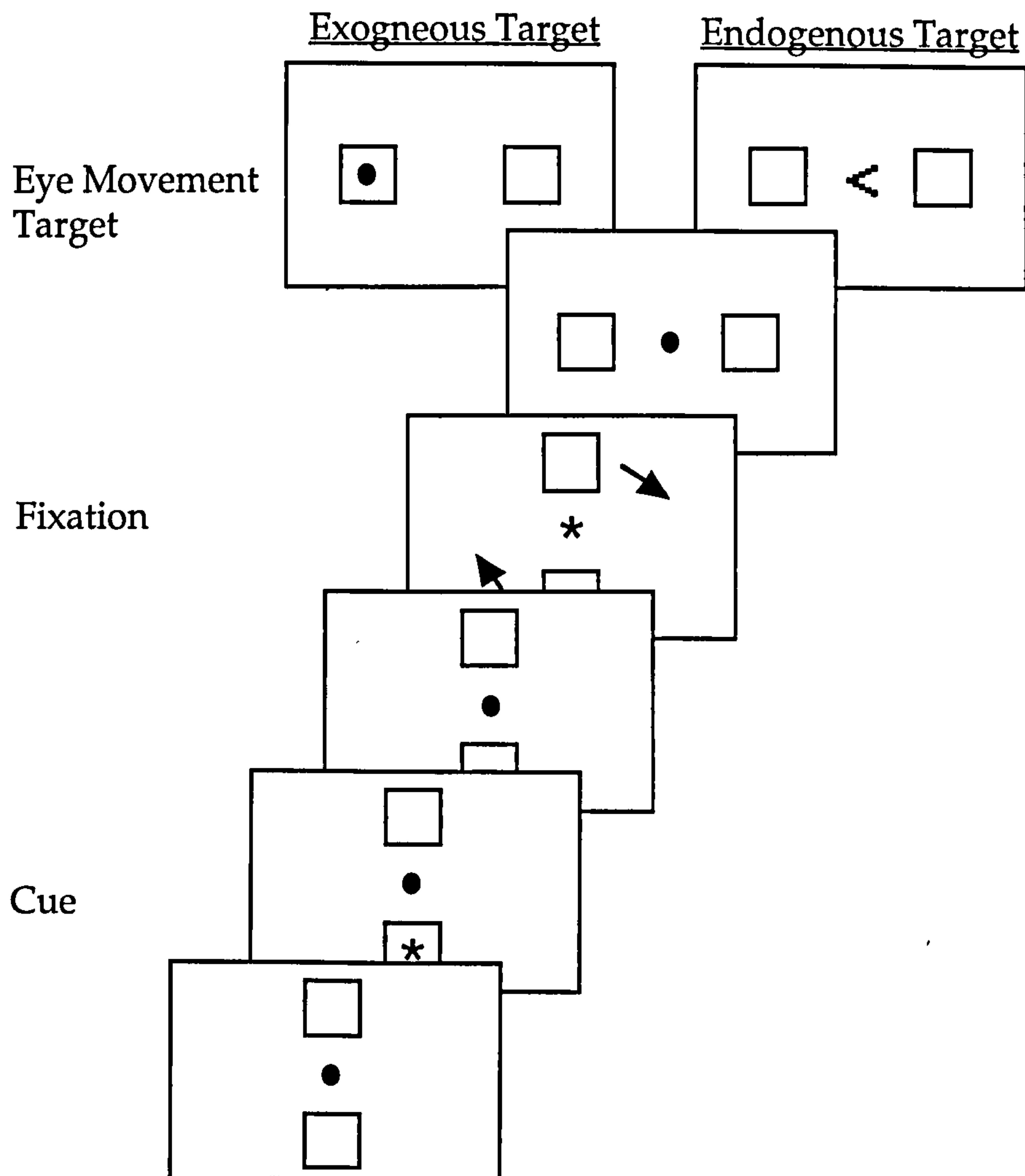
Table 2.1

The effect of manipulating the SOA on the magnitude of the location- and object-based IOR effects (Tipper & Weaver, in press). There was no interaction between location cueing (cued location - uncued) and SOA. In contrast there was a highly significant interaction between object cueing (cued object - uncued RTs) and SOA.

IOR effects	SOA		
	598 ms	1054 ms	3560 ms
Location-based	18 ms	15 ms	24 ms
Object-based	31 ms	15 ms	1 ms

Covert attention resources at a location enhance perceptual sensitivity by increasing the speed of visual processing and/or signal strength at the cued location (e.g. Bashinski & Bacharach, 1980; Downing, 1988; Smith, 1998). Reports of covert orienting affecting the efficiency of processing visual stimuli at or near (e.g. Downing & Pinker, 1985; LaBerge & Brown, 1986) to the cued location are numerous in the literature (e.g. Corbetta, Miezin, Dobmeyer, Shulman & Petersen, 1990; Hawkins, Hillyard, Luck, Mouloua & et al., 1990; Mangun & Hillyard, 1991; Müller, 1987). If the IOR effect is the result of inhibition of returning attentional resources to a region of the visual scene, this implies that there is a reduction in the speed and /or efficiency of perceptual processing at a cued location. Thus, perceptually-based dependent measures which gauge attentional costs and benefits should be sensitive to inhibitory effects on visual processing as well as on motor responses. Reuter-Lorenz, Jha and Rosenquist (1996) noted that the magnitude of attentional costs and benefits are; larger for visual compared to auditory targets; larger for low intensity compared to high intensity targets and equivalent for manual and saccadic responses. If the IOR effect is the product of inhibition generated in the attentional rather than the oculomotor system, the magnitude of the IOR effect should be modulated by target modality, target intensity and response mode. Reuter-Lorenz et al (1996) tested this hypothesis and found that the results for IOR were consistent with attentional orienting effects; IOR effects were greater with visual versus auditory targets, greater with low versus high intensity targets; and, equivalent for manual and saccadic responses.

Unfortunately, Reuter-Lorenz et al (1996) made no attempt to examine the attentional effects in the separate location- and object-based IOR effects. Abrams and Dobkins (1994) examined this specific issue using eye movement latency as the dependent measure. They showed that participants are slower to initiate eye movements to previously attended locations, even though no response to the peripheral cue was required. Even when attention was endogenously directed to a peripheral location by a central arrow, a (smaller) IOR effect was observed. The relative magnitude of the IOR effects in the exogenously and endogenously cued procedures suggested that there was an attentional and movement related inhibitory component for a spatial region that is marked by an outline box. However, when Abrams and Dobkins cued an object which moved into a new location (following Tipper et al., 1991) they failed to find any evidence for the movement-related (oculomotor) component. The initiation of eye movements in response to a central arrow pointing towards previously cued object were not impaired (Figure 2.6, Left Panel). In contrast, the initiation of eye movements was slower when an exogenous target appeared in the cued object (Figure 2.6, Right Panel). An object-based inhibitory effect was found on the attentional (target detection) but not the eye movement component of the task. In contrast, the location-based effect was the result of inhibition of both attentional and oculomotor components.

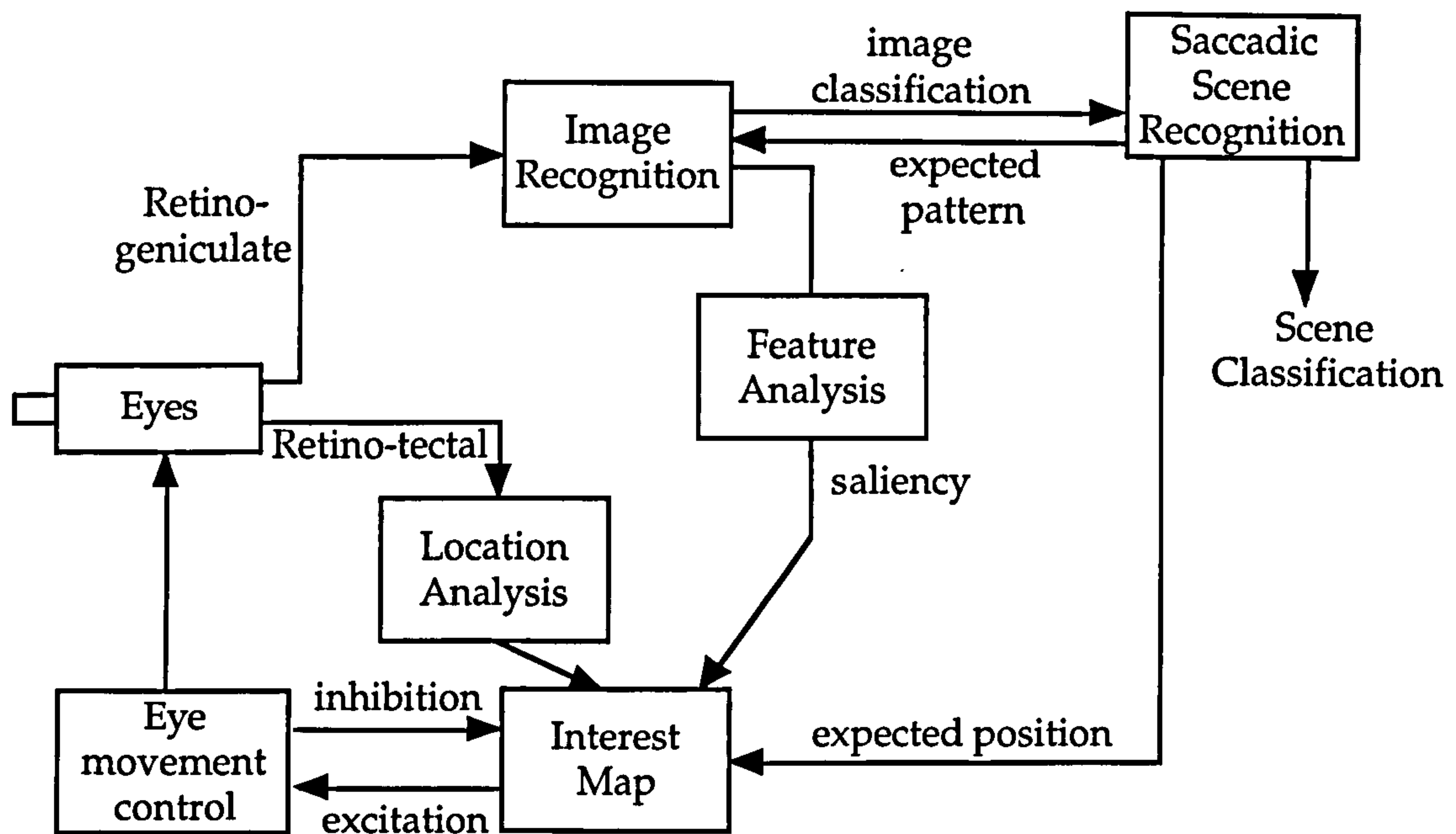


**Figure 2.6** Sequence of events used by Abrams and Dobkins (1994) to examine the effects of object-based IOR on eye movement latencies. The arrows in the fourth box indicate movement of the boxes and were not present in the display. Object-based IOR was observed in the initiation of eye movements with an exogenous, but not an endogenous target.



There is converging empirical evidence that there are separate location- and object-based inhibitory effects. These are generated in different neural centres and have different characteristics. Abrams and Dobkins' (1994) study suggests that while both location- and object-based IOR effects are found in the attentional components of visual tasks, only location-based effects have an oculomotor component. Janßen's (1996) saccadic camera system inhibits spatial regions of the visual scene, but will not produce the equivalent of empirical object-based IOR effects. Several simple changes to Janßen's saccadic camera system would produce behaviour that is more consistent with our knowledge of the implementation of IOR in the HVS. The revised version (Figure 2.7) is intended to be as parsimonious as possible with Janßen's saccadic camera system. A location analysis module is added in parallel to the feature analysis module, which takes the raw peripheral image as the sole input and outputs via a low band pass spatial filter to the interest map. This is sufficient to mediate a location-based effect in response to low frequency luminance changes in the visual field. The location and feature analysis modules output to a single interest map, which controls movements of the camera. This is consistent with the abolition of IOR effects in patients with PSP. As activation levels on the interest map are a function of both location and feature analysis modules, it would be a segmented master map, representing spatially variant object information (see also Logan, 1996).

Phylogenetically, it seems plausible that an inhibitory mechanism in the oculomotor system evolved with the saccadic eye movement system. As Janßen's (1996) model shows, an inhibitory mechanism is necessary to prevent perseverance of saccade targets. Subsequent encephalisation of visual processing allowed for more complex stimulus analysis, and the ability to select certain visual information for priority processing i.e. attentional selection. However, the input and output of cortical processing is determined by the phylogenetically ancient motor systems and therefore the inhibitory mechanism in the oculomotor system remained directly influential in what is available for cortical visual areas to process. The oculomotor inhibitory mechanism plays a direct role in location-based IOR (Abrams & Dobkin, 1994). However, attentional mechanisms in cortical areas also seem to have "borrowed" the inhibitory algorithm, and account for the object-based IOR effect.



**Figure 2.7** Modified schematic model of the role of inhibition in the oculomotor system which incorporates empirical findings about the IOR effect in the human visual system. Parallel location and feature analysis modules register spatial regions of "interest" in the visual scene on the space-based interest map. The location analysis, interest map and camera control modules are probably implemented in the mid-brain structures of the visual system, while the remaining modules are probably cortical.

## 2.5 Evidence for the Confounding of Location- and Object-based IOR effects

Tipper et al (1994b) found indirect evidence that suggests that location- and object-based IOR effects may be confounded when a static object occupies a location in the visual scene. Examining the size of the observed IOR effects in static and dynamic displays does support Tipper et al's (1994) conclusion that the effects are confounded (Table 2.2). Of most interest is Weaver et al's (in press) study in which they compare the effect of practice on the observed IOR effects in static and dynamic displays. In both cases they presented three peripheral boxes around a central fixation box. In the dynamic condition the peripheral boxes moved 120 degrees between the onset of the peripheral cue and the target i.e. the prototypical dynamic procedure (Tipper & Weaver, in press). In the static display condition, the peripheral boxes remained stationary through the trial. Examining the data for the first block of (180) trials indicates that the IOR effect is much smaller in the dynamic condition than in the static condition.

Table 2.2

A comparison of the size of IOR effects (ms) across experimental procedures which would be expected to confound object- and location-based IOR (A and C2) or provide a measure of each effect separately (B and C1).

	Location+Object	Location	Object
<u>A. Posner &amp; Cohen (1984)</u>			
- Locations marked with objects	45 ms		
<u>B. Wright &amp; Richards (1996)</u>			
- Locations unmarked with objects		21 ms	
<u>C. Weaver et al (1998)</u>			
1. Moving Boxes		15 ms	23 ms
2. Static Boxes	57 ms	-	-

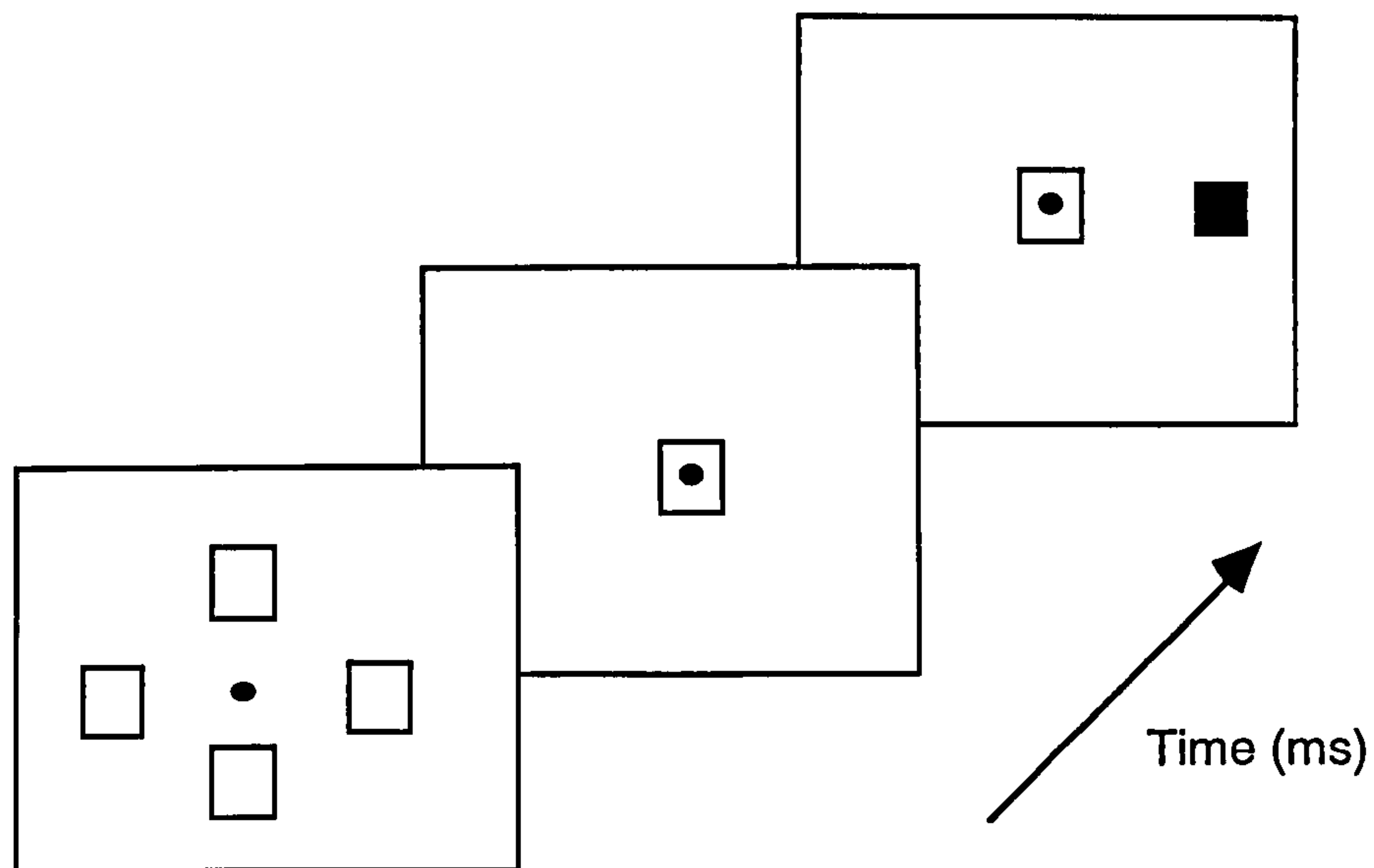
Converging evidence that the presence of outline placemarkers confounds the location- and object-based IOR effects comes from procedures in which the peripheral locations were not marked with objects. There are only two such studies, to my knowledge, which report data from studies in which the cues and target are presented in an empty (unmarked) display. The first study was conducted by Abrams and Dobkins (1994). However, in this case, participants responded with eye movements that produce faster RT's and generally smaller IOR effects than key press responses. The second study was carried out by



Wright and Richard (1996), who were examining the effect of multiple peripheral cues on the magnitude of the IOR effect. Peripheral placemarkers are presented and subsequently removed before the onset of the cue(s) and target. Up to four peripheral cues were simultaneously presented at eight possible positions in a circular array on an unlit computer monitor. This event was followed by the appearance of a fixation cue and subsequently a target (Figure 2.8). The absence of placemaker at the onset of the peripheral cue(s) and target, may be sufficient to eliminate object-based IOR effects. However, the central fixation spot remained visible throughout the trial and thus the cue and target positions may be encoded relative to this object. Multiple simultaneous cues may produce diffuse spatial inhibition of a large region of the visual scene (c.f. Abrams & Pratt, 1996) that would result in a smaller IOR effect than would be expected with inhibition of a limited region. However, in trials with a single cue 21 ms of inhibition is observed (Table 2.2, Panel B). This is approximately the same size as the pure location-based IOR effect observed in dynamic displays. In conclusion, there is indirect evidence that location- and object-based IOR effects are confounded in the traditional static IOR procedure.

### 2.5.1 A case study of confounding location- and object-based IOR effects: Two-choice target discrimination tasks

The possible confounding of location- and object-based inhibitory effects in the static IOR procedure has made it difficult to interpret apparently contradictory empirical findings. One example of this problem has been the interpretation of early failures to observe IOR in choice discrimination tasks. Several studies attempted, and failed, to find evidence of IOR effects in choice target-discrimination RT tasks. Egly, Rafal and Henik (1992) and Terry, Valdes and Neill (1994) used a shape discrimination task. Kingstone and Gazzaniga (1992, reported in Klein & Taylor, 1994) and Tanaka and Shimojo (1996)

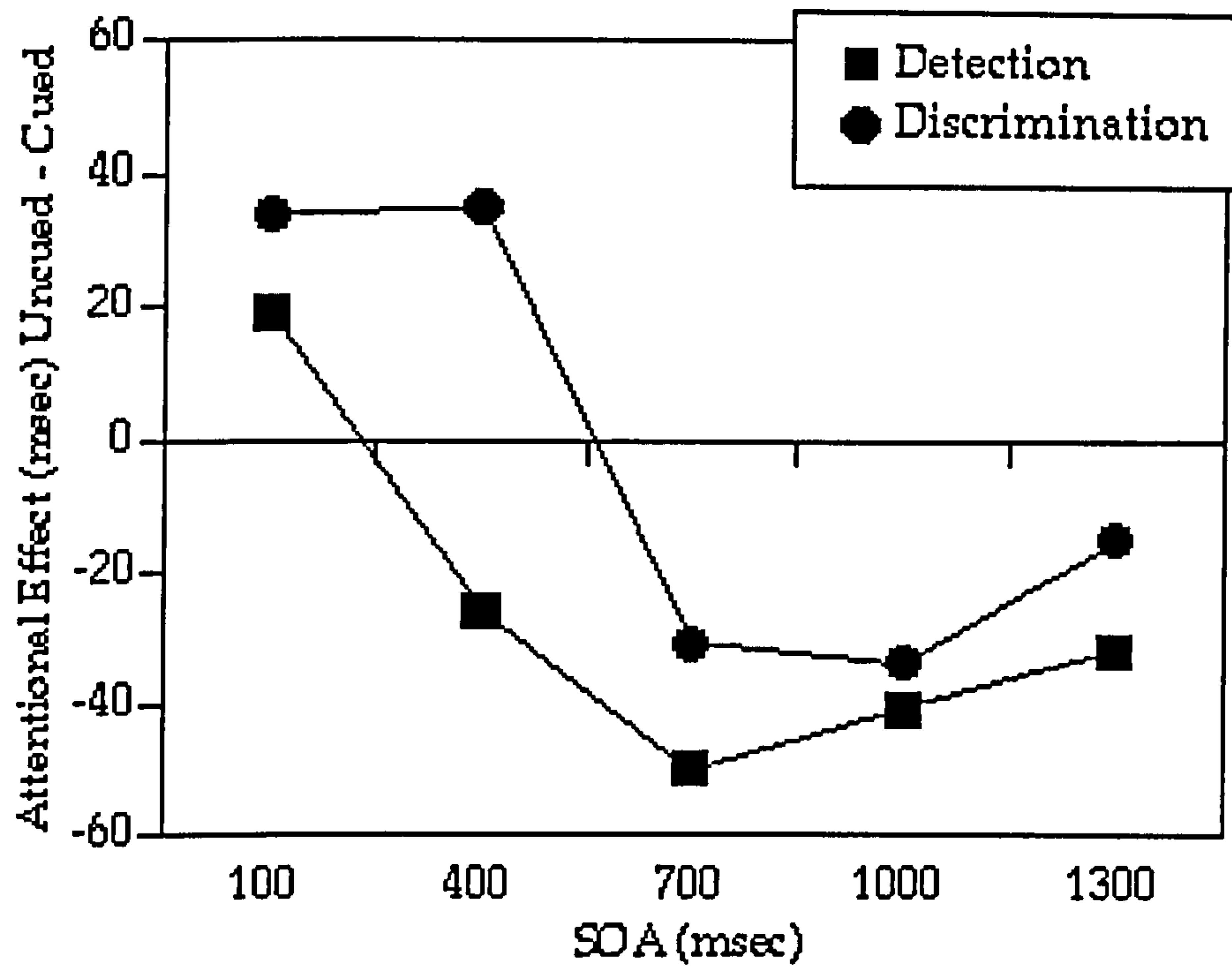


**Figure 2.8** Example of stimulus displays used by Wright & Richards (in press) to demonstrate the effect of multiple simultaneous cues on inhibition of return (from Wright & Richard, 1996, figure 1). In this case four peripheral cues are presented and the target occurs at a cued location.

reported a colour discrimination task. Pontefract and Klein (1988, reported in Klein & Taylor, 1994) and Tanaka and Shimojo used size discrimination and finally Tanaka and Shimojo used orientation, vernier and luminance discrimination. Pratt (1995) did report IOR in a discrimination task in which eye movement latencies were the dependent measure. However, although the participants did have to discriminate between a target and a distractor, eye movements to a target imply a localization response. Therefore, it was unclear whether IOR could be observed in a non-spatial discrimination task where oculomotor components could be excluded. The failure to observe an IOR effect has been used as evidence that the IOR effect is the result of inhibition in oculomotor and not attentional mechanisms (e.g. Klein & Taylor, 1994).

Lupiáñez, Milán, Tornay, Madrid and Tudela (1997) conclusively demonstrated that IOR can be observed in both detection and discrimination tasks, but the necessary experimental conditions differ. Firstly, IOR can be observed in a target-target detection task (Maylor, 1985), but requires a cue-target procedure to observe it in non-spatial discrimination tasks. This has also been observed as a boundary condition for IOR with auditory cues and targets (Spence & Driver, 1998a; Spence & Driver, 1998b). The reason for this distinction is not completely clear, but it may be due to the endogenous maintenance of attention at the cued location (Spence & Driver, 1998b). Failure to orient attention away from the cued region predicts excitatory rather than inhibitory effects (Houghton & Tipper, 1994). Secondly, while IOR is observed in detection tasks with a shorter (400 ms) cue-target SOA, discrimination requires a longer (700 ms) interval (Lupiáñez, Milán, Tornay, Madrid and Tudela, 1997; Figure 2.9). Lupiáñez et al also noted that the IOR effect in the discrimination task began to decay and disappear earlier than in the detection task. They speculated that the differences in the time-course of IOR effects in detection/discrimination tasks reflect the time-course of space- (detection) and object-based (discrimination) IOR effects. It may be that object-based inhibition not only decays sooner (Tipper & Weaver, in press), but also may accrue more slowly.





**Figure 2.9** The time course of cueing effects (facilitation and inhibition) for detection and discrimination tasks in Lupiáñez, Milán, Tornay, Madrid and Tudela (1997).

There are two important points that arise from the misinterpretation of the failure to find IOR effects in two-choice target discrimination tasks. Firstly, the failure to find an IOR effect in a particular experimental situation should not have been interpreted as excluding the possibility of inhibition as an attentional component of perceptual-motor processing. Secondly, it illustrates the possible danger of confounding independent mechanisms, and the difficulty it produces in interpreting the observed effects. The same issue exists for the prototypical static IOR procedure when target detection tasks are used. At present, location- and object-based IOR effects have only been dissociated in dynamic displays in which motion is exploited to unalign object and spatial representations. In contrast, the majority of studies of IOR effects use variations of the static traditional IOR procedure (Figure 2.2) and it is unclear how the results from these tasks should be interpreted.

The first problem is that there is no direct evidence that the location- and object-based IOR effects are confounded in static displays that mark the peripheral cue-target locations with placemarkers. At present, only indirect evidence exists that the location- and object-based IOR effects operate additively in static displays (Tipper et al., 1994b see also section 2.4). It is possible that motion of the previously attended object is necessary in order to observe the object-based inhibitory effect. This possibility has guided the thoughts of some authors (e.g. Müller & von Mühlénen, 1996) who consider that the “object-centered IOR in dynamic displays” to be different from “[inhibitory] cueing effects in static displays” (p. 246). This lead Müller and von Mühlénen to:

“cast doubt on the generality, if not the functional significance, of dynamic, object-centered IOR, which is supposed to move with the previously attended object. It appears that dynamic, object-centered IOR is observed only under some special experimental conditions, and only early during (inexperienced) subjects’ performance on the task.”

(1996, p. 247)

However, the literature reviewed in this chapter suggests that the (separate location- and object-based) IOR effects in the dynamic IOR procedure are the same (confounded location+object-based) effects as those observed in the static display. It is necessary to examine this issue by dissociating the location- and

object-based IOR effects in static displays using a procedure which is as close as possible to the traditional IOR procedure (Figure 2.2).

The second problem is that, although some differences in the characteristics of the location- and object-based IOR effects are known (see section 2.4, Tipper & Weaver, in press), the boundary conditions for each remain unclear. The two IOR effects appear to be independent and mediated by separate neural structures. Elucidating the boundary conditions of each of the mechanisms would (a) confirm whether the location and object-based IOR effects are completely independent and (b) suggest neural structures that may be involved in generating the inhibitory effects. Additionally, it may help to predict which inhibitory effects are present in various IOR procedures and clarify seemingly contradictory empirical observations.

### Aim of Thesis

At present, studies in the IOR literature use one of two approaches – static procedures where a single IOR effect is measured (e.g. Posner & Cohen, 1984) or a dynamic procedure that reports two separate effects (e.g. Tipper et al 1994). The relationship between the effects observed in the two different procedures is unclear. The focus of this thesis is to revisit the traditional static IOR procedure, and attempt to dissociate the possible contributions of the location- and object-based IOR effects which are observed in the dynamic procedure. This would provide direct evidence that the location- and object-based IOR effects are confounded in these procedures, and provide suitable procedures for use in future IOR studies. Additionally, it would clarify which effects are likely to be present in patient studies that use the traditional static procedure. This would make interpretation of the neuronal structures that are associated with specific deficits easier to interpret.



## Chapter 3

### *Location-based IOR in the Presence/Absence of Object-based IOR in Static Displays*

#### 3.1 Summary

Separate object- and location-based IOR effects can be observed in dynamic displays in simple reaction time target detection tasks (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b; Tipper et al., 1994b; Weaver et al., in press). Recent research has noted that the object-based IOR effect in dynamic displays is much smaller than the effect observed in static displays, and hence may be of little functional value (Müller & von Mühlennen, 1996). The experiments in this chapter demonstrate that, on the contrary, the large effects observed in static displays are produced precisely because of the existence of an object-based effect. The magnitude of the observed effects is consistent with the notion that location- and object-based IOR effects can be additive in the traditional static IOR procedure. Additionally, the pure location- and confounded object+location-based IOR effects show a similar decline with practice.

### 3.2 Introduction

Tipper and his colleagues have demonstrated that separate location- and object-based IOR effects can be observed in a single display (Tipper et al., 1994b, see section 2.4). However, the object-based IOR effect observed in dynamic displays tends to be much smaller than those normally observed in traditional IOR paradigms (static: 40-50 ms, dynamic: 15-20 ms). This observation led Tipper et al (1994b) to suggest that the two IOR effects operate additively in traditional static paradigms (Sternberg, 1969). Traditional static IOR procedures mark the peripheral cue/target locations with outline boxes (Figure 2.2). Tipper et al's (1994b) study provides indirect evidence that the presence of these place-marking objects in the visual field is sufficient to trigger object-based inhibitory mechanisms. If this is correct then all studies that use the traditional static IOR procedure potentially confound the location- and object-based IOR effects. In contrast, Müller and von Mühlhausen (1996) assumed that the object-based IOR effect is only present in dynamic IOR procedures. They noted that, compared to the effects observed in the static IOR procedures, the pure object-based IOR is relatively small and they question the utility of this effect in visual processing. Thus, two separate laboratories have cited the same data to support very different conclusions about the importance of the object-based IOR.

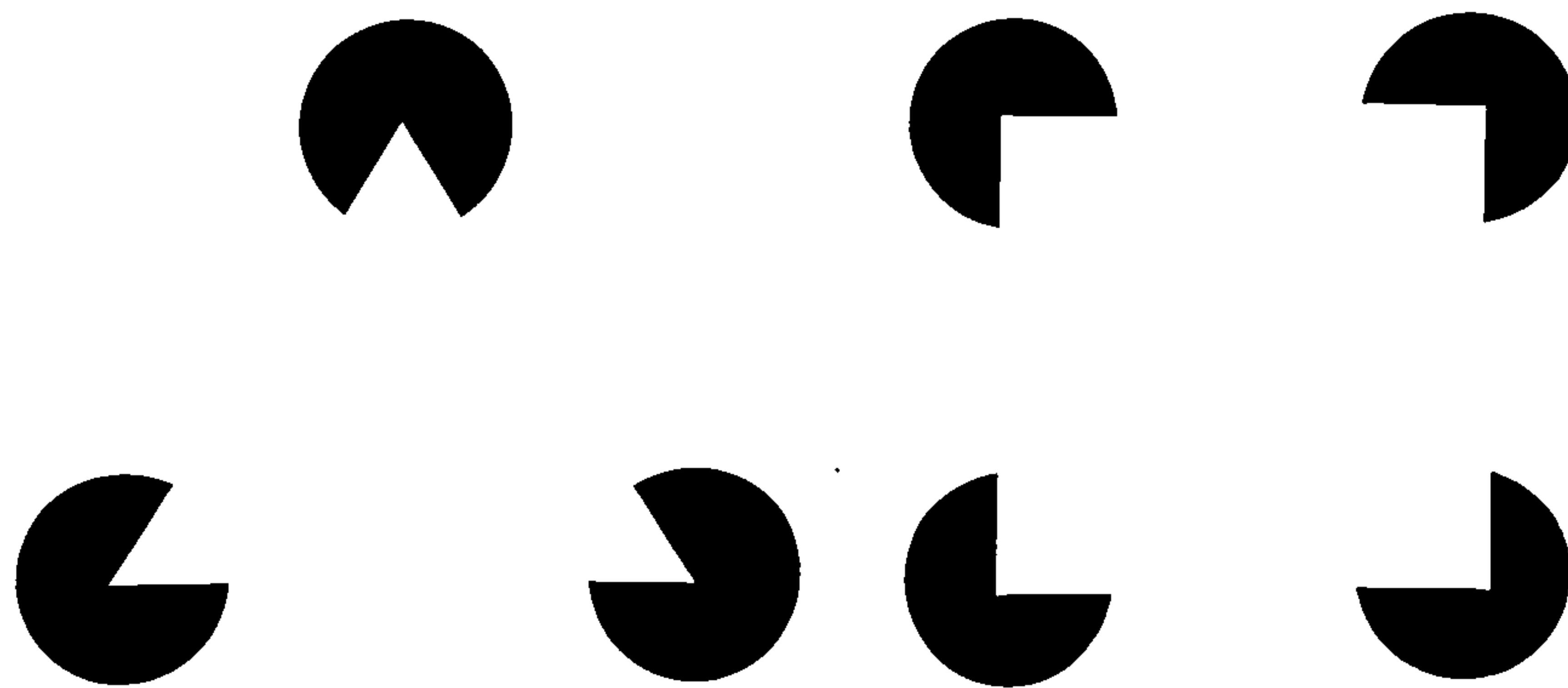
The assumption that separates these two authors is whether object-based IOR effects are present in static IOR procedures when place-markers are present. Is the presence of an object sufficient to observe an associated inhibitory effect, or is the motion of the objects in dynamic IOR procedures (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b; Tipper et al., 1991; Tipper et al., 1994b) necessary to observe this effect? The possibility that object and location effects are confounded in the traditional static IOR procedure has not been considered at all in the IOR literature. However, there are several lines of converging data which do suggest that object- and location-based IOR effects are confounded in the traditional static IOR procedure; static IOR effects are larger than dynamic effects and IOR effects in procedures which use place-markers are larger than those in empty displays (see section 2.5). Thus, in order to ascertain whether location- and object-based IOR effects are confounded in static displays it is simply necessary to examine the magnitude of the IOR effects in displays in which peripheral place-markers are present (object+location) or absent (location). Müller and von

Mühlénen (1996) predict that the IOR effects observed in the presence or absence of place-markers will be similar, while Tipper et al (1994) would predict that more IOR will be observed in the presence compared to the absence of place-markers.

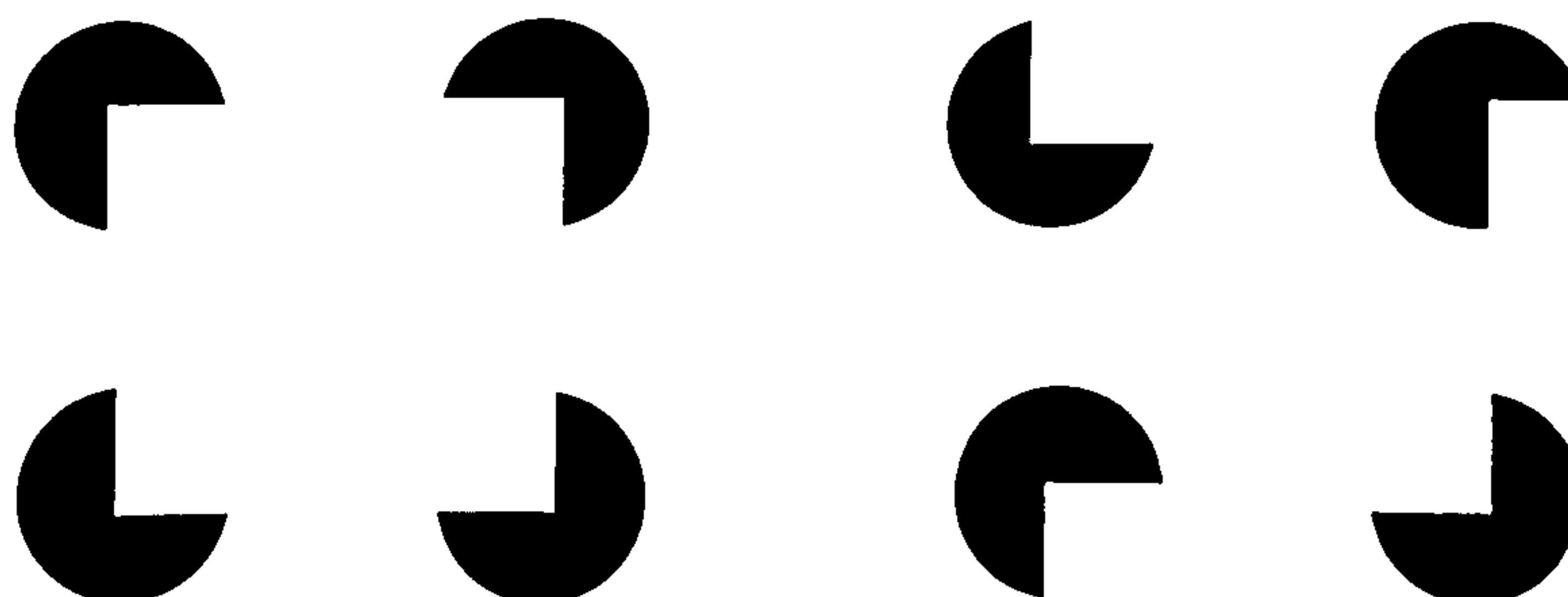
However, there several problems associated with comparing the magnitude of IOR effects between displays containing place-markers (e.g. Posner & Cohen, 1984) and those which are empty (e.g. Wright & Richard, 1996), even within the same task. It is possible that the peripheral place-markers may mask the cue and target in the situation where Tipper and colleagues would predict a confounded object+location-based IOR effect. Less salient peripheral cues produce larger IOR effects (Lambert & Hockey, 1991; Reuter-Lorenz et al., 1996). It is reasonable to suggest that larger IOR effects in regions that are marked by objects may be due to perceptual (e.g. masking) factors, rather than inhibitory mechanisms. A second possible problem is that it may be easier to localise visual stimuli which appears within a placeholder compared to one which appears in featureless space. Participants may narrow their "attentional focus" to the marked region, so detecting the target more efficiently (Tsal, 1983). This would tend to decrease the magnitude of the IOR effect. A related possibility is that it is easier to maintain an accurate "memory trace" for a previously attended region when it is marked by an object. This possibility will be dealt with in Chapter 3.

In order to examine the role of the place-markers in the traditional static IOR procedure, it is necessary to compare the effects between displays in which the minimal physical changes occur. In order to achieve this, the Kanizsa illusion was used to produce the subjective experience of place-marking objects. When "pacmen" inducers are oriented correctly illusion contours and bright regions are perceived to occur, even though no actual luminance or contour discontinuity is present (Figure 3.1). A modally completed (Michotte, 1964) opaque subjective





**Figure 3.1** Two examples of the Kanizsa illusion. The figure on the left shows an example of a Kanizsa triangle which is produced by the alignment of removed portions from three inducing circles. This is the most common example of this illusion. The figure on the right illustrates the use of four inducing circles to create the subjective experience of a box, similar to the placeholders used in the static IOR procedure. Experiments 3.1 to 3.4 exploit this Kanizsa square illusion to examine the additional IOR associated with an object which occupies a location in the visual field.



**Figure 3.2** An illustration of an apparent object (left) and the same misaligned inducers where no object is visible.

**Note:** The experiments reported in this chapter use peripheral cues and targets which occur well within the region of the inducers, even when they are misaligned (right panel), to reduce any problems with metacontrast masking. Additionally, there was a relatively long (1120 ms) time interval between the removal of circle portions, producing the Kanizsa inducers, and the onset of the initial (peripheral) cue. This controls for any metacontrast forwardmasking confound.

surface is perceived as lying in front of the inducing circles, and the apparently obscured inducers subjectively do not appear changed in colour or brightness (e.g. Kanizsa, 1979).

There is some discussion in the literature whether modal completion is the product of high- or low-level visual processing. Some have suggested that the subjective figures are constructed by 'inferential' processes at relatively late stages in processing and require focal attention to the cluster of inducers (e.g. Gregory, 1972). Others have shown that subjective features may reflect activity within low spatial-frequency channels of early vision (Ginsberg, 1975) or low-level brightness contrast mechanisms (e.g. lateral inhibition, Brigner & Gallagher, 1974). Ffytche and Zeki (1996) recently found evidence of V2 involvement in the perception of Kanizsa figures and this is consistent with single-cell recordings of neurones of Rhesus monkeys which indicated selective responsiveness to subjective bars of particular orientations (Peterhans & von der Heydt, 1992; Peterhans, von der Heydt & Baumgartner, 1986). The orientation tuning of each cell for subjective bars corresponded to those found for luminance-defined bars. Thus, there is evidence for both low- and high-level processes in subjective figure perception.

Modally completed Kanizsa subjective figures, are processed in parallel and coded without the involvement of focal attention (Davis & Driver, 1994; Davis & Driver, 1998). Thus, the Kanizsa subjective figure appears to be an appropriate candidate for partially dissociating location- and object-based IOR in static displays. When the inducers are oriented as shown in Figure 3.2 (Left Panel) a subjective object is apparent, occupying a location in the region of the inducers. When the same inducers are misaligned, no object is visible (Figure 3.2, Right Panel). Using the Kanizsa illusion it should be possible to examine the effect of the objects present (object+location) and objects absent (location) conditions in very similar displays. By merely misaligning the Kanizsa inducers, Tipper and colleagues would predict that a larger IOR effect will be observed in the presence of an apparent object compared to the same region of misaligned inducers.

## Experiment 3.1

### 3.3.1 Method

*Participants.* Fourteen undergraduates (3 male) from the School of Psychology, UWB, participated in this study for course credit. The mean age of the subjects was 21.5 years (range: 18 to 35 years). All reported normal or corrected-to-normal acuity. All participants reported seeing the Kanizsa illusion clearly in the debriefing session at the end and were naive as to the purpose of the experiment.

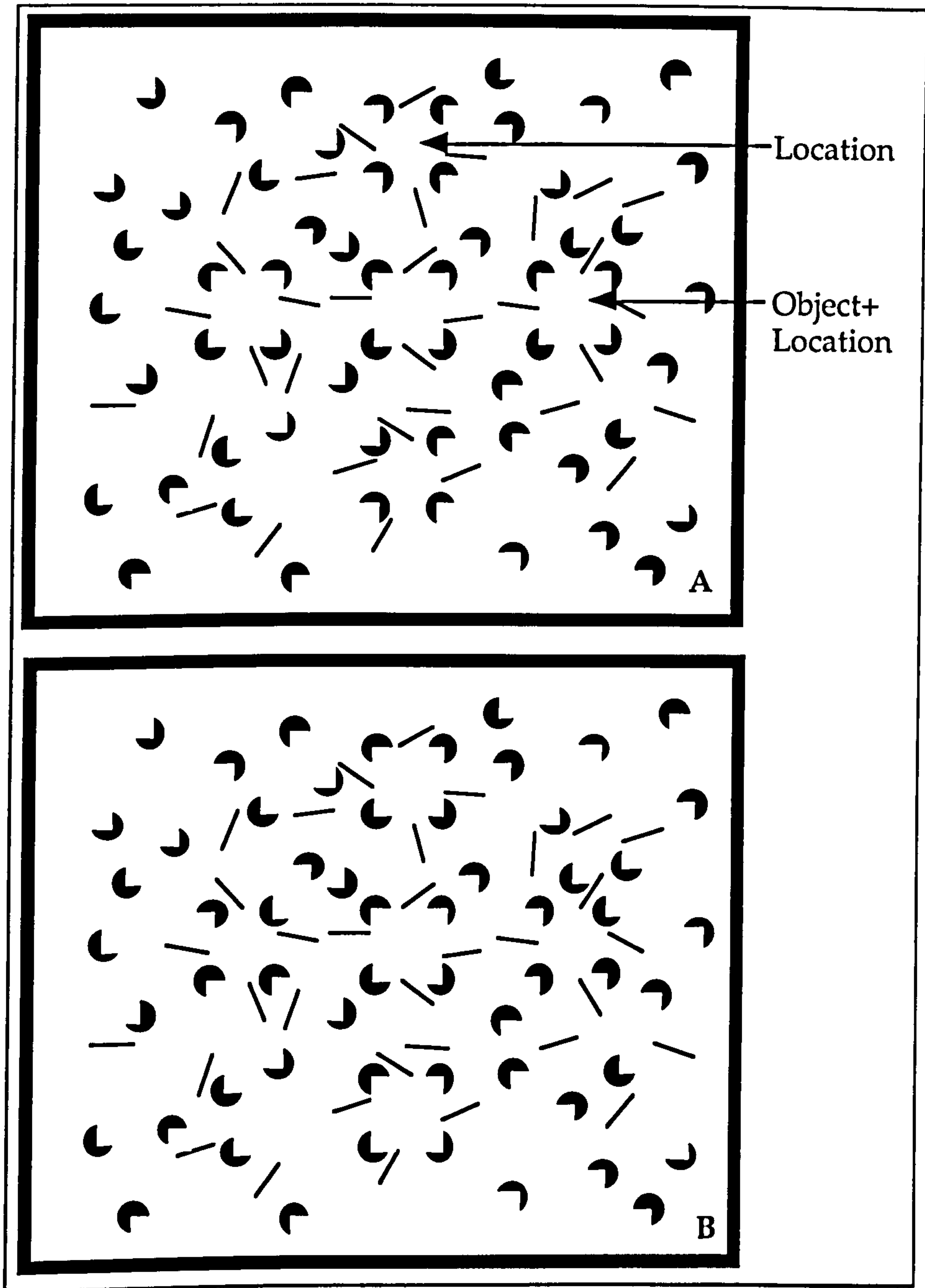
*Apparatus.* The study was conducted in a darkened room. Subjects were seated at a table 70 cm in front of a 14 inch colour monitor with their heads resting on a chin rest. The VDU was adjusted so that they were looking directly at the centre of the screen. The study was carried out on a 486/33 IBM compatible PC and stimulus presentation and response recording were controlled using Micro Experimental Laboratory (MEL) 1.0 (Schneider, 1988) software. Responses were collected using the buttons on an analogue joystick that was interfaced with the computer through the game port.

A black cardboard collar was fitted around the monitor so that an area 19 by 19 cm of the screen was visible. The collar was 9 cm deep, which was sufficient to obscure the plastic surround on the monitor.

*Stimuli.* The stimuli consisted of black 'pacmen' and lines on a grey background (Figure 3.3). The display measured 18 X 18 cm (subtending 14 X 14 degrees visual angle at a viewing distance of 70 cm). The 'pacmen' were made up by drawing filled black circles which were 1 cm in diameter and then overlaying one quarter of each with a grey 0.5 X 0.5 cm square. The black lines were 1.5 cm in length and one pixel in width.

Three apparent (illusory) squares (i.e. Kanizsa squares) which subtended 2° visual angle appeared when the inducer 'pacmen' were appropriately oriented (Figure 3.3). An apparent object always appeared in the centre of the display





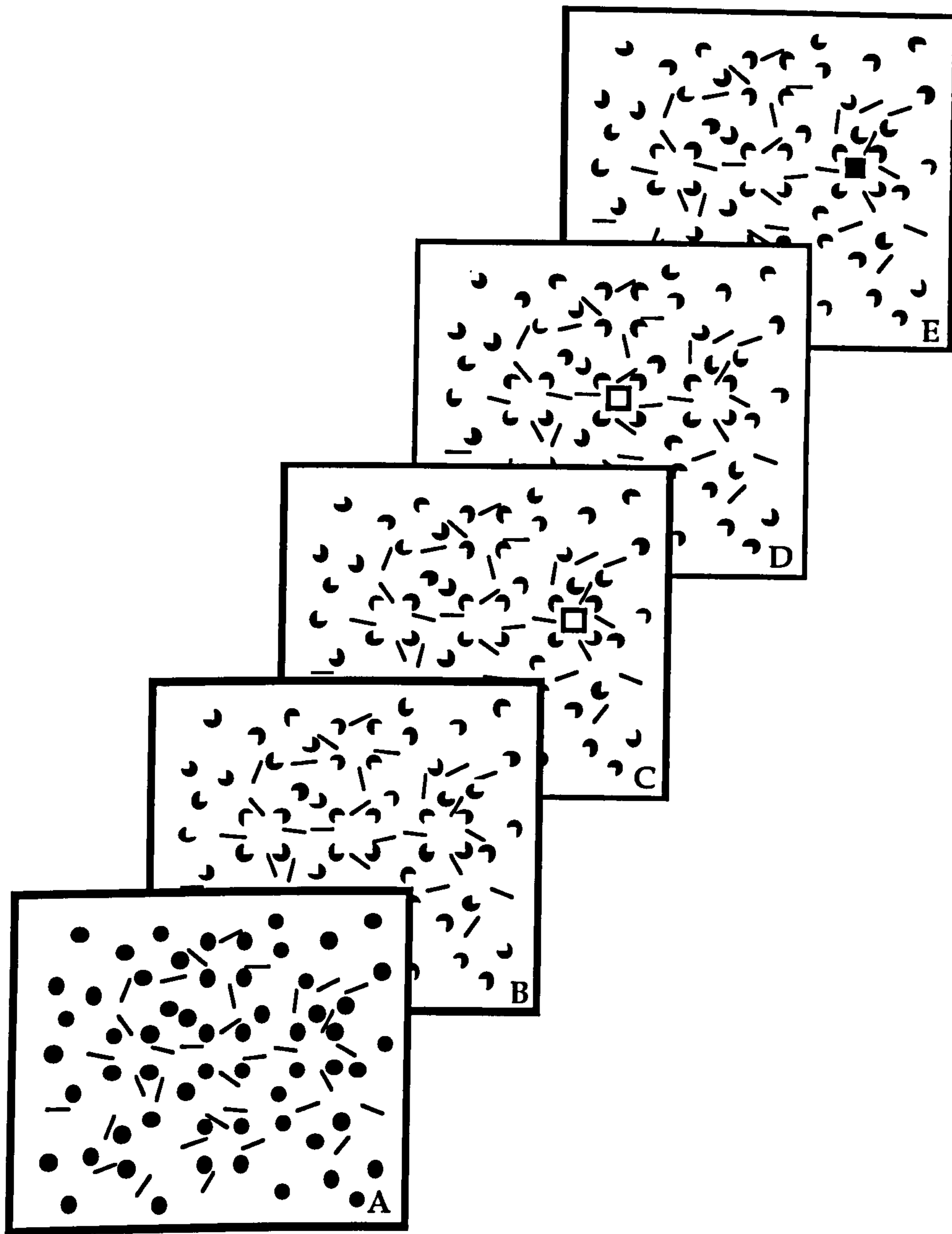
**Figure 3.3** Experimental displays showing apparent objects (Kanizsa squares) on the horizontal (Panel A) and vertical (Panel B) axis. See text for details.

(fixation box). The other squares flanked it on either the horizontal or vertical axis. The centre of the peripheral apparent objects was  $5^\circ$  visual angle into each appropriate visual field. The remainder of the pacmen were oriented to prevent inadvertent apparent object completion (i.e. filler stimuli). The position and orientation of the filler stimuli remained constant across all trials. It was found necessary to present filler stimuli because the four pacmen features, when misaligned to prevent the perception of a Kanizsa square, could still be grouped together through the use of proximity. Such figure-ground grouping may have given the misaligned pacmen the status of features belonging to an object. The presentation of the filler features prevented this proximity grouping, and hence provided a purer measure of location-based cueing.

The target consisted of a  $1 \text{ cm}^2$  filled white box, which occupied the centre of the modally completed box. The cues were differentiated by appearing as white hollow outline boxes subtending  $1.5 \times 1.5 \text{ cm}$  with a line width of 5 pixels.

*Procedure.* The target appeared with equal probability in the peripheral apparent squares (Kanizsa squares) or the empty locations (misaligned inducers), equal distances above, below, left and right of the central square. The target was presented on 80% of the trials and the remaining 20% of trials were catch trials (target absent), requiring no response. Participants were told that luminance changes (white outline squares) prior to the target were distractors and to be ignored. The initial luminance change appeared in one of the four peripheral loci (peripheral cue), and the second in the central location (central cue), before the onset of the target.

The display was described to the participants who were told that “grey squares” would appear shortly after the beginning of the trial. There was no reference made to the “Kanizsa illusion”. They were told that the three squares would appear on either the horizontal or vertical axis and this would vary from trial to trial. The participants were instructed that they were to perform a target detection task, and that the target would appear above, below left or right of the



**Figure 3.4** An illustration of the procedure used in Experiment 3.1 to examine the affect of the presence of apparent objects on IOR effects. This is an example of a cued object+location condition, with the apparent objects on the horizontal axis. The background of each display was light grey, and the cues (Panel C and D) and the target (Panel E) were white. The cues and target were presented for 83 ms. See text for further details.



centre of the display with equal probability. At the end of the practice trials all subjects reported observing the three apparent objects (Kanizsa squares).

The participants initiated each trial by pressing the space bar. At the start of each trial black circles and lines appeared on a light grey background (Figure 3.4, Panel A). After 1120 ms the display was overwritten so that one quarter of each circle was removed, resulting in the appearance of 'pacmen' (Figure 3.4, Panel B). Initial presentation of the filled circles, with subsequent removal of each quarter, should reduce any perceptual masking due to changes in contrast and increased the saliency of the apparent objects (G. Davis, personal communication, April 1996). In half the trials the apparent objects (Kanizsa squares) appeared on the horizontal axis (Figure 3.3, panel A), whereas no object appeared on the vertical meridian due to misaligned inducers. In the remaining 50% of trials the vertical meridian was occupied by the Kanizsa squares, and the horizontal meridian by the misaligned inducers (Figure 3.3, panel B).

After 1120 ms the (peripheral) cue was presented for 83 ms (Figure 3.4, Panel C) and then overwritten, followed after 500 ms by a cue in the central square (central cue) for 83 ms (Figure 3.4, Panel D). After a delay of 520 ms the target appeared equiprobably in one of the four locations for 83 ms (Figure 3.4, Panel E) and overwritten. The SOA from the cue to the target was 1186 ms.

Participants were instructed to report the onset of the target by pressing the target button on the response box as quickly as possible, without making anticipatory errors. The trial was terminated if no response was made within 1000 ms of the onset of the target. Failure to respond within this period resulted in a feedback signal. This consisted of a 500 Hz computer-generated tone for 500 ms. Responding to a catch-trial resulted in the same feedback. Each participant completed twenty practise trials before commencement of the experimental trials. There were three rest breaks during the experimental trials, one after every 120 trials. The participants were debriefed at the conclusion of the experiment, which lasted approximately forty minutes.

*Design.* Two orthogonal factors were manipulated within subjects; Type of Stimuli (with two levels; Object+Location, Location) and Cueing (with two levels; cued, uncued). The peripheral apparent objects appeared on the horizontal and vertical axis with equal probability from trial to trial (Figure 3.3). The target appeared with equal probability in the peripheral apparent squares

(Object+Location) or regions with misaligned inducers (Location). The target could appear in the same (Cued) or mirrored location (Uncued) as the peripheral cue. Thus, Type of Stimuli and Cueing factors were manipulated orthogonally within-subject.

There were 100 trials in the Location condition, 50 of which were cued trials. There were 100 trials in the Object+Location condition, 50 of which were cued. Two hundred filler trials were presented where the cue appeared in a region marked by a Kanizsa square and the target appeared in an unmarked region or vice versa. Although these trials were not analysed, they were included to ensure that cue location did not predict target location. The remaining 20% of trials consisted of catch trials in which no target appeared

Participants completed 15 practise trials before starting the experimental block of trials. These were randomly selected and replaced from the experimental block.

### 3.3.2 Results

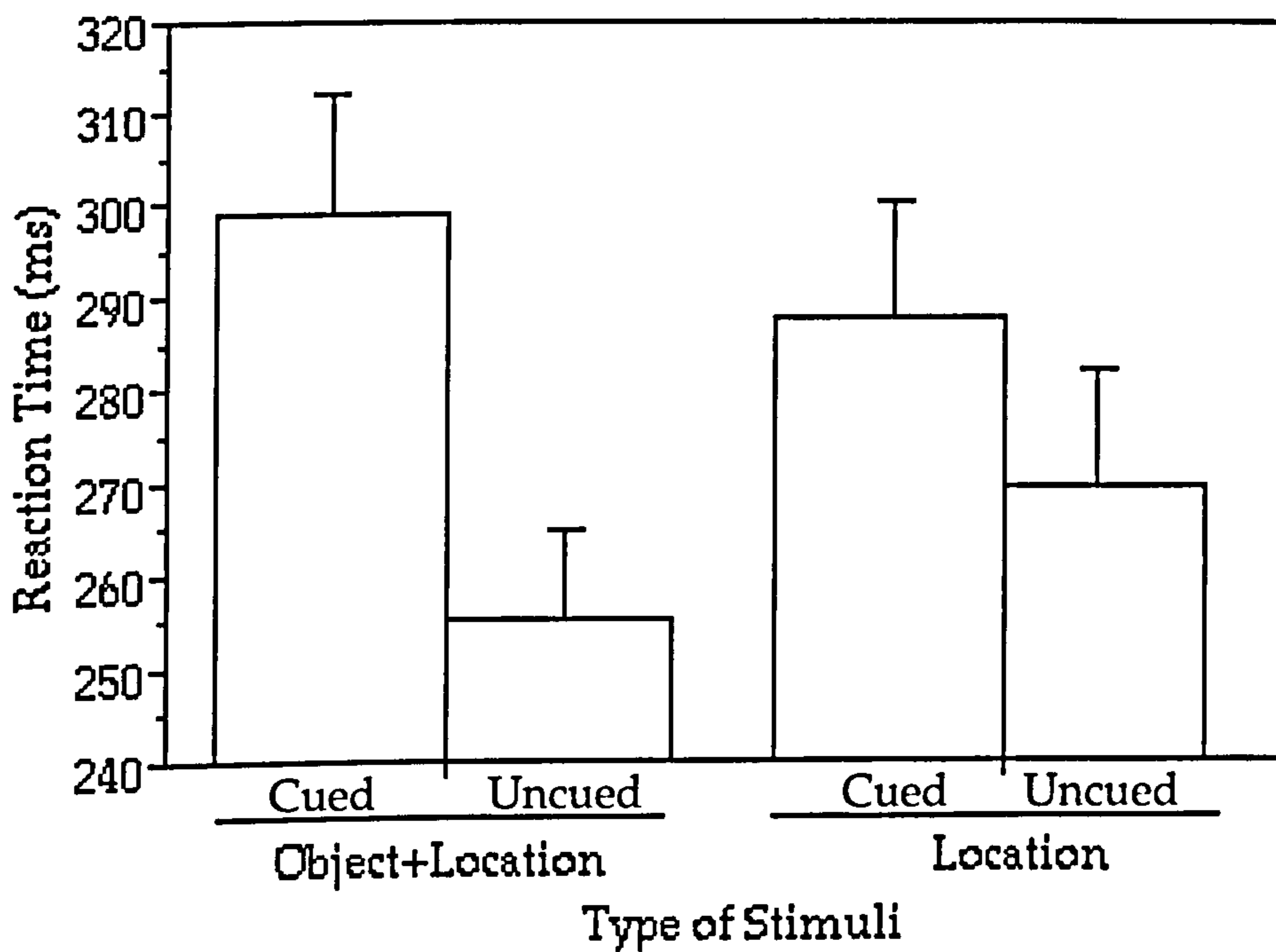
Trials with anticipatory (< 100 ms), very slow (> 1000 ms) or inappropriate responses (i.e. failure to respond in presence of target) were excluded from subsequent analyses.

*Error Rate Data.* The mean error rate for each condition is shown in Table 3.1. A 2 (Cueing) X 2 (Type of Stimuli) repeated measures ANOVA was carried out on the percentage errors for each condition. There was no significant main effects for Type of Stimuli [ $F(1,13) < 1$ ] or Cueing [ $F(1,13) < 1$ ]. Similarly, there was no hint of an interaction between Type of Stimuli and Cueing,  $F(1,13) < 1$ .

**Table 3.1**

Mean error rate (%) and SE for each of the conditions in across all participants.

	Object + Location			Location		
	Cued	Uncued	Catch trials	Cued	Uncued	Catch trials
Mean	2.7	2.4	0.9	2.4	2.1	0.9
SE	0.3	0.5		0.5	0.4	



**Figure 3.5** Mean median RT (ms) and Standard Error bars for each condition in Experiment 3.1.



*Reaction Time Data.* The median RT's for each condition (Figure 3.5), were analysed using a 2 (Type of Stimuli; Object+Location, Location) X 2 (Cueing; Cued, Uncued) repeated measures analysis of variance (ANOVA).

The presence of an apparent object had no effect on the detection of a target,  $F(1,13) < 1$ . There was a significant IOR effect [ $F(1,13) = 34.5$ ,  $MSE = 372.8$ ,  $p < .001$ ] and the interaction between Type of Stimuli and Cueing was reliable in this experiment,  $F(1,13) = 21.2$ ,  $MSE = 99.3$ ,  $p < .001$ . Planned contrast t-tests were carried out to examine this interaction. A larger IOR effect (43 ms;  $t(13) = 11.3$ ,  $p < .001$ ) was observed when an apparent object (Object+Location) occupied the cued region in comparison to when no apparent object (Location) is visible (18 ms;  $t(13) = 4.8$ ,  $p < .001$ ).

### 3.3.3 Discussion

When a target is presented at a spatial location that was previously cued, a significant IOR effect is observed. Simply aligning the inducers to produce an apparent object produces a benefit in the IOR effect observed. This is consistent with the notion that location- and object-based IOR effects can be observed in static displays. When an object is present at a previously attended location, this is sufficient to trigger an object-based IOR effect. Table 3.2 compares the magnitude of the IOR effects observed in this study with those of previous studies. It can be noted that the Object+Location IOR effect is similar to those observed in the traditional IOR procedure (Table 3.2, Panel A). In contrast, the IOR effect observed in the Location condition is similar to those observed in studies which would be expected to measure a pure location-based IOR effect (Table 3.2, Panel B & C1).

Clearly, this experiment indicates a larger IOR effect when the cued region is occupied by an apparent object (Kanizsa square). However, it is possible that the larger Cueing effect is an artefact of perceptual detection of the cue and/or target stimuli within the object, rather than greater inhibition associated with the apparent object. There are three ways in which this could be the case. First,

**Table 3.2**

A comparison of the size of IOR effects (ms) between previous experimental procedures which would be expected to confound object- and location-based IOR (A and C2) or provide a measure of each effect separately (B and C1) and Experiment 3.1

	Object+Location	Location	Object
<u>A. Posner &amp; Cohen (1984)</u> - Locations marked with objects	45 ms		
<u>B. Wright &amp; Richards (1996)</u> - Locations unmarked with objects		21 ms	
<u>C. Weaver et al (1998)</u> 1. Moving Boxes		15 ms	23 ms
2. Static Boxes	57 ms	-	-
Experiment 3.1	43 ms	18 ms	-

Reuter-Lorenz, Jha and Rosenquist (1996) examined the effect of target detectability (via luminance intensity) on the IOR effect. They showed that targets which were harder to detect, with associated longer RTs, produced larger IOR effects. Therefore it is essential to confirm that the larger IOR effect when an object+location is cued is not due to harder target detection compared to the location condition.

Examining the RTs to detect targets in the baseline uncued conditions show that this possible confound cannot explain the data. That is, there is a trend for target detection to be faster when it is presented within an object. Therefore, if anything, the size of IOR in cued objects is underestimated.

The second way in which target detection performance could influence the interpretation of the cueing effects is as follows; Because target detection in the uncued condition of the object present condition is faster than that of the object absent condition, the larger IOR in the presence of an object could be produced by the combination of slower cued trials and faster uncued trials. To confirm that the larger IOR in the object present condition is not caused by the faster uncued trials, a re-analysis was performed which used the data from the uncued object absent condition in both the object present and object absent analysis. The interaction between display type and cueing was still significant



[ $F(1,13) = 10.8, p < .05$ ]. Therefore the greater IOR when an object is cued is not due to faster RTs to uncued targets when appearing within an object.

Finally, it was necessary, of course, to undertake a further control experiment to ensure that cue detection was not facilitated by the presence of an apparent object. That is, if the cue was more salient when presented within an object, this may evoke greater inhibitory feedback (e.g. Houghton & Tipper, 1994). A simple target detection task was carried out, measuring the effect of the Type of Stimuli on the detection of a target. The target was the peripheral cue from the previous experiment.

### 3.4 Experiment 3.2

#### 3.4.1 Method

*Participants.* Fourteen undergraduates from the School of Psychology, UWB, participated in this study for course credit. Their mean age was 19.1 years (range: 18 to 21 years). They all reported normal or corrected to normal acuity and were naive to the purpose of the experiment.

*Apparatus and Stimuli.* The apparatus used in this experiment was identical to that in Experiment 3.1. The stimuli were also identical, but the peripheral cue from Experiment 3.1 became the target in this experiment.

*Procedure.* The participants were presented with the first three displays from Experiment 3.1 (Figure 3.4, Panels A - C) and instructed to detect the onset of the white outline box (previously the peripheral cue) which could appear above, below, left or right of the centre of the display. In half of the trials the target appeared in a region marked by an apparent object. The target was displayed for 83 ms, the same duration as the peripheral cue in the previous experiments, and overwritten in grey. The trial was terminated by the participant's response or after 1,000 ms.

*Design.* In 50% of trials three apparent objects appeared on the horizontal axis as in Experiment 3.1 (Figure 3.3, Top Panel) and in the remaining trials they appeared on the vertical axis (Figure 3.3, Bottom Panel). In 80% of trials the target appeared in one of the four peripheral locations with equal probability.



The remaining trials were catch-trials in which no target appeared and participants were instructed to withhold a response.

All participants completed 20 practice trials and 116 experimental trials.

### 3.4.2 Results and Discussion

Trials with anticipatory (< 100 ms), very slow (> 1000 ms) or inappropriate responses (i.e. misses) were excluded from subsequent analyses. The mean error rates were too low to analyse (Table 3.3).

**Table 3.3**

Mean (percentage) error rate and SE of each of the conditions in Experiment 3.2.

	Object+Location	Object	Catch trials
Mean (%)	0.1	0.0	0.0
Standard Error	0.1	0.0	0.0

*Reaction Time Data.* The mean median RT for targets appearing in regions which were marked with an apparent object was 315 ms (S.D. 42 ms), compared to those where an apparent object was not visible which was 317 ms (S.D. 44 ms). A two-tailed repeated measures t-test was carried out and this indicated that there was no reliable difference between the two conditions,  $t(13) = -0.6, n.s.$ . There was no evidence that the presence of an apparent object had any effect on the detectability of the peripheral cue.

This control experiment, in conjunction with the lack of evidence of (1) a main effect for Type of Stimuli in Experiment 3.1 and (2) an interaction between Type of Stimuli and Cueing when the uncued Location condition was compared with the Cued Object+Location and Cued Location conditions suggest that the larger IOR effect in the Object+Location condition is not an artefact of the use of apparent objects (Kanizsa squares).

The majority of IOR experiments use the traditional static IOR procedure described in section 2.1. Cues and targets occur in marked locations to the left or right of the target (e.g. Posner & Cohen, 1984). In contrast, the peripheral cue and target appeared in four locations, above, below, left or right of the centre of the display in Experiment 3.1. The following experiment adapts the procedure used in Experiment 3.1 to the traditional static IOR procedure. Apparent objects are only presented to the left and right of the central (fixation) square in half of the

trials (Object+Location). In the remaining trials no apparent objects appear (Location). The results from the previous experiment predict that a larger IOR effect will be observed when the peripheral cue and target occur in regions marked by an apparent object compared to the same unmarked regions.

### 3.5 Experiment 3.3

#### 3.5.1 Method

This experiment replicates Experiment 3.1 with the exception of the following changes.

*Participants.* Ten undergraduate students (1 male) from the School of Psychology, UWB volunteered to participate in this study for course credit. Their mean age was 22 years (Range: 18 to 32 years). They reported normal or corrected-to-normal acuity and were naive to the purpose of the experiment.

*Stimuli.* When the participants initiated the trial in response to a message displayed on the screen, filled black circles and lines were presented for 1000 ms. Grey portions (quarters) were overwritten on all of the filled circles in the display to produce pacmen. In 50% of the trials, the Kanizsa inducers aligned producing three apparent objects on the horizontal meridian of the display. In the remaining trials, the inducers were misaligned so that no objects were visible in the display.

*Design.* Each participant completed 20 practise trials and 200 experimental trials during a fifteen minute period. There were 80 trials where the apparent objects were present on the horizontal axis (Object+Location), half of which were cued. There were 80 trials in which no apparent objects were visible, half of which were cued. The remaining 20% of trials were catchtrials where no target appeared. Participants were given a short rest break after completing 100 trials.

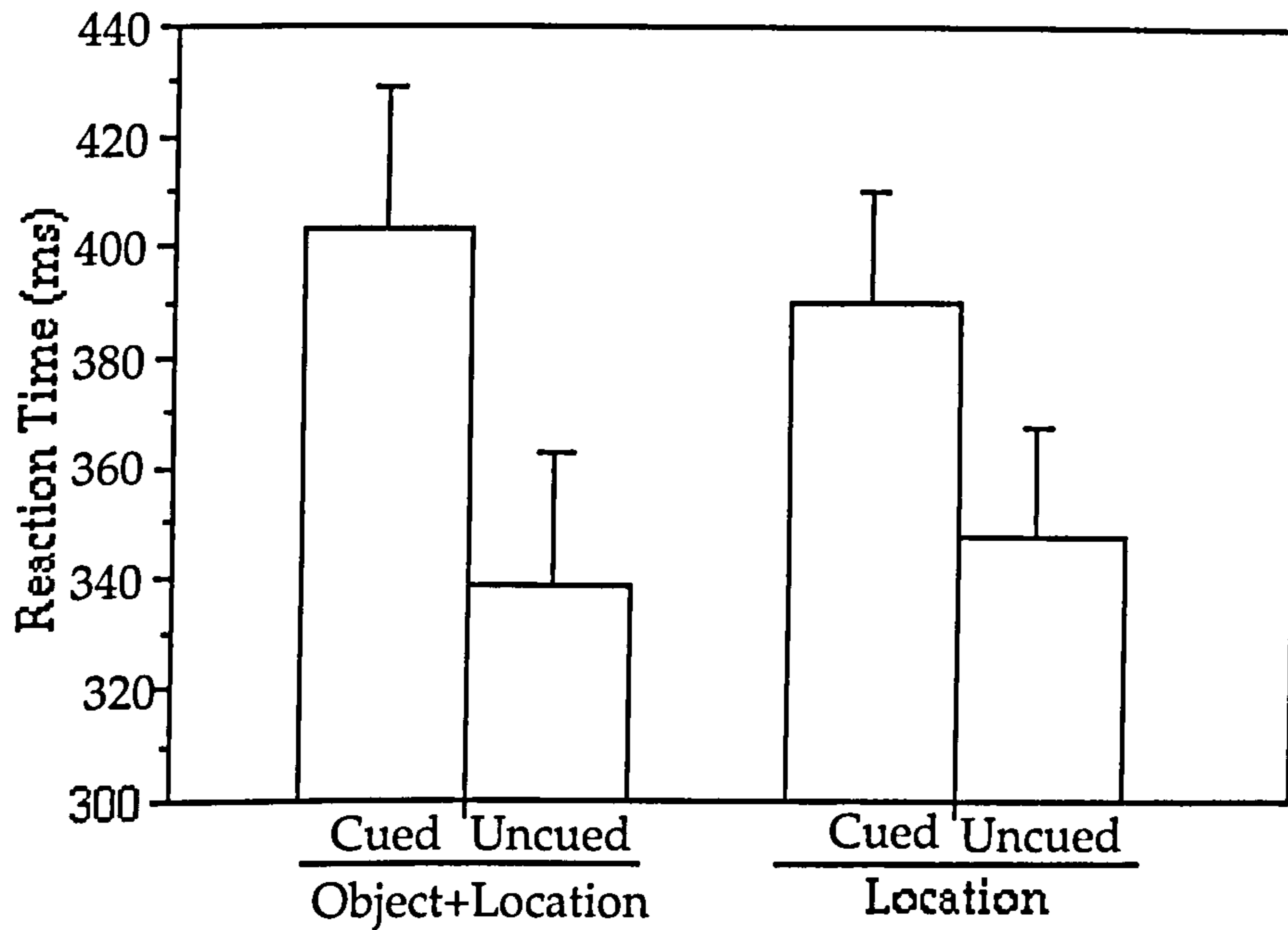
#### 3.5.2 Results and Discussion

Trials with incorrect responses (false alarms or misses), slow (> 1000 ms) or anticipatory (< 100 ms) responses were excluded as error trials. The mean median RT for each condition is shown in Figure 3.6 and the (percentage) error rate for each condition is shown in Table 3.4

**Table 3.4**

Mean error rate (%) and SE of conditions in Experiment 3.3 (N = 10)

	Object+Location			Location		
	Cued	Uncued	Catch Trials	Cued	Uncued	Catch Trials
Mean (%)	0.8	0.4	0.4	0.4	0	0
SE	0.5	0.4	0.4	0.4	0	0



**Figure 3.6** Mean median RT and Standard error bars for each of the conditions in Experiment 3.3.



*Error Rate Data.* A 2 (Type of Stimuli; Object+Location, Location) X 2 (Cueing; Cued, Uncued) repeated measures ANOVA was performed on the mean error rate (%) of correct trials (Table 3.4). There was no main effect for either Type of Stimuli [ $F(1,9) = 2.3$ ,  $MSE = 0.7$ , n.s.] or Cueing [ $F(1,9) = 2.3$ ,  $MSE = 0.7$ , n.s.] and no hint of a significant interaction,  $F(1,9) < 1$ . A repeated measures t-test showed that there was no difference in error rate between the catch-trials in the Type of Stimuli conditions,  $t(9) = 1.0$ , n.s.

*Reaction Time Data.* A 2 (Type of Stimuli; Object+Location, Location) X 2 (Cueing; Cued, Uncued) repeated measures ANOVA was performed on the median RT's of correct trials (Figure 3.6). This indicated that IOR was observed in this experiment [ $F(1,9) = 23.3$ ,  $MSE = 1269.5$ ,  $p < .001$ ] and that RT's were not affected by the presence of an apparent object in the target location,  $F(1,9) < 1$ . Critically, there was a significant interaction between Type of Stimuli and Cueing,  $F(1,9) = 6.3$ ,  $MSE = 194.2$ ,  $p < .05$ . Planned contrasts indicated more IOR in the Object+Location (66 ms;  $t(9) = 10.5$ ,  $p < .001$ ) compared to the Location condition (43 ms,  $t(9) = 7.0$ ,  $p < .001$ ).

Once again, this experiment indicates that there is a larger inhibitory effect when attention is re-oriented to a spatial location that is occupied by an object, compared to an unmarked region. In this experiment, the only difference between the Type of Stimuli conditions were the orientation of the Kanizsa inducers in the peripheral regions of the display. This is the smallest possible difference using this type of display to examine the effect of the presence of objects on the resultant IOR effect. It seems clear that presenting contourless modally completed objects in a display increases the magnitude of the subsequent IOR effect. This is consistent with the notion that both location- and object-based IOR effects can be observed in static displays, and that they are confounded in the traditional static IOR procedure.

It can be noted that the Object+Location and Location-based IOR effects observed in this study are larger than those observed in Experiment 3.1. This may be due to the reduction in the number of experimental trials from 442 to 200 trials. Although this type of IOR procedure is relatively robust to practice effects (see Chapter 6), most of these effects occur early in an experiment (Weaver et al., in press). Reducing the number of experimental trials will reveal the early (and larger) IOR effects. Additionally, the number of possible target locations has been

reduced from 4 to 2. These differences appear to increase the size of both the pure Location- and Object+Location-based IOR effect. This is consistent with the notion that the Object+Location-based IOR effect is the additive effect of separate object and location components.

The following experiment confirms that the IOR effects observed in Experiments 3.1 and 3.3 are robust and replicable and investigates the effect of practice on the location-based IOR effect in comparison to the location- and object-based mechanisms operating additively. Müller and von Mühlenen (1996) claimed that IOR in static displays is robust over “many thousands of trials” in comparison to the observation of a decline in pure location and object-based IOR effects in dynamic displays. A survey of the literature fails to find strong support for Müller and von Mühlenen’s claim that confounded object+location-based IOR effects are robust. Most IOR experiments in the literature use a moderate number of trials e.g. Pratt, Kingstone and Khoe (1997 Experiment 1) used 240 trials, Pratt (1995) used 280 trials, Tipper et al. [1994b, Experiment 1) used 384 trials, and Maylor and Hockey (1985) used 480 trials. In addition, the effects of practice on the IOR effect observed in static displays is known to be modulated both by the saliency of the peripheral cue (Lambert & Hockey, 1991) and the temporal certainty between the peripheral cue and subsequent target (Lupiáñez, Weaver, Tipper & Madrid, under review).

It is possible that the additive effects of the location- and object-based IOR effects are more robust under practice conditions than the pure location-based effect in the apparent object absent condition. When Weaver et al (in press) explicitly examined the effect of practice on the location- and object-based IOR effects in dynamic displays and the object+location-based effect in static displays, they reported that all of the effects declined at similar rates. Their procedure did not allow them to explore whether the confounded object+location-based IOR effect is more robust than an unconfounded effect in a single display. The procedure developed in this chapter does provide a means of exploring this specific question. The following experiment (Experiment 3.4) replicates Experiment 3.1 over 1860 trials observation to examine the decline with practice of the location- and object+location-based IOR effects. Based on Weaver et al’s (in press) observations, it is predicted that the decline in the IOR effects should be equivalent in the object+location and location conditions.



## 3.6 Experiment 3.4

### 3.6.1 Method

3.6 Experiment 3.4 used the same procedure as Experiment 3.1, but the same program was run four times (twice each day for two consecutive days). Therefore only a description of details which differ are given here.

*Participants.* Twelve participants from the community subject pool of the School of Psychology UWB volunteered to take part in the study for a payment of £3 per hour. Their mean age was 21 years (range: 18 to 33 years). All participants reported normal or corrected-to-normal acuity and were naive to the purpose of the experiment.

*Apparatus.* The study was carried out in two separate darkened experimental rooms where participants were seated 70 cm from the display with their heads resting on a chin rest. The computer monitor was adjusted so that they were looking at the centre of the screen. Two 486/66 IBM-compatible PC's were used and responses were collected using the 'H' key (target key) and spacebar (trial initiation) on the computer keyboard. Half of the participants performed the task on each computer. They were assigned the same computer on both days. Subsequent analysis of the data revealed no differences in the data between the two computers used.

*Procedure.* Participants were required to complete Experiment 3.1 four times in total in two experimental sessions that were twenty four hours apart. They were given a ten minute break between the two experiments on both days. Participants were debriefed on completion of the second session.

*Design.* Three orthogonal variables were manipulated in a repeated measures design: Practice, Cueing, and Type of Stimuli.



The first factor, Practice had four levels (one, two, three and four) referring to each repetition of the experiment. Each block consisted of 480 trials. Participants completed the first two blocks in one session and returned 24 hours later to complete the remaining two blocks.

The second factor, Cueing (with two levels: cued, uncued) relates to the relationship between the cue and target. In the cued trials the cue and target appeared in the same region of the display. In the Uncued trials the cue and target occurred in opposite regions, but on the same axis, of the display. The third factor was Type of Stimuli (with two levels: Object+Location, Location).

There were 100 trials in the apparent object absent (location IOR) condition, 50 of which were cued trials. There were 100 trials in the apparent object present (object- and location-IOR) conditions, 50 of which were cued. Two hundred filler trials were presented where the cue appeared in a region marked with a Kanizsa box and the target appeared in an unmarked region or vice versa. Although these trials were not analysed, they were included to ensure that cue location did not predict target location. The remaining 20% of trials consisted of catch trials where no target appeared.

### 3.6.2 Results and Discussion

The mean median RT and error rate for each condition is shown in Table 3.5. Trials with an incorrect response or a response time less than 100 ms or longer than 1000 ms were excluded as error trials.

*Error Rate Data.* A 4 (Practice) X 2 (Type of Stimuli) X 2 (Cueing) repeated measures ANOVA was carried out on the percentage errors for each condition. There was no significant main effect or interaction for Cueing,  $F(1,11) < 1$ , Type of Stimuli,  $F(1,11) = 1.8$ ,  $MSE = 3.8$ ,  $p = .21$  or Block,  $F(3,33) < 1$ .

Similarly a 4 (Practice) X 2 (Type of Stimuli) mixed design ANOVA indicated that there was no difference in the number of anticipatory errors made in the catch-trials between each Block,  $F(1,11) < 1$ .

**Table 3.5.**

The mean median RTs for correct trials, mean (percentage) error rate (left panel) and the magnitude of the IOR effect (right panel) observed in each condition for each session in Experiment 3.4.

	Mean median RTs (ms) and Error Rate (%)				Size of IOR effect	
	Cued Object+ Location	Uncued Object+ Location	Cued Location	Uncued Location	Object+ Location- based IOR	Location- based IOR
Block 1	314.1 (1.4)	280.3 (1.0)	310.4 (0.4)	285.6 (1.0)	33.8	24.8
Block 2	286.7 (1.4)	257.9 (1.0)	279.2 (1.4)	266.4 (0.7)	27.8	12.8
Block 3	276.3 (1.7)	248.0 (1.0)	273.0 (0.4)	253.4 (0.7)	28.3	19.6
Block 4	266.2 (1.7)	242.9 (1.4)	260.6 (1.0)	246.5 (1.4)	23.3	14.1

*Reaction Time Data.* A 2 (Cueing) X 2 (Type of Stimuli) X 4 (Block) repeated measures ANOVA was carried out on the median RT for correct trials of each of the four conditions, for each subject, in each session.

There was a main effect for Block which indicates that RTs decreased with practice,  $F(3,11) = 14.8$ ,  $MSE = 1152.9$ ,  $p < .001$ . This is consistent with previously reported effects in studies that use RT as the dependent measure (Mowbray & Rhoades, 1959). There was a main effect for Cueing indicating slower RTs for cued targets compared to uncued ones regions,  $F(1,11) = 56.1$ ,  $MSE = 454.8$ ,  $p < .0001$ . This is consistent with the IOR effect. There was no main effect for Type of Stimuli indicating that target detection was not affected by the presence of an apparent object,  $F(1,11) < 1$ .

The Type of Stimuli by Cueing interaction was significant,  $F(1,11) = 8.4$ ,  $MSE = 157.0$ ,  $p < .01$ . Overall, there was a larger IOR effect for locations which are occupied by apparent objects (28 ms,  $t(11) = 11.1$ ,  $p < .0001$ ) compared to those which are unoccupied (18 ms;  $t(11) = 7.0$ ,  $p < .0001$ ). These data are consistent with those observed in Experiments 3.1 and 3.3. There was a marginal interaction for Cueing by Practice which indicates that the inhibition effect



decreases across the sessions,  $F(3,33) = 2.8$ ,  $MSE = 95.3$ ,  $p = .056$ . This replicates Weaver et al (in press).

The results of this study are reasonably clear. Firstly, the contrast in the magnitude of the IOR effects when an object is cued compared to when a location is cued, has been replicated. The IOR effect is consistently larger when the target occurs in a previously attended location, which is occupied by an apparent object compared to an empty region. This pattern of data occurred in every block. This replicates Experiment 3.1 and 3.3 and lends further support to the notion that in static displays IOR is the product of additive location- and object-based frames of reference. Secondly, the marginal interaction between Cueing and Practice indicates that there is a trend for IOR to decline with practice. This replicates reports that the IOR effect decreases with practice (Lambert & Hockey, 1991; Lupiáñez et al., under review; Weaver et al., in press). Thirdly, the decline in IOR seems to be equivalent, whether or not an apparent object is present at the cued location, as there is no hint of a three-way interaction across the entire experiment of 1,856 trials,  $F(3,33) < 1$ . The Object+Location-based IOR effect declined from 34 to 23 ms. Cueing an empty location shows a comparable reduction in the IOR effect with practice from 25 ms to 14 ms. The pure location- and confounded object+location-based IOR effects decline in the same way over the large number of trials in this study.

### 3.7 General Discussion

The findings in this chapter are consistent with reports that separate location- and object-based IOR effects are observed in dynamic procedures (Tipper et al., 1991; Tipper et al., 1994b). It has been noted that the separate object- and location-based IOR effects in dynamic displays are smaller than those observed in static procedures. The prediction that the static IOR effect is the product of both location- and object-based IOR mechanisms is clearly confirmed. Although the physical properties of the object+location and location conditions were essentially the same, more IOR was associated with a region occupied by an apparent object than to a location alone (Table 3.6, shaded region). In each of the critical experiments (3.1, 3.3 and 3.4) there was a significant interaction between Type of Stimulus and Cueing. This increase in magnitude of the IOR effect in the object+location compared to the location condition has proved to be robust and the effect has been replicated consistently across all three experiments.



A substantial literature exists which reports object- as well as spatial effects on visual attention (e.g., Baylis & Driver, 1992; Duncan, 1984; Kahneman & Gibbs, 1984; Kramer & Jacobson, 1991; see chapter 1). The present results, combined with other studies (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b; Tipper et al., 1991; Tipper & Weaver, in press; Tipper et al., 1994b; Weaver et al., in press) confirm that object-based IOR can be observed in a variety of circumstances. More importantly, both location- and object-based effects were observed in the same display, providing evidence that attention can gain access to multiple forms of representation. This supports evidence, reviewed in Chapter 1, that visual neglect can be mediated by both location- and object-based frames of reference (e.g. Behrmann & Tipper, 1994; Caramazza & Hillis, 1990; Driver & Halligan, 1991; Tipper & Behrmann, 1996) and these effects can appear in both frames at once in certain circumstances (Humphreys & Riddoch, 1994; Humphreys & Riddoch, 1995; Riddoch & Humphreys, 1994; Tipper & Behrmann, 1996). Thus, these experiments add to the powerful converging evidence that attention can access multiple forms of representation in both clinical and normal populations.

Previous authors (Müller & von Mühlelen, 1996) have noted that the pure object-based IOR effect in dynamic displays is small and suggest that it is of little functional utility. The contribution of the object-based effect to the IOR observed in the object+location condition can be estimated by subtraction (i.e. object+location - location; see Table 3.6). This suggests that the object-based IOR effect is slightly smaller than the location-based effect observed in the location (apparent object absent) condition. However, in light of the fact that other authors have failed to find object-based attentional effects in RT detection tasks which used unpredictable exogenous cues (e.g. Vecera & Farah, 1994), it is almost surprising to observe any object-based contribution in these experiments. The presence of apparent objects is completely irrelevant to the behavioural goal of detecting a luminance increment. Even when the task was carried out over a very large number of trials, there is no evidence that the object component of the Object+Location-based IOR effect declined more than the location contribution. Therefore, far from being of no functional significance, the object-based IOR



**Table 3.6**

A comparison between the size of IOR effects observed in Chapter 3 (shaded region) and those previously reported in the literature (Table 2.2).

Note: The object-based IOR effect was not observed directly in the experiments reported in this chapter. The size of the object-based IOR component is calculated by subtraction of the observed location-based effect from the observed object+location IOR effects. This is based on the assumption that separate location- and object-based IOR effects work additively (Sternberg, 1969) in static displays.

	Object+Location	Location	Object
<u>Posner &amp; Cohen (1984)</u>			
• Two locations marked with objects	45 ms		
<u>Wright &amp; Richards (1996)</u>			
• Four Locations unmarked with objects		21 ms	
<u>Weaver et al (1998)</u>			
• Three Moving Boxes		15 ms	23 ms
• Three Static Boxes	57 ms	-	-
<u>Experiment 3.1</u>			
• Four Locations marked with objects (Object+Location)	41 ms	-	
• Four Unmarked Locations	-	22 ms	19 ms (41- 22)
<u>Experiment 3.2</u>			
• Two Locations marked with objects (Object+Location)	66 ms	-	
• Two Unmarked Locations	-	43 ms	23 ms (66 - 43)
<u>Experiment 3.4</u> (across 1860 trials)			
• Four Locations marked with objects (Object+Location)	28 ms		
• Four Unmarked Locations		18 ms	10 ms (28 - 18)



effect appears to be obligatory when attention is oriented away from a region in which an object is present in this task. This suggests that the traditional static IOR procedure (Figure 2.2) which marks peripheral cue and target regions confounds the object- and location-based IOR effects.

The experiments in this chapter provide a partial dissociation of the object and location-based IOR effects in a static display. The following chapter attempts to complete this dissociation by observing the IOR effect in regions that share object identity but not location identity.



## Chapter 4

### *Object-based IOR in the Presence/Absence of Location-based IOR*

#### 4.1 Summary

The experiment in this chapter demonstrated that it is possible to observe object-based IOR in the presence/absence of location-based IOR using a variation of the procedure developed by Egly, Driver and Rafal (1994). Having attended to one end of an object, inhibition was observed to spread to a novel locus within the same object. However, this spread of inhibition declined with exposure to the task, being generally non-significant in the second half of the study. This effect of practice was modulated by the saliency of the object. It is suggested that the impact of object-based representations on attentional processes, are modulated by the participants behavioural goal.

## 4.2 Introduction

In the previous chapter, location-based IOR effects were observed in the absence of inhibition that was associated with an object. More inhibition was associated with a region that was marked by an object compared to an empty location. This is consistent with a confounded Object+Location-based IOR effect when place-markers are present, and a pure location-based effect when the objects were removed. The aim of this chapter is to attempt to complete the dissociation of location- and object-based IOR effects in static displays (Table 4.1).

**Table 4.1**

Summary of the previous and present work in dissociating object- and location-based IOR effects.

	Object+ Location IOR	Object-based IOR	Location-based IOR
Dynamic IOR procedure (e.g. Tipper et al, 1994)		✓	✓
Chapter 3	✓		✓
Chapter 4	?	?	

In Chapter 1, several studies which used motion to dissociate location- and object-based attentional effects were described (e.g. Behrmann & Moscovitch, 1994; Tipper & Behrmann, 1996). By rotating either the stimulus or the viewer it is possible to unalign these forms of reference. The use of motion is a useful and common strategy to observe the separate effects of location and object-based representations in mediating attentional effects. Pure object-based IOR has been observed in dynamic displays in which a previously attended object moved into a new location prior to the onset of the target (Tipper et al., 1991; Tipper et al., 1994b; Weaver et al., in press, for review see section 2.4). However, Müller and von Mühlenen (1996) questioned the generality of the object-based IOR effect in the dynamic procedure and suggested that this effect is only observed for dynamic objects. Observing inhibition in a region that shares object but not location identity with the peripheral cue would confirm the generality of the object-based IOR effect.

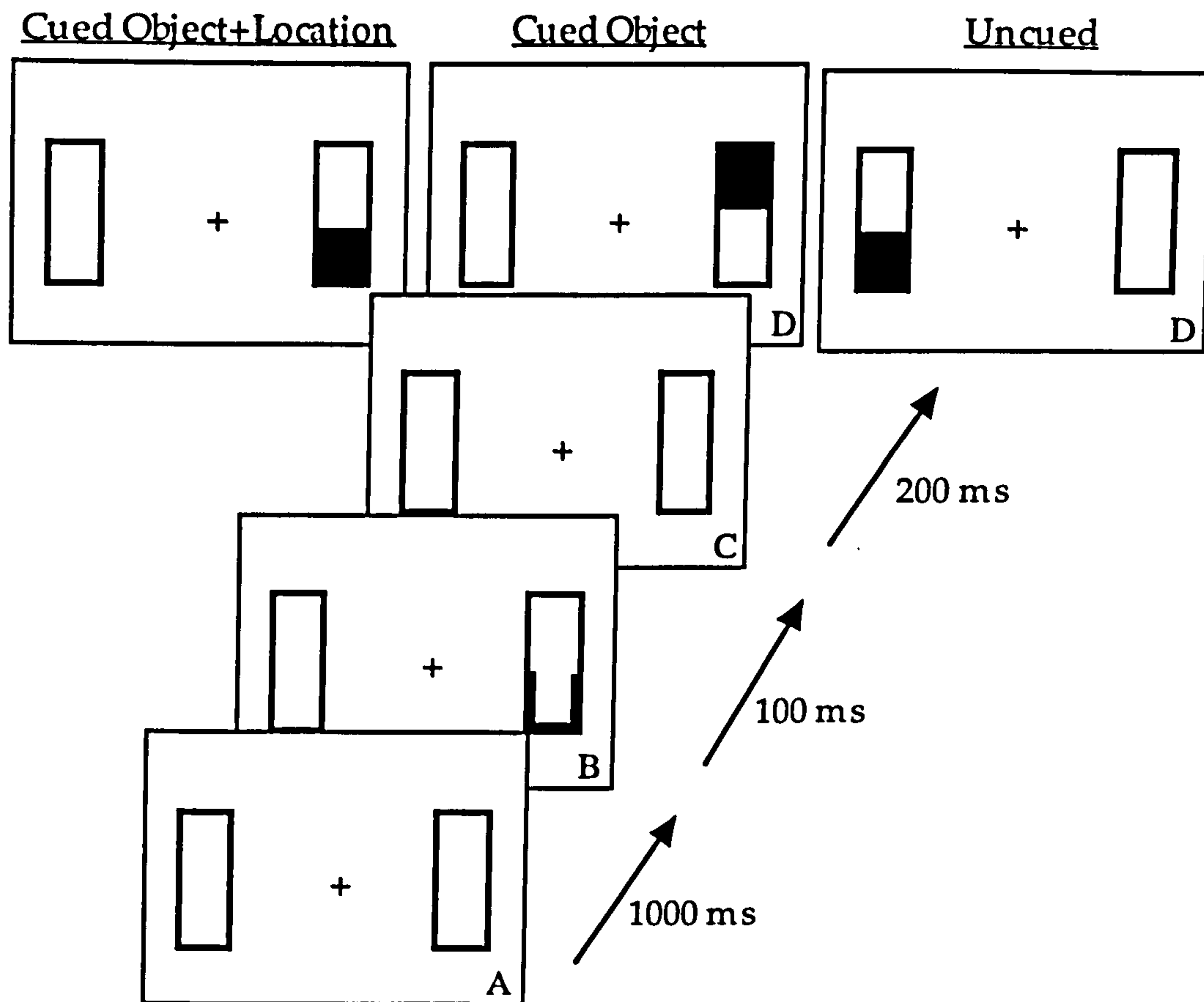
Egly, Driver & Rafal (1994) demonstrated an alternative method of dissociating location- and object-based attentional effects, in a static display. They



presented participants with two outline rectangles either above and below or to the left and right of a central fixation marker (Figure 4.1). Participants were instructed to detect a square which “filled in” one end of one rectangle. Prior to the appearance of the target, a predictive cue (luminance increment) was presented at one end of a rectangle. The target could occur in; the same location within the same object (Object+Location); a novel location within the same object (Object) or a region which shared neither location nor object identity (uncued) with the peripheral cue. Analysis of the RTs indicated the conventional cueing effect in responding to validly cued compared to invalidly cued targets within an object. This benefit is a spatial effect, as the peripheral cue and target shared object identity. A separate analysis of the invalidly cued trials indicated that the cost (i.e. less facilitatory effect) of re-orienting attention to a location in a different object, compared remaining within the cued object, was larger although spatial distance was held constant. Orienting attention to a location within an object facilitated subsequent target detection, even when the target appeared in a location 8 degrees visual angle away. Facilitatory components of attention appear to have spread across the surface of an object. This is inconsistent with the claim that object-based effects are only observed within narrow, spatially-attended regions (Lavie & Driver, 1996).

Egly et al's (1994) procedure was the first to measure the costs of moving attention to different loci within a single object and the additional costs of moving to a region which is part of a different object and has been replicated in several independent laboratories (Abrams & Law, under review; Macquistan, 1997; Moore, Yantis & Vaughan, 1998; Vecera, 1994). Subsequent studies have extended Egly et al's (1994) findings and shown that facilitatory attentional effects are observed in a variety of tasks e.g. target detection (Egly et al., 1994; Egly, Rafal, Driver & Starrveveld, 1995), target discrimination (Macquistan, 1997; Moore, Yantis & Vaughan, under review; Moore et al., 1998) and temporal order (Abrams & Law, under review) tasks. These effects have been observed with predictive exogenous (luminance increment) (Abrams & Law, under review; Egly et al., 1994; Egly et al., 1995) and endogenous (central arrow) (Abrams & Law, under review; Macquistan, 1997) cues. Moore, Yantis and Vaughan (1998) have



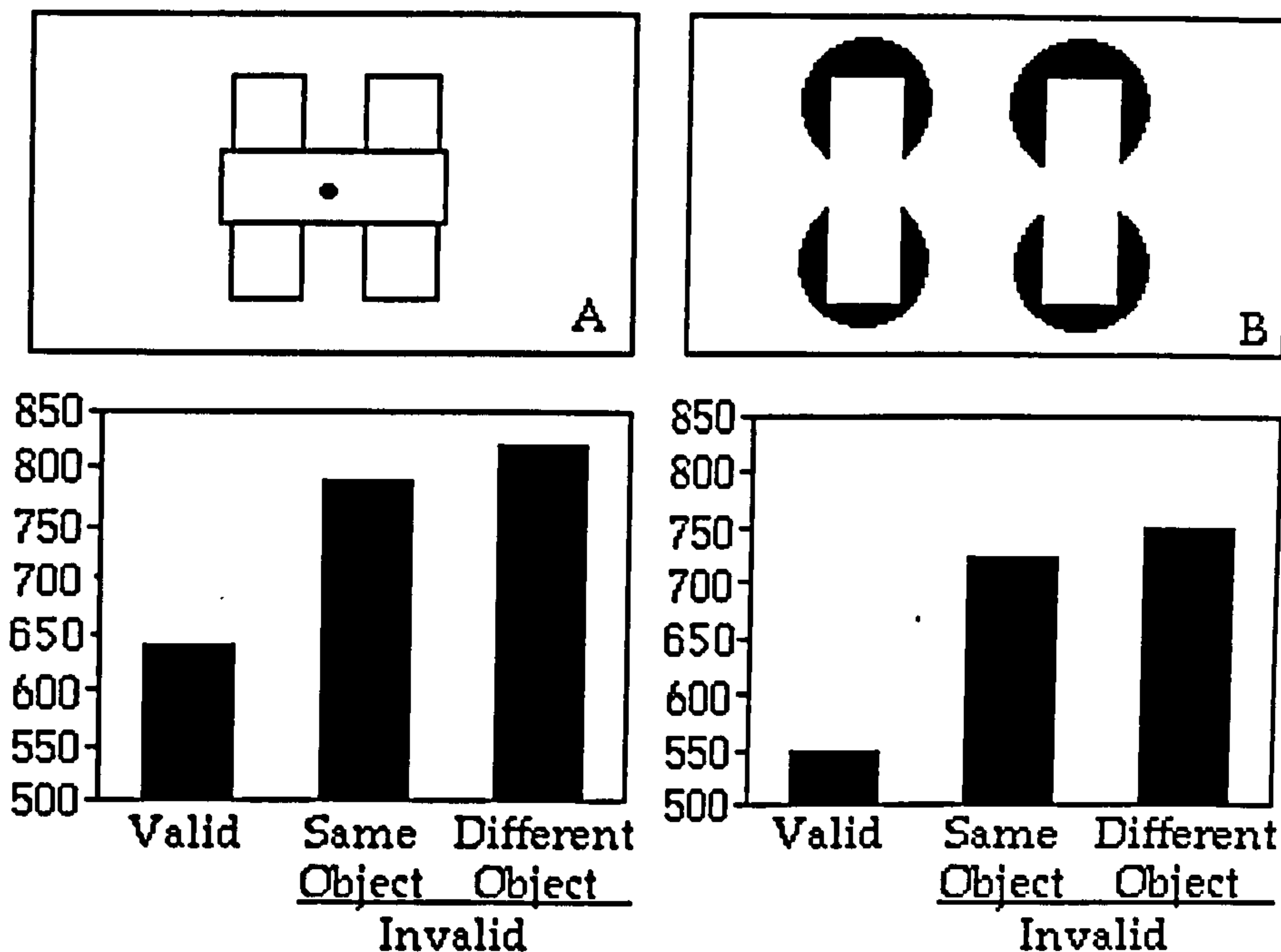


**Figure 4.1** An illustration of the procedure reported by Egly, Rafal and Driver (1994) which measures spatial and object-based attentional components in a single display. The fixation marker, rectangles and target (D) were presented in grey on a black background. The cue, panel C, consisted of a brightening of three sides of the cued rectangle and was 75% predictive of the location of the target. The target in these validly cued trials shared both object and location identity with the cue (panel D, left). In the remaining invalidly cued trials, the target appeared in either (a) the cued object but a different location (panel D, centre) or (b) the uncued object equidistant in space from the cued region (panel D, right). The rectangles appeared to the left and right of the fixation marker as depicted in 50% of trials, and horizontally oriented above and below the marker on the remaining trials. The initial display (panel A) was presented for 1,000 ms after which the cue (panel B) appeared for 100 ms at one of the four ends of the rectangles. The cue was removed for 200 ms (panel C) and then the target appeared in 80% of trials and remained visible until the participant responded or 2,000 ms if there was no response.

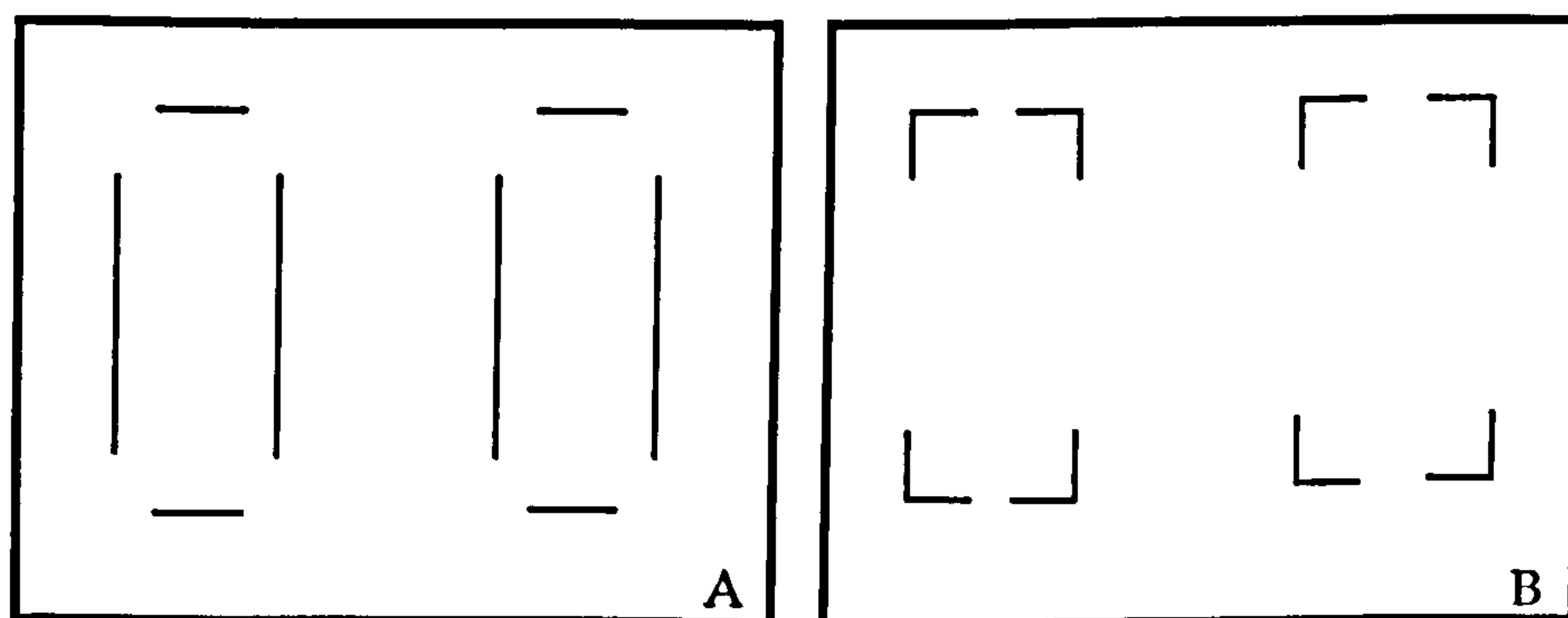
recently shown that facilitatory attentional effects spread across a variety of objects, including modally and amodally completed surfaces (Figure 4.2). Thus, Egly et al's procedure appears to demonstrate replicable and robust object-based facilitatory attentional effects. However, the use of a predictive cue encourages the participants to orient and maintain covert attention in the cued region. It remains an open empirical question as to whether the spread of excitation across an object's surface when strategically maintaining attention to the cued site, generalises to the inhibitory components of attention.

The study in this chapter uses a similar logic to Egly et al (1994), although a longer SOA and an unpredictable peripheral cue is used. Predictive cues encourage the maintenance of covert attention at the cued location prior to the onset of the target, producing facilitatory effects. In IOR studies, the cue is always unpredictable of the subsequent target location. Participants are informed of this and encouraged to ignore the irrelevant peripheral cue throughout the experiment. It is predicted that the IOR effect will be observed when the peripheral cue and target share object and location identity (object+location condition). The object+location IOR effect should be similar in magnitude to the object+location-based IOR effect in Experiment 3.1. If pure object-based inhibitory components of attention can be observed in static displays, a smaller IOR effect should be observed at a novel location within a previously attended object (object condition). This effect should be approximately the same size as the object+location-based - location-based IOR effect in the same experiment (see Table 3.6).

The second issue of interest is the role of saliency of the object in mediating any spread of inhibition. The schematic model of IOR which was described in Figure 2.7 suggested that the more salient the object is, the stronger its representation on the interest map. This in turn will promote a larger excitatory, and once processing resources are oriented away, a larger inhibitory activation. There is some evidence that saliency does modulate the facilitatory attentional effects which are the product of the excitatory mechanism. Gilds and Vecera (Gilds & Vecera, 1997) have shown that both the location- and object-based facilitatory effects in Egly et al's procedure are modulated by the quality of the stimuli. Object-based facilitatory effects can be abolished when the



**Figure 4.2** Top; Examples of the amodally (Panel A) and modally (Panel B) completed object displays reported by Moore, Yantis and Vaughan (1996). To enhance the perception of occlusion in the amodally completed condition, the occluding surface was presented stereoscopically so that it appeared to float in front of the depth plane which contained the two occluded objects. Bottom; Mean response times (ms) for correct target discrimination responses in the amodally (left panel) and modally (right panel) completed object conditions (taken from Moore, Yantis & Vaughan, 1996).



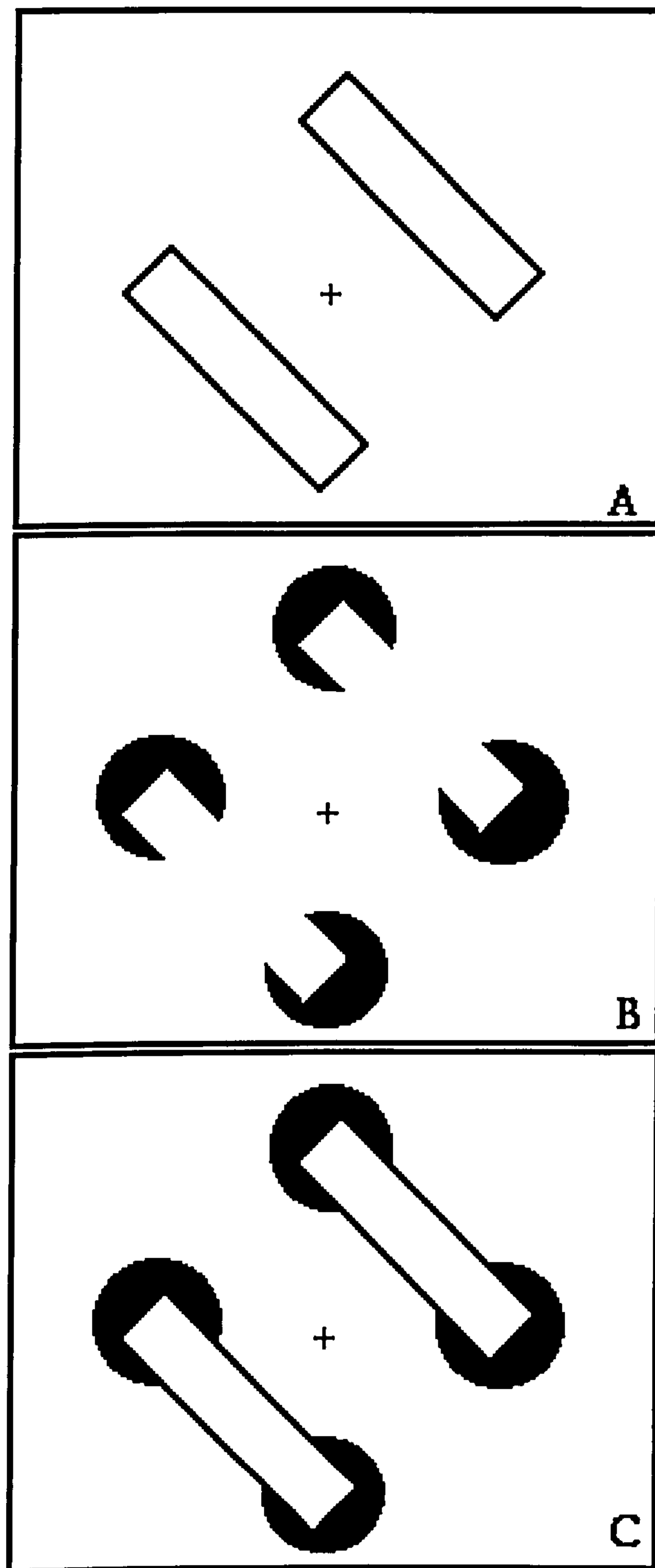
**Figure 4.3** Displays used by Gilds & Vecera (1997) to disrupt object-based effects in Normals completing the Egly et al (1994) procedure. Panel A shows the mid-sections only display and Panel B shows the Corners only display.



objects are degraded by presenting either mid-sections (Figure 4.3, Panel A) or corners (Figure 4.3, Panel B) only. This suggests that the object-based facilitatory effect is sensitive to the “goodness” or saliency of the object. Spatial effects can also be disrupted by the use of a computer generated ‘peppery-mask’ (see also Champion & Latto, 1985).

Experiment 4.1 examines three forms of objects to examine whether Egly et al’s (1994) excitatory effects generalise to inhibitory attentional effects. One set of stimuli replicate those used in the original Egly et al (1994) study (Figure 4.4, Panel A). The second stimulus type (Figure 4.4, Panel B) examines whether inhibition spreads across an apparent Kanizsa figure (c.f. Moore, Yantis & Vaughan, 1998; Davis & Driver, 1997; Chapter 3). The third object form (Figure 4., Panel C) is a combination of the outline rectangles (Figure 4., Panel A) and the apparent rectangles (Figure 4., Panel B). From informal subjective ratings, these figures appear to vary in their saliency, where the apparent rectangle (Figure 4.4, Panel B) is the weakest, and the figure depicted in Panel C is the strongest.

Janßen (1996) implemented a modified Gaussian function that is particularly sensitive to changes in the greyscale of the peripheral image across the entire visual field (see Appendix 1). Thus, it provides a measure of both local distinctiveness and invariance which, along with temporal change and task-dependent cues, are a useful definition of visual saliency (Janßen, 1996). In order to examine the saliency of the displays as defined by Janßen’s differential geometric equation, specialist software is required, which is not presently available in the School of Psychology, UWB. However, in order to explore the relationship between the displays, a series of Gaussian filters were applied to scale drawings of each of the displays using Adobe Photoshop 3.0, sampling with a factor of two. The most salient objects, according to Janßen’s definition, are those in which changes do not occur between samples. A visual examination of Figure 4.3 suggests that the subjective ratings of the saliency of the objects are consistent with the method used in the schematic model of IOR depicted in Figure 2.7.



**Figure 4.4** An illustration of the Stimuli Displays used in Experiment 4.1. Panel A shows the Outline Stimulus Display condition where the objects appear as outline rectangles, following Egly et al (1994). Panel B illustrates the Apparent Object Stimulus condition, where the objects are the result of the Kanizsa illusion. Panel C illustrates the Physical object Stimulus condition, which is the result of the conjunction of both the Outline and Apparent object Stimulus conditions. Each panel shows the stimuli in the -45 degrees orientation. The areas appearing as white in this figure were light gray in the experimental display.



In summary, Experiment 4.1 attempts to observe object-based IOR in the presence/absence of location-based IOR. The logic of the procedure is similar to that reported by Egly Driver and Rafal (1994). When the cue and target share both object and location identity (Figure 4.6, Panel B), increased response latency for the detection of the target compared to an uncued region (Figure 4.6, Panel D) is predicted. This increased IOR effect would be consistent with object- and location-based IOR operating simultaneously (Object+Location). The critical comparison is between the detection of a target that appears at a novel location within a previously attended object (Figure 4.6, Panel C) and the uncued condition. If the saliency of objects modulate the magnitude of the object-based IOR effect, the IOR effects should be largest in the physical object condition (Figure 4.4, Panel C) and the smallest/least robust in the apparent rectangles condition (Figure 4.4, Panel B).

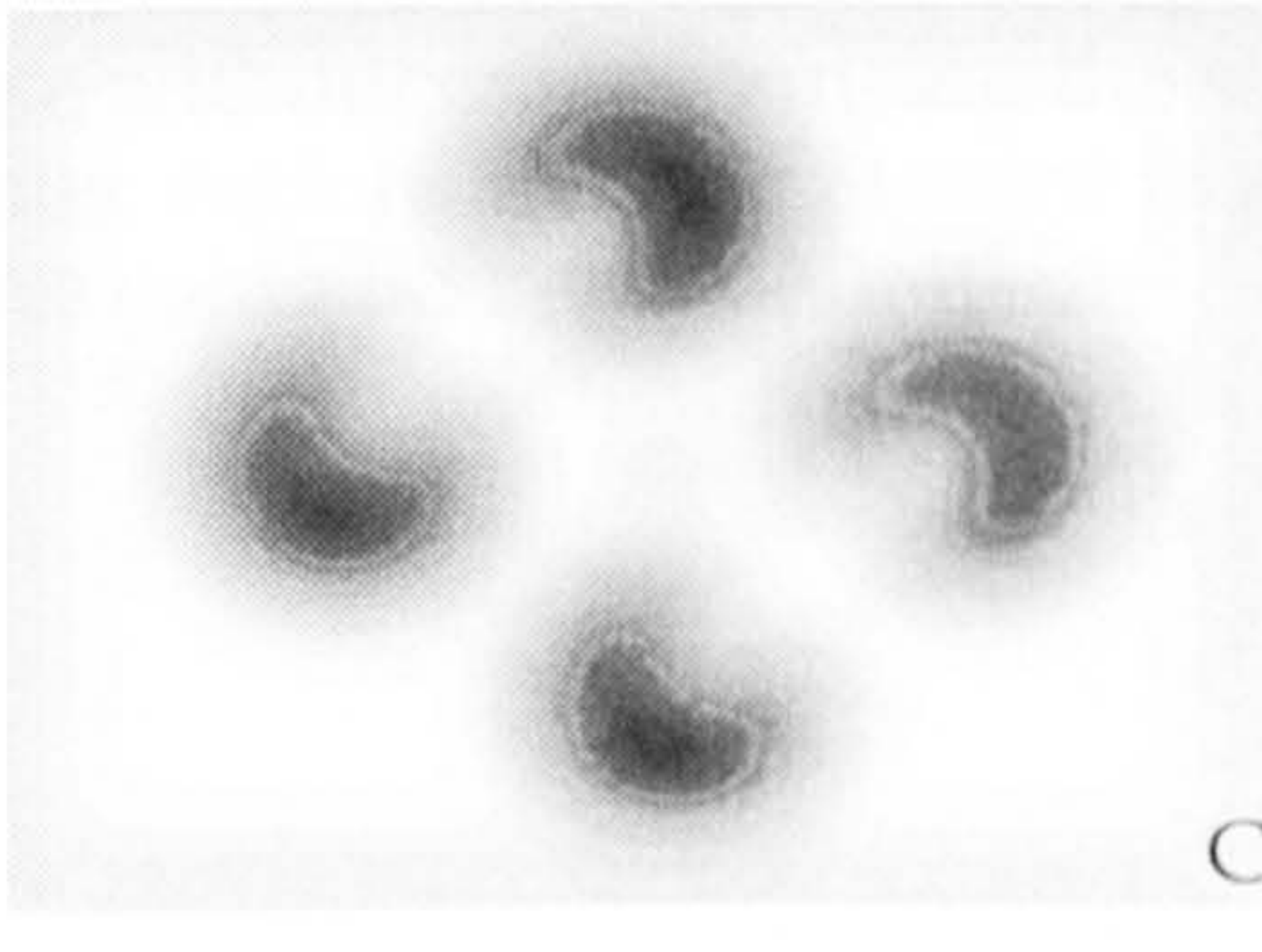
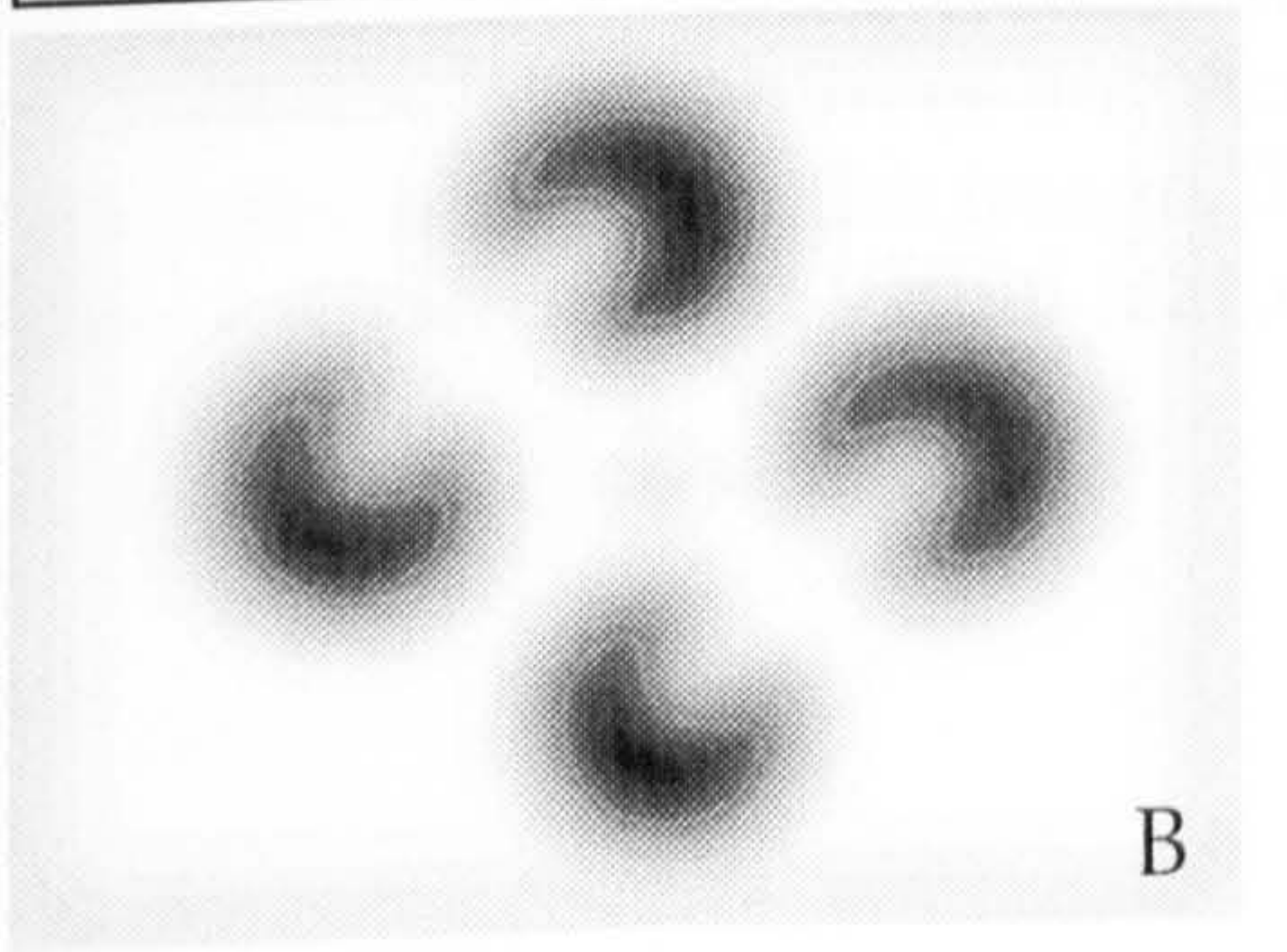
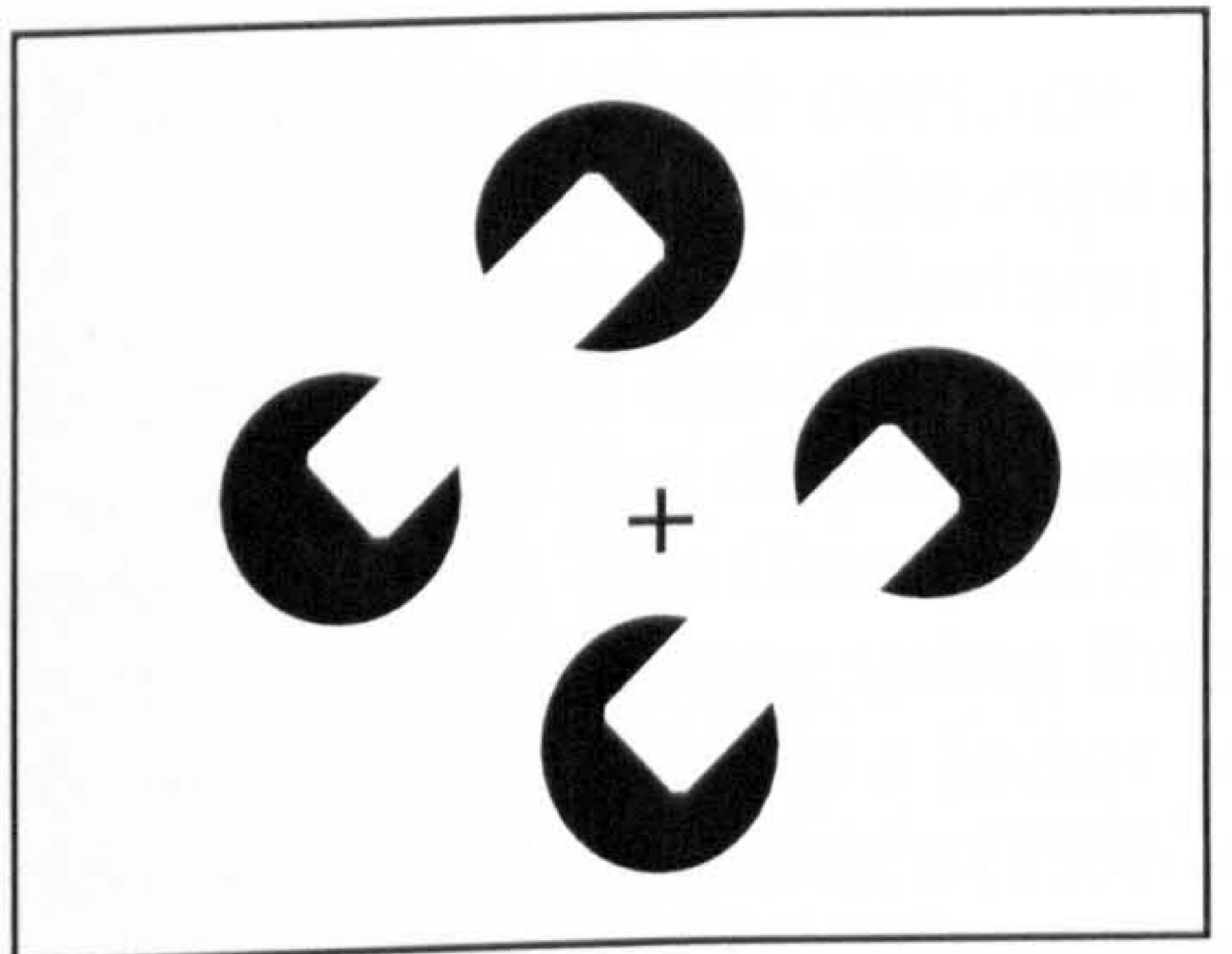
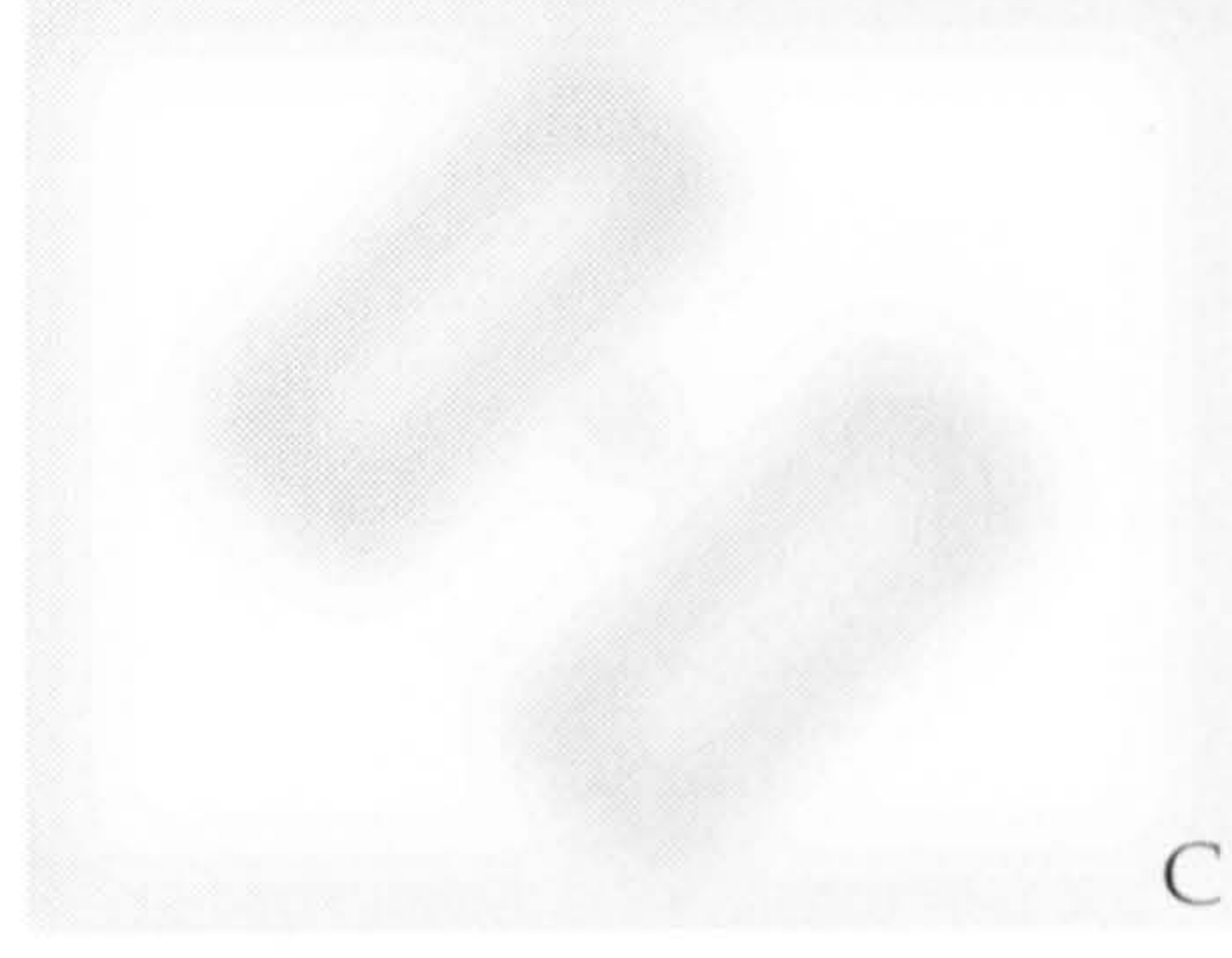
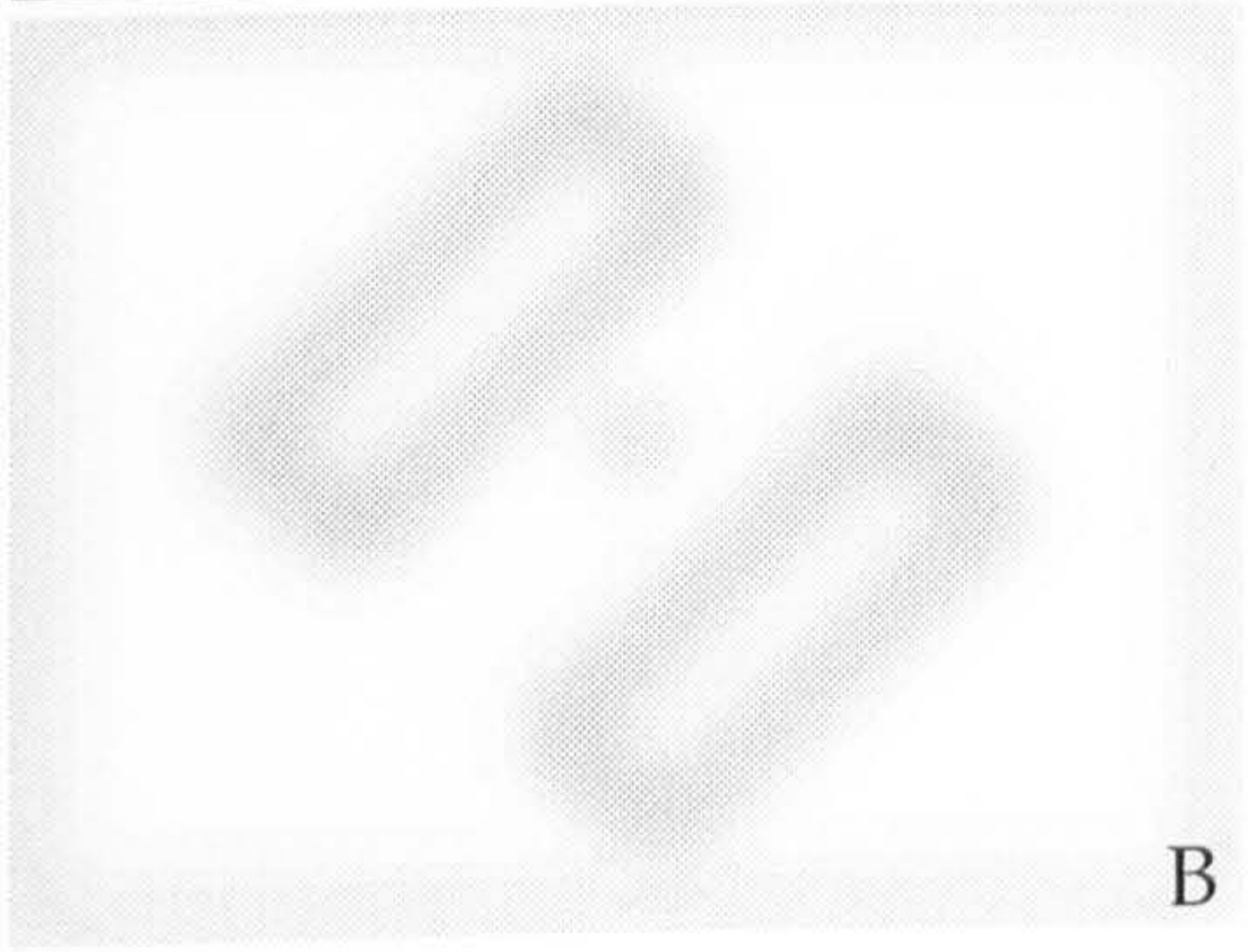
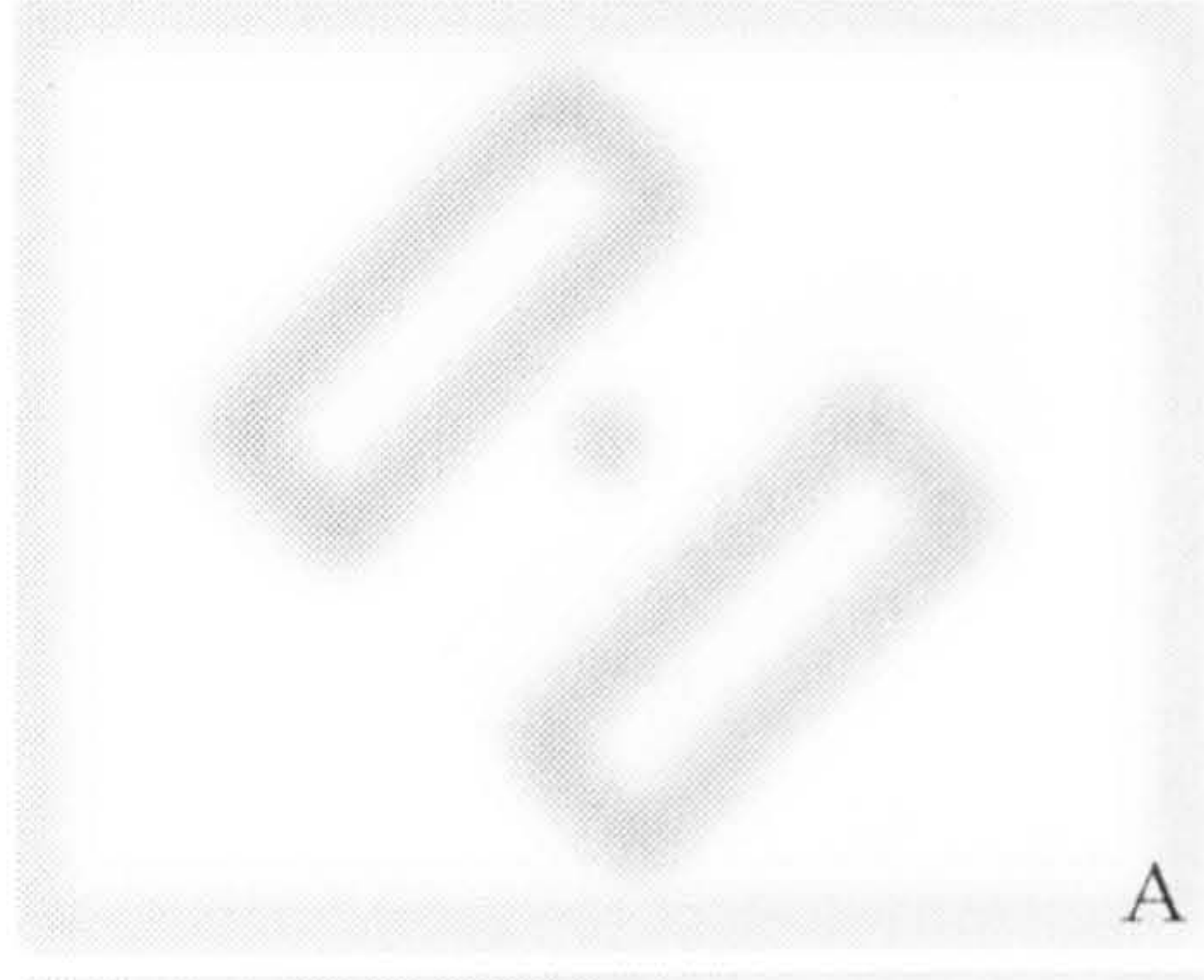
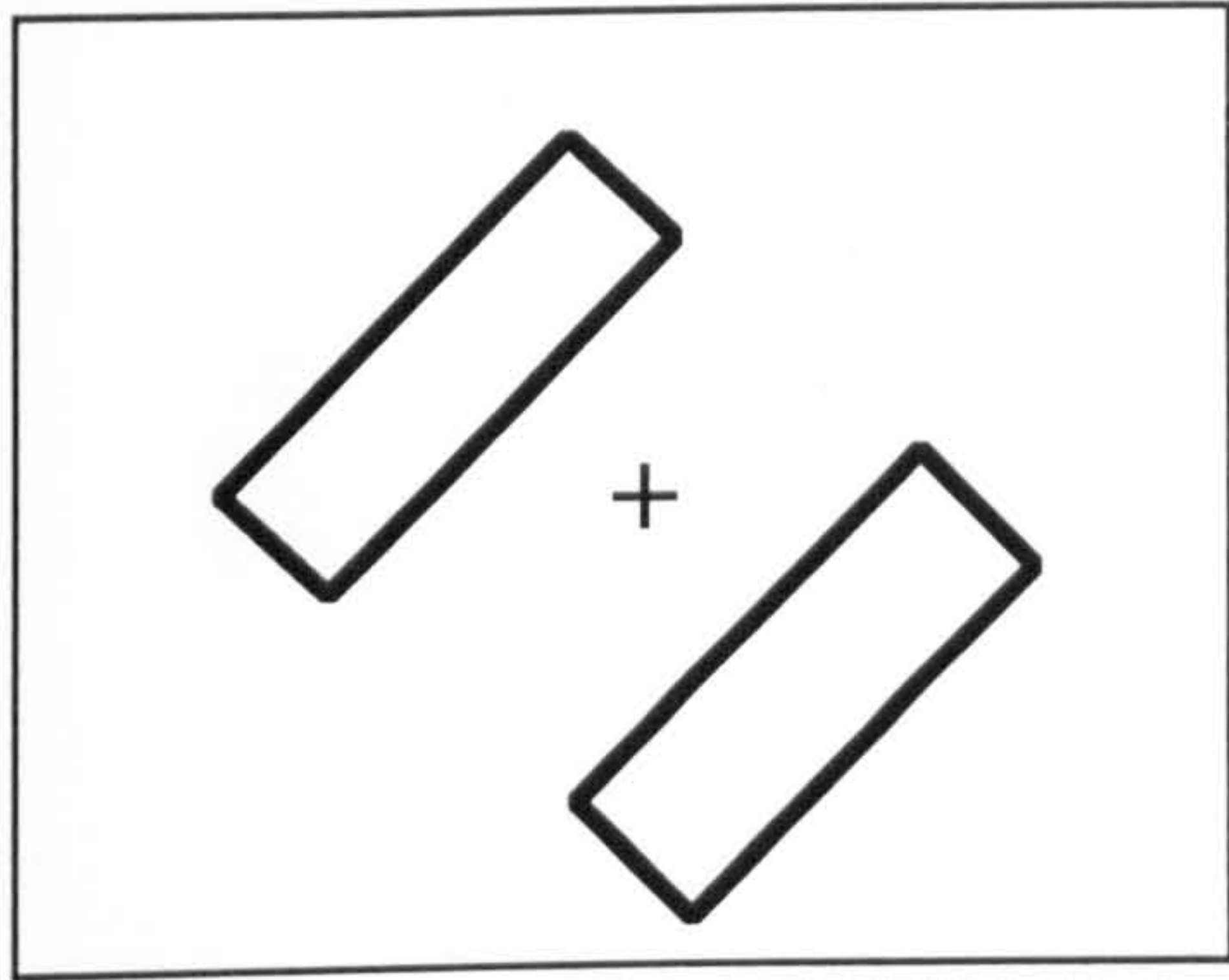
#### 4.3 Experiment 4.1

The logic of this experiment is shown in

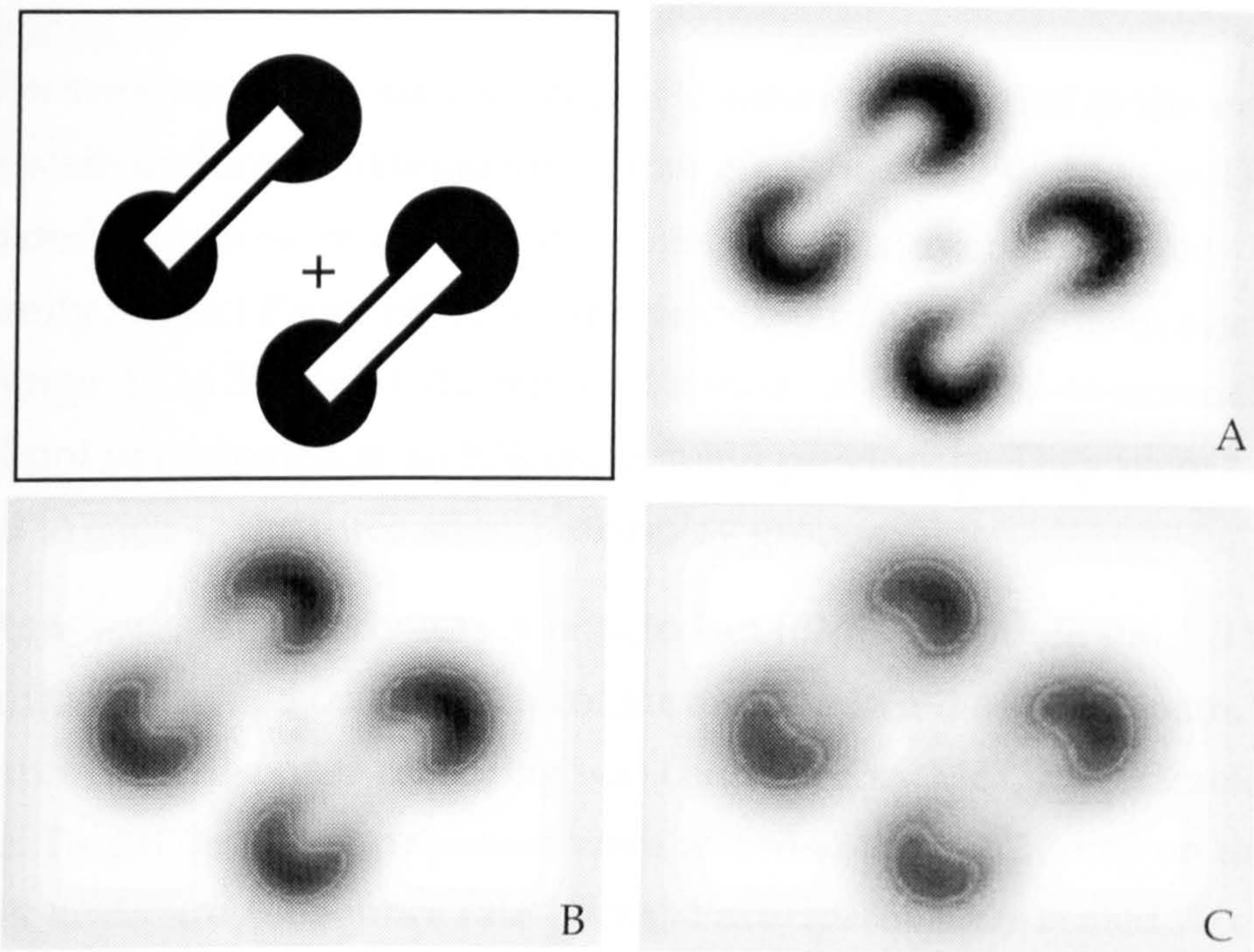
Figure 4.6. It is important to note that the spatial distance between the Object+Location location is identical to that between the Location and Uncued locations. This controls for spatial properties of inhibition (Maylor & Hockey, 1985). Furthermore, the spatial arrangement of the cue/target locations avoids interpretations in terms of whole hemifield inhibition (i.e. upper V's lower, left V's right: e.g. Berlucchi, Tassinari, Marzi & Di Stefano, 1988; Tassinari, Aglioti, Chelazzi, Peru & Berlucchi, 1994). In the example illustrated in

Figure 4.6, the cue is presented in the upper visual field on the vertical meridian. Both targets in Panels C and D are equal distances into the left and right visual fields on the horizontal meridian.









**Figure 4.5** Illustration of the outcome of the application of varying spatial frequency Gaussian filters to the experimental displays in Experiments 4.1. Outline (Top) and Apparent (Bottom) Objects are shown on the previous page, and the Physical Object condition is shown here.

The stimuli in each of the displays were drawn to scale (although within a smaller display area). The Gaussian filter option in Adobe Photoshop 3.0 was applied to this scale drawing using three different spatial frequency settings. Each of these filters varied by a factor of 2.

In order to emulate the Janßen's (1996) definition of visual saliency, it is necessary to sum the absolute Gaussian curvatures from each of the spatial frequencies (A-C). This removes any noise without compromising the sensitivity to the structures present in the image. Thus, regions that are present in each of the samples A-C are salient visual features using Janßen's definition.



### 4.3.1 Method

*Participants.* Thirty-six volunteers (13 male) participated in the experiment. Twenty were undergraduate students from the School of Psychology, UWB, who participated for course credit and the remainder were members of the Community Subject Panel who received payment of £3. Their mean age was 23.3 years (range: 19 to 38 years). All reported normal or corrected-to-normal acuity and had not participated in an IOR experiment previously. They were randomly assigned to each of the three stimulus display groups.

*Apparatus.* The study was conducted on an IBM-compatible 486/33 PC and the stimulus presented on a 14 inch colour monitor in a darkened room. Stimulus presentation and response recording was controlled by MEL 1.0 (Schneider, 1988) software. Target detection responses were recorded via the 'H' key on the computer keyboard (debounce rate 14 ms). Participants were seated 70 cm from the monitor with their heads resting on a chin rest. The height of the monitor was adjusted so that each participant was looking directly at the centre of the display.

*Stimuli.* The stimulus consisted of two rectangles that measured 1.4 X 6.4 degrees of visual angle (Figure 4.7), presented on a light grey background. The rectangles were produced by presenting unfilled rectangles with black boundary lines (0.2 degrees visual angle). The orientation of the objects was manipulated randomly between trials, appearing at either +/- 45 degrees from vertical. The ends of the object were situated 3.7 degrees above, below, left or right of the central fixation cross.

The fixation cross was a plus (+) sign, which subtended 0.3 X 0.3 degrees visual angle and was situated in the centre of the monitor display. Initially presented in black, it was overwritten in white and then black again to act as the central cue.

The target consisted of a solid white square subtending 0.8 X 0.8 degrees visual angle. In contrast, the peripheral cue appeared as a hollow white box (with a grey centre) subtending 1.2 X 1.2 degrees visual angle with an outline 5 pixels in width. The peripheral cue and target appeared in the same four spatial locations across all of the object types.

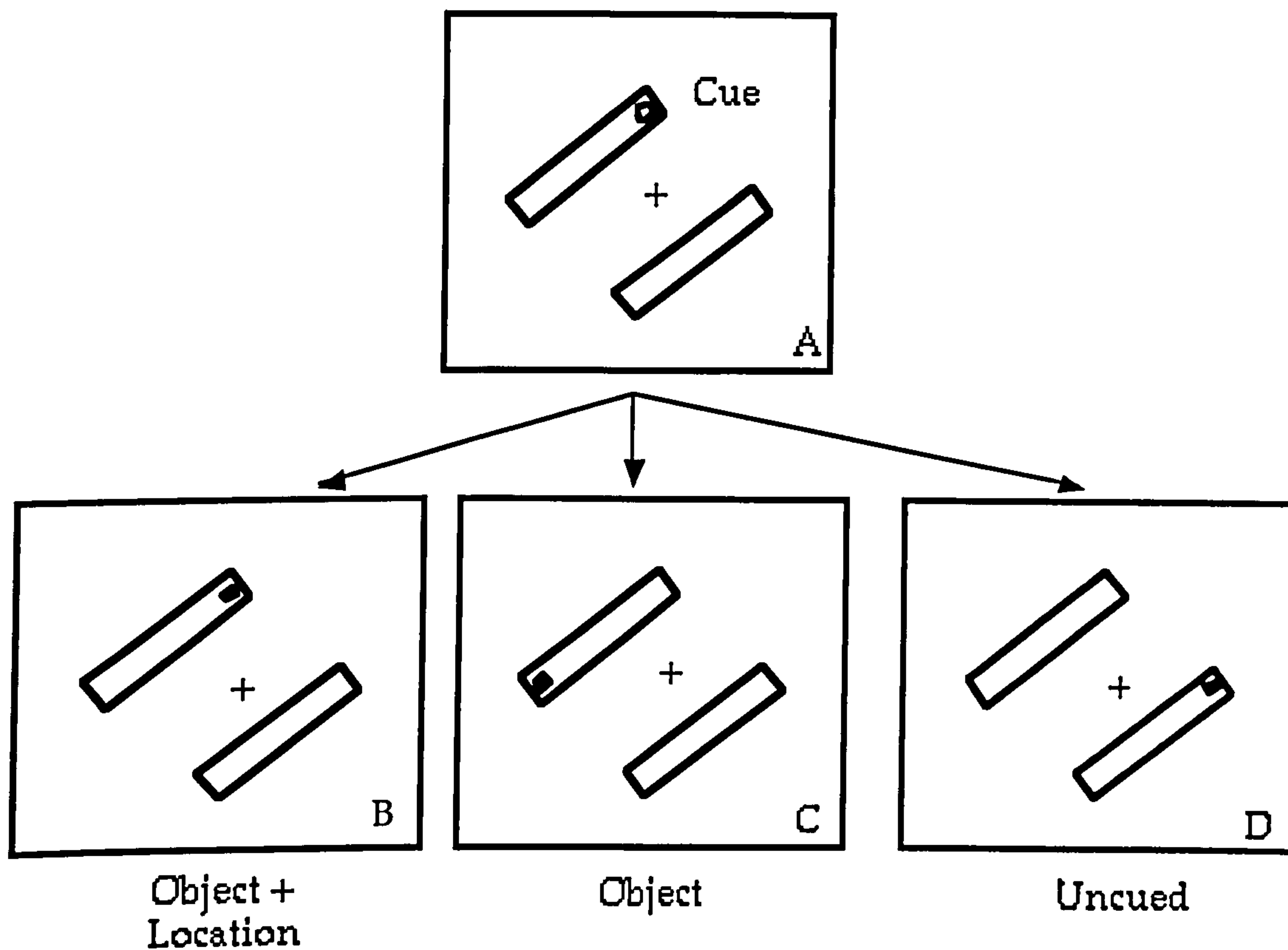
*Procedure.* Each trial was initiated by the participant pressing the spacebar in response to a message that reminded them to do so. The placeholders and the



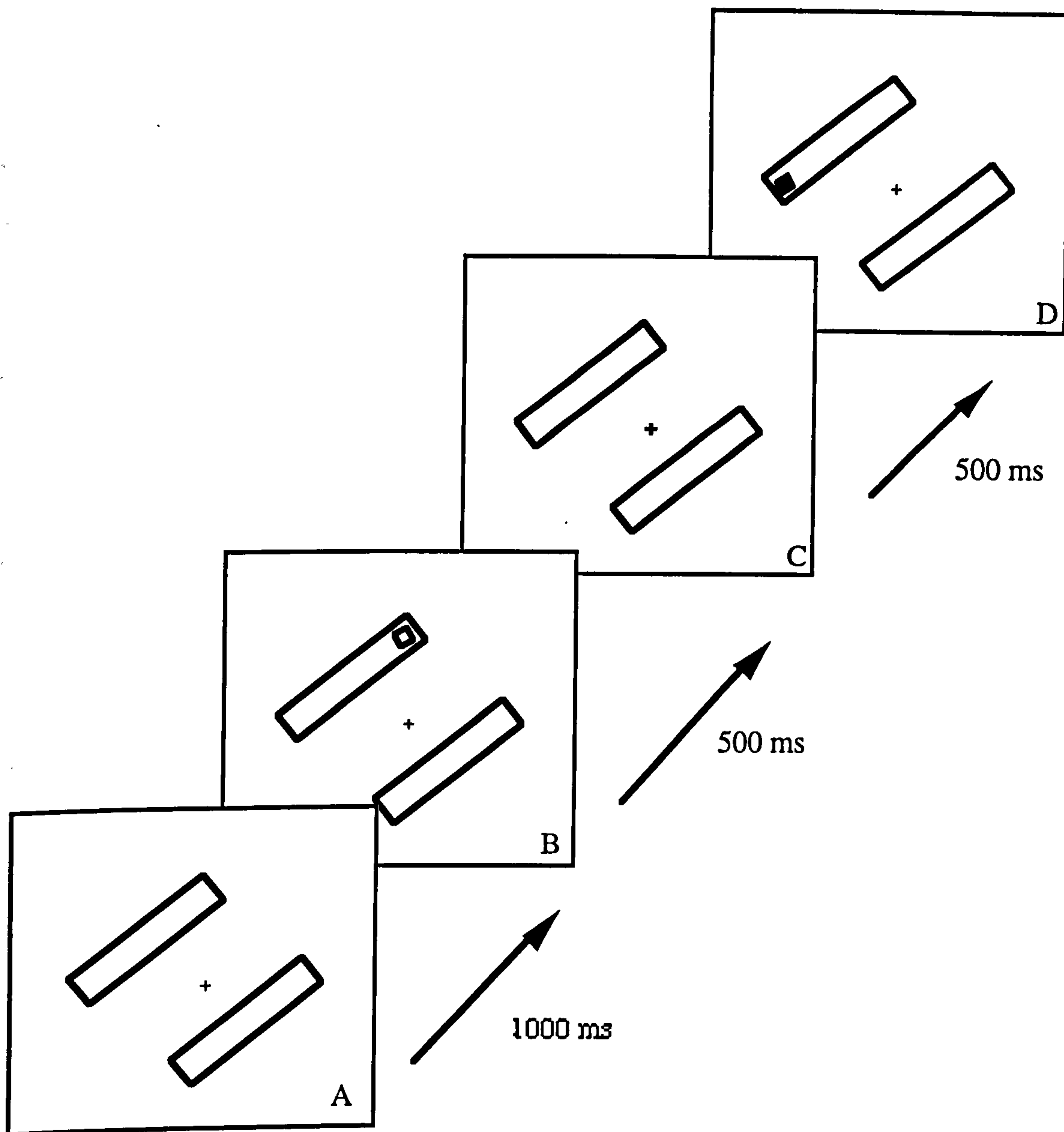
fixation cross appeared on the screen for 1000 ms (Figure 4.7, A). A peripheral cue appeared for 83 ms in one of the four placeholders with equal probability (Figure 4.7, Panel B), and was then overwritten. After 500 ms has elapsed, the central fixation cross changed from black to white for a duration of 83 ms (Figure 4.7, Panel C) and 500 ms after the offset of the fixation cross the target appeared in one of the placeholders for 83 ms in 80% of trials (Figure 4.7, Panel D). The target was overwritten and the display remained on the screen until the participant made a response or after 1000 ms had elapsed. In the remaining 20% of trials no target appeared and the participants were instructed to withhold a response. If the participant made a response in the absence of a target, or they failed to respond when a target did appear, the computer produced a 500 Hz tone for 500 ms as an error message. This terminated the trial and the trial initiation message was displayed.

Participants were instructed that they were performing a target detection task and that they were to respond to the presence of a target by pressing the 'H' key on the computer keyboard as quickly as possible. They were aware that the target would not appear on 20% of the trials and a response on those was considered an error. Furthermore, they were told that a white outline box (the peripheral cue) would appear during the trial but that it did not predict the location of the target and therefore to ignore it. They were strongly cautioned to fixate on the cross at the centre of the display for the duration of each trial. The experimenter visually monitored any eye movements during the practise phase (c.f. Tipper, Brehaut & Driver, 1990).

*Design.* In 25% of the target present trials the target appeared in the previously cued location (Cued Object + Location). In another 25% of trials the target appeared in the location which formed the opposite end of the cued object (Cued Object). In a further 25% the target appeared in the other object



**Figure 4.6** Illustrates the logic of the Cueing conditions in this series of experiments. The peripheral cue is presented above the centre of the display, at one end of an object (Panel A). If the target subsequently appears in the same region of the display, both the location and the object in which it appears have been previously cued (Panel B). Panel C illustrates the Cued Object condition, in which the target appears in the previously cued object, although at a novel location. In contrast the target can appear in the other object, at a location which is the same distance from the cued region as the Cued Object condition (Panel D).



**Figure 4.7** The procedure used in Experiment 4.1. The trial illustrated in a cued object uncued location trial in the amodally completed object condition. Although the peripheral cue and target are shown in black for clarity, they appeared as white in the experiment. The background was light grey. The duration of the cue, fixation flash and target were 83 ms.



(Uncued). The spatial distance between the cued region and the target region in the cued object and uncued conditions are identical. Finally, in the remaining 25% of trials the target appeared in the location opposite to the cued region. These trials were not analysed as they were confounded with spatial distance and therefore not of theoretical importance in this study.

A mixed design with two factors was used in this experiment. The first factor was Stimulus Display that was manipulated between groups of subjects. The second within-subjects factor was Cueing condition (with three levels: Cued Object+Location, Cued Object and Uncued).

Each participant completed 200 experimental trials, 40 of which were catch trials where no target appeared. Each Cueing condition occurred 40 times, the target appearing in each of the four possible locations with equal probability.

#### 4.3.2 Results.

The response latencies in trials with incorrect responses, anticipatory (less than 100 ms) or very long (greater than 1000 ms) were designated as error trials and were excluded from subsequent analysis. This resulted in less than 1.5% of trials being excluded, as can be observed in Table 4.2. As the error rate is so small, no further analysis was carried out.

*Reaction time data.* In order to examine the effect of the Cueing conditions in the various Stimulus Displays, a 3 (Display: Rectangles, Apparent and Physical Object) X 3 (Cueing Conditions: Cued Object+Location, Cued Object, Uncued) mixed design ANOVA was carried out on the median RTs for each participant in each experimental Cueing condition. Display was a between-subjects factor, and Cueing was a repeated measure.

There was a main effect for Display which reflected that fact the fastest RTs were observed in the outline object display condition and the slowest in the physical objects display,  $F(2,33) = 4.8$ ,  $MSE = 10054.8$ ,  $p < .05$ . This contrast is a between-subjects comparison and therefore is probably due to a sampling artefact.

**Table 4.2**

Mean median RTs (ms) and error rates (%) for Cueing conditions in each of the displays.

Type of Rectangle		Object+Location	Object	Uncued	Catch trials
Outline	RT	337	309	297	-
	% errors	0.4	0.6	0.4	2.7
Apparent	RT	357	317	312	-
	% errors	0.7	0.7	1.6	0.7
Physical	RT	403	385	364	-
	% errors	1.7	0.6	1.0	1.0
Mean	RT	365	337	324	-
	% errors	0.9	0.6	1.0	1.5

There was a highly significant main effect for Cueing with the longest RTs in the Object+Location Cueing condition and the shortest in the Uncued condition,  $F(2,66) = 53.3$ ,  $MSE = 408.0$ ,  $p < .001$ . This is consistent with the predicted pattern of IOR effects. More importantly, the interaction between Cueing and Display was not significant, which indicates that the observation of a large IOR effect for Object+Location and a smaller one for Object is similar across all Stimulus Displays,  $F(4,66) = 1.4$ ,  $MSE = 299.3$ , n.s..

Fishers LSD t-tests were carried out to examine the IOR effect in each Cueing condition separately. These showed that there is a highly significant 41 ms IOR effect for the Object+Location Cueing condition ( $t(70) = 10.0$ ,  $p < .001$ ). In the critical Cued Object condition, there was a significant 13 ms IOR effect, ( $t(70) = 3.0$ ,  $p = .004$ ), where IOR is observed at a non-cued location within a cued object. Thus, it appears that inhibition did spread across the surface of an object.

#### 4.4 Discussion

This is the first report of a pure object-based IOR effect in a static display. Contrary to Müller and von Mühlhelen's (1996) assumption that object-based IOR effects are only present in dynamic IOR procedures, inhibition, which is associated with a previously attended object, can be observed in the absence of motion. The data obtained in the present study supports the conclusion that pure object- and location-based IOR effects can be observed in static displays and that



the large IOR effect observed in the traditional procedure is the additive effect of the two mechanisms.

The magnitude of the IOR effect in the Cued Object condition is smaller than the effect observed when the target shares both object and location with the peripheral cue. Thus, Experiment 4.1 partially dissociated the location- and object-based IOR effects in a static display and is consistent with the observation of a smaller IOR effect in the Cued Location cueing condition (25 ms) compared to the Cued Object+Location condition (43 ms) in Chapter 3. Additionally, the partial dissociation of the object- and location-based IOR effects in this experiment compliments that from the previous chapter. Taken together, the data from Chapters 3 and 4 provides a complete dissociation of the object- and location-based IOR effects in static displays and provides evidence that these effects are the result of independent mechanisms (Table 4.3).

**Table 4.3**

A summary of the IOR effects observed in the Experiments in chapter 3 and 4. The observation of pure location- and pure object-based IOR in Chapters 3 and 4 respectively provides a complete dissociation of these two effects in static displays.

	Object+ Location IOR	Object-based IOR	Location-based IOR
Dynamic IOR procedure (e.g. Tipper et al, 1994)		✓	✓
Chapter 3	✓		✓
Chapter 4	✓	✓	

Additionally, the data from this experiment suggests that marking regions of the display with objects does not modulate the IOR effect by making it easier to remember where the peripheral object appeared (see section 3.2). If the IOR effect is larger in the presence of an object in the visual scene simply because the visual system has a landmark to “remember”, it is difficult to argue that the “wrong” end of the cued object is easier to “remember” than the cued end. The notion that there is only a single inhibitory effect, which is larger when associated



with a "landmark", is consistent with the data in Chapter 3. In this experiment attention is oriented to an object and an additional benefit in the IOR effect is observed when the cue and target share spatial identity. Rather, the most parsimonious explanation for the data in Chapter 3 and 4 together is that there is two separate inhibitory mechanisms in operation.

#### 4.4.1 IOR Effects with Practice

Müller and von Mühlenen (1996) stated that the pure dynamic object-based IOR effect is particularly fragile, and is observed only in naive participants. Experiment 3.4 suggests that both the location- and location+object-based IOR effects in static displays declined with practice (see also Weaver et al., in press). In order to examine whether the pure object-based (object versus uncued conditions) IOR effect in this experiment was reduced in magnitude with practice, the effect was analysed in the second half of the experiment. The pure object IOR effect was only 8 ms and non-significant ( $t(70) = 1.7, p = .09$ ). In contrast, this effect was 18 ms in the first half of the experiment and significant ( $t(70) = 3.2, p < .004$ ). This suggests that Object-based IOR does decline with practice, as reported by Müller & von Mühlenen (1996) and Weaver et al (in press).

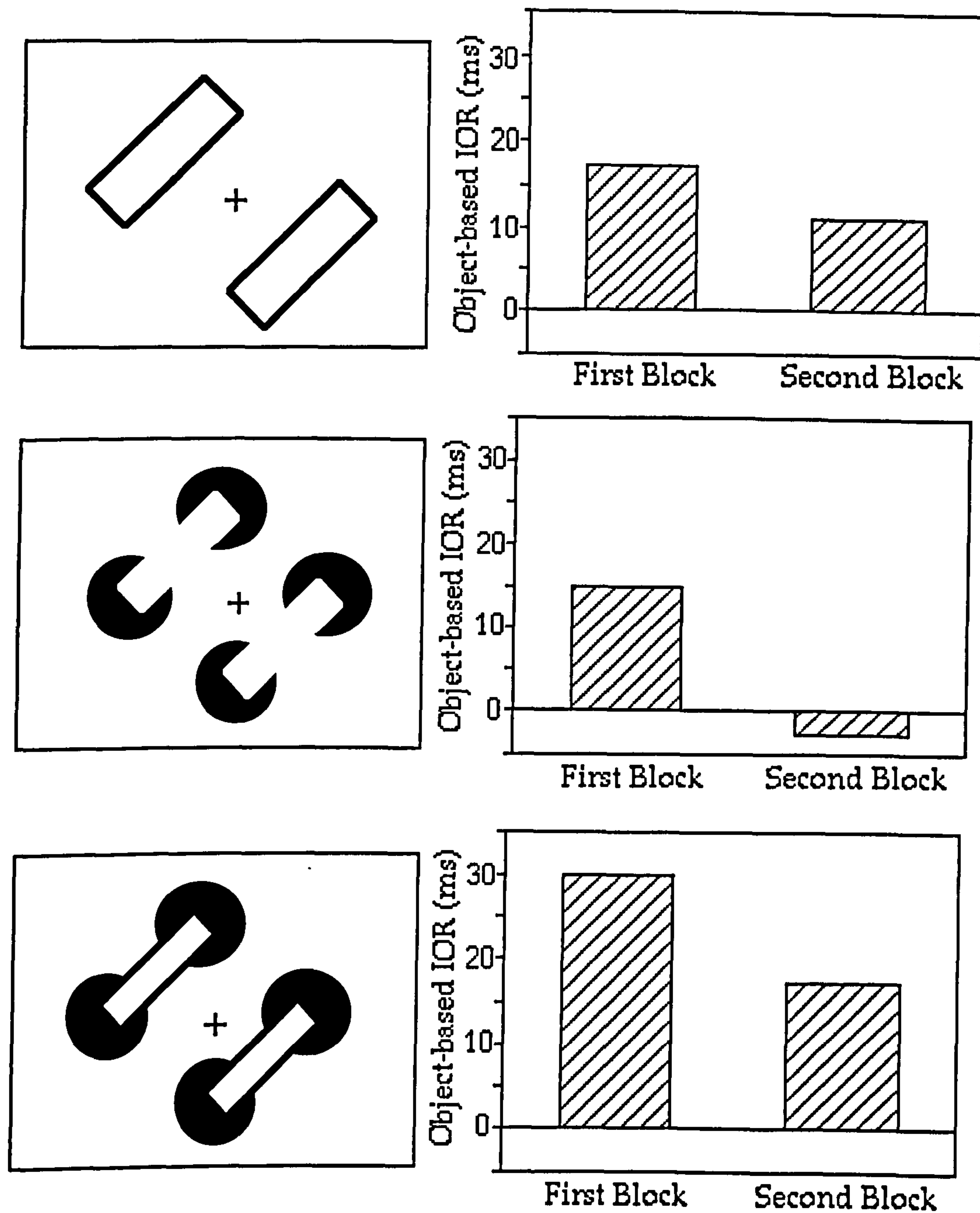
The fragility of the effect is probably due to the experimental procedure that is employed to examine IOR effects. In these tasks, the effects of object-based representations on attentional processes are examined, although the objects themselves are irrelevant to the participant's behavioural goal (e.g. Tipper, Weaver & Houghton, 1994a). Vecera and Farah (1994) noted that the object-based effects reported by Duncan (1984) are found when the response was contingent on the objects in the display, but disappeared in a target detection task, similar to that employed here. It is possible that, with practice, participants habituate to the presence of the irrelevant objects. This results in the response irrelevant objects ceasing to have any impact on the inhibitory mechanisms of attention.

Note that subjective reports suggest that the apparent (Kanizsa) object (Figure 4.4, Panel B) is less salient than the object produced by combining apparent and outline (Physical) objects (Figure 4.4, Panel C). The data is consistent with this observation. In the case of the apparent object condition,

there was no evidence of a pure object-based IOR effect in either the first half of the experiment (5 ms;  $t(22)=0.9$ , n.s.). The same analysis of the second 100 trials showed that RTs to targets appearing in the cued object were (non-significantly) faster than the uncued condition (3 ms;  $t(22) = -0.3$ , n.s.). This is a stark contrast to the significant IOR effects observed in both the first (21 ms;  $t(22) = 2.7$ ,  $p < .008$ ) and the second half (17 ms;  $t(22) = 2.1$ ,  $p < .05$ ) of the experiment (Figure 4.8). This suggests that it is possible to habituate rapidly to relatively unsalient visual stimuli. In comparison, the object-based IOR effects associated with more salient task-irrelevant background objects is more robust, and is observed after a larger number of trials. This finding is consistent with the proposed role of saliency in the schematic model of IOR (Figure 2.7) and is discussed further in Chapter 7.

In summary, there is evidence that pure object-based IOR effects can be observed in static displays. The observation of pure object-based IOR effects in this chapter, in conjunction with pure location-based IOR effects in Chapter 3, provides a complete dissociation and evidence that these inhibitory effects are the product of independent mechanisms (see also Chapter 7). Unlike exogenous cueing effects at short SOA's (Jonides, 1981), IOR effects are modulated by the characteristics of stimuli other than the peripheral cue and target.





**Figure 4.8** Displays and magnitude of the object-based IOR effects with practice observed in Experiment 4.1. In each case the object+location-based IOR effect was significant ( $\alpha < .001$ ). In contrast, the pure object-based IOR effect was significant ( $\alpha < .05$ ) in the first block of the Outline stimuli display and both blocks of the Physical objects display.



## Chapter 5

### *Object- and Location-based Inhibition of Return in Dynamic Procedures: Object Structure and Object Dimension Information.*

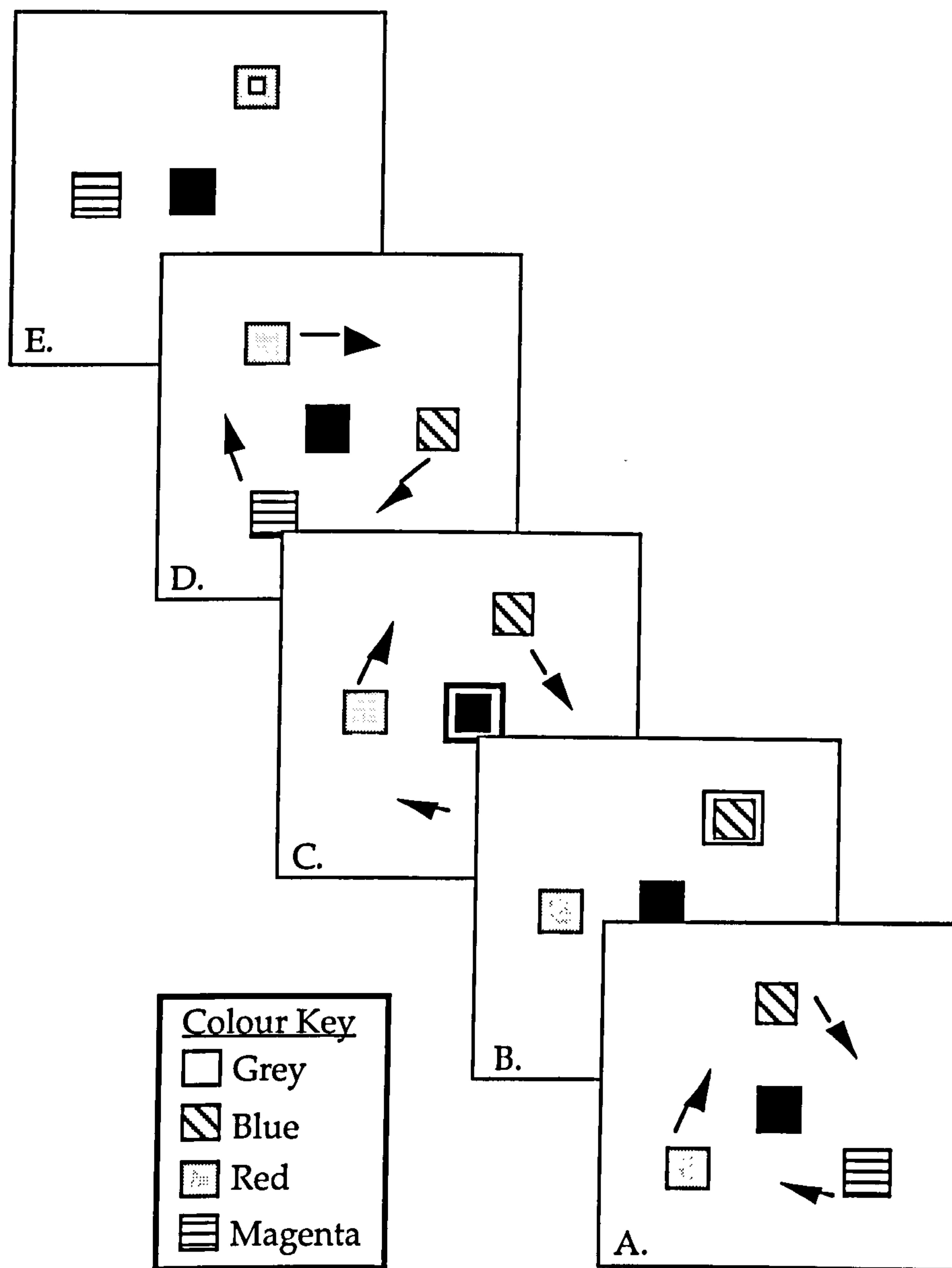
#### 5.1 Summary

The previous chapters together provided a complete dissociation between the location- and object-based IOR effects in static displays. The experiments reported here confirmed that the two inhibitory effects are independent, as they are subject to different boundary conditions. Changes in the structural relationships between the peripheral objects in the display modulated the location-based IOR effect (Experiment 5.1 - 5.3). This suggests that this effect is mediated by an "object-aware" spatial representation, which must be located in a cortical region. In contrast, the object-based IOR effect was modulated by changes in the quantity of object dimension information defining the peripheral boxes. It was tentatively suggested that the saliency of the peripheral objects, relative to the display background, modulated the effect of practice on the object-based IOR effect.

## 5.2 Introduction

The experiments in Chapters 3 and 4 demonstrated that it is possible to completely dissociate the location- and object-based IOR effect in static displays. The presence of an apparent object in the peripheral cue and target region is sufficient to observe the object-based IOR effect (Chapter 3). This object-based inhibitory effect spreads across the entire region occupied by the object, and can be observed at a novel within-object location (Chapter 4). The complete dissociation of the location- and object-based IOR effects provides evidence that they are the product of independent mechanisms. However, in order to confirm this observation, it is necessary to show that each inhibitory mechanism has individual boundary conditions. Elucidation of the boundary conditions of each effect will provide converging evidence that they are separate effects. It will also help to elucidate the role of each mechanism, how the IOR effects work together and possibly provide some clues about the neural structures that generate each.

All of the experiments in this chapter are a variation on the three-box dynamic IOR procedure that completely dissociates object- and location-based IOR effects. (Tipper & Weaver, in press; Weaver et al., in press). Four boxes are presented on the screen, one in the centre and the other three spaced equally around it (Figure 5.1, Panel A). After cueing a peripheral (Figure 5.1, Panel B) and the central box (Figure 5.1, Panel C), the three peripheral boxes move 120° in polar co-ordinates on the circumference of an imaginary circle. The target is presented in one of the peripheral objects (Figure 5.1, Panel E). Targets can appear in a region which shared neither location or object identity with the peripheral cue (uncued condition). If the target appears in the same object as the cue (cued object), which has moved to a new location, an object-based IOR effect (cued object - uncued) is observed. Similarly, the target can appear in the same spatial location (cued location), which is now occupied by a different object, and a location-based IOR effect (cued location - uncued) is observed. Thus, the dynamic procedure completely dissociates the location- and object-based IOR effects within a single display. All of the studies in



**Figure 5.1** Illustration of the dynamic three-box IOR procedure first reported by Weaver, Lupiáñez and Watson (in press). The example shown here is the Cued Location condition in which the peripheral cue (Panel B) and the target (Panel E) appear in the same spatial location. The background of the display was light grey. The arrows denote motion of the peripheral boxes, and were not drawn in the actual displays. In 50% of trials the peripheral boxes moved clockwise, as shown here, and in the remaining trials they moved anticlockwise.

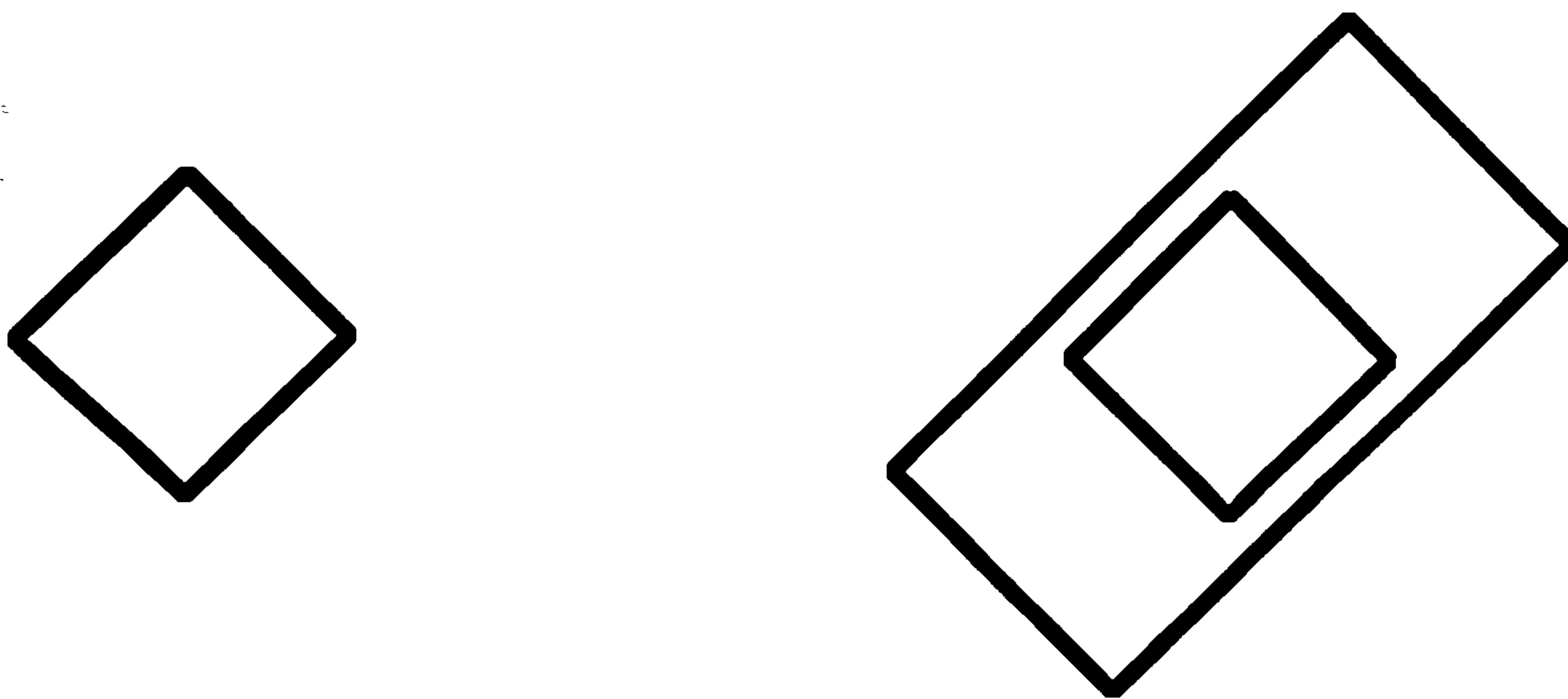


this chapter use a modification of this procedure in an attempt to abolish the location- and object-based IOR effects separately, and establish boundary conditions of each effect.

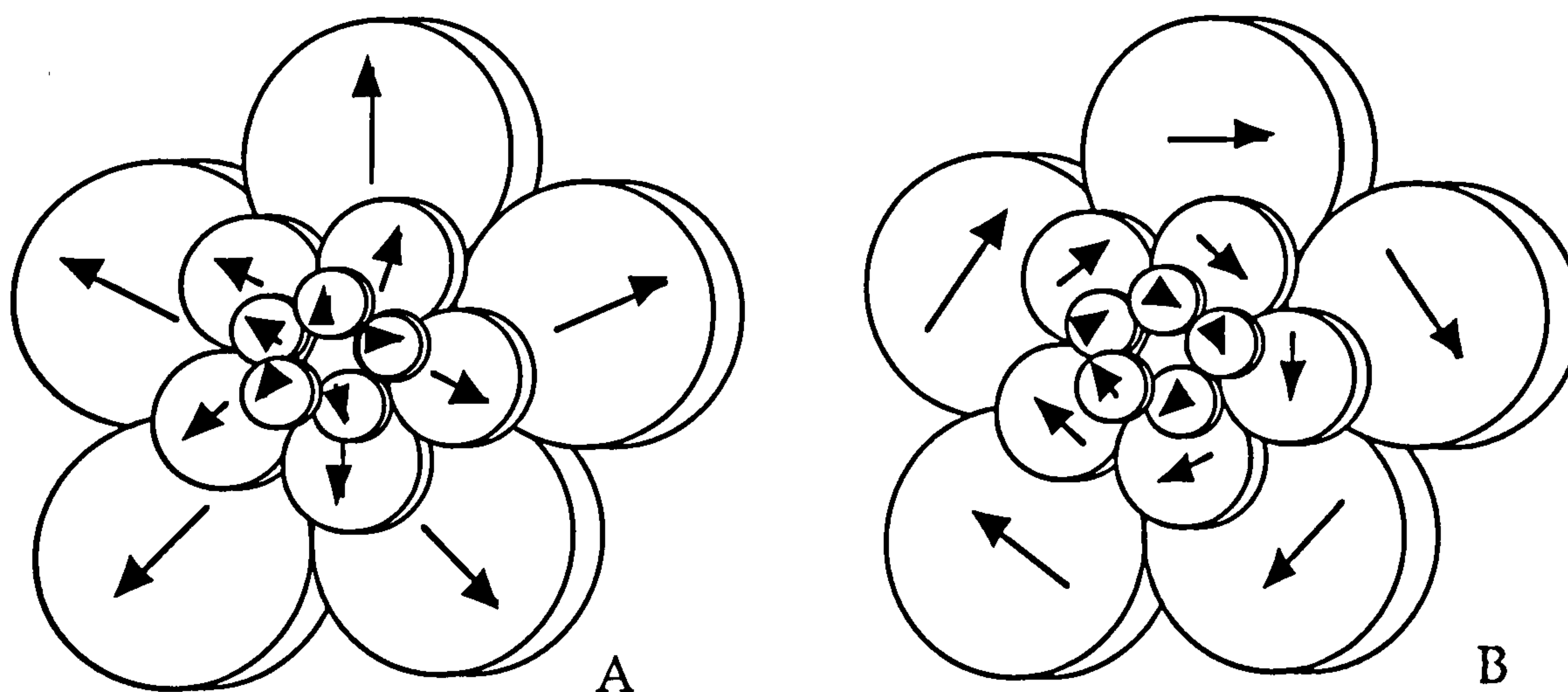
### 5.2.1 The role of object structure information on the object- and location-based IOR effect.

A basic tenet of the Gestalt school of psychology was that the relationship between, rather than the identity of, perceptual elements determines the percept of the whole. A classic example in vision is illustrated in Figure 5.2, where the percept of a diamond is changed into a square by the addition of an oriented rectangle (Ivry & Robertson, 1998). In chapter 1 several studies, with neurologically compromised patients were reviewed, which showed that the structural description of object information modulates the spread of attention. The performance of patients with both Bálint syndrome (Humphreys & Riddoch, 1993; Luria, 1959) and unilateral visual neglect (Behrmann & Tipper, 1994; Tipper & Behrmann, 1996) is modulated by the structural relationships between object elements in the display. For example, Behrmann & Tipper (1994; Tipper and Behrmann, 1996) presented left visual neglect patients with a barbell stimulus. When the barbell remained static, detection of targets on the left of this stimulus was impaired. However, when the barbell rotated around the computer screen through 180°, neglect appeared to move with the object. That is, the left neglect rotated into the good field, such that target detection was now worse on the right side of the object. However, when the black connecting bar was removed, so that two separate circles were observed to rotate, neglect did not rotate with the left circle. This suggested that neglect in this task was mediated by an object-centered frame of reference. Excitatory attentional mechanisms appear to be sensitive to the structure of objects. Adding lines to connect two circles into a “dumbbell” shape was sufficient for selective facilitatory attentional mechanisms to treat separate objects as a single one.

In the dynamic IOR paradigm, the three peripheral boxes move around the circumference of a single imaginary circle, at a constant speed (Tipper & Weaver, in press; Weaver et al., in press). When the visual system needs to “keep track” of separate moving objects it must code the location of each



**Figure 5.2** The diamond (left panel) is perceived as a square (right panel) when the tilted global rectangle, which defines a tilted "object-centered" orientation. (From Ivry & Robertson, 1998, p. 21)



**Figure 5.3** An illustration of a candidate models for selectivity of (a) expanding and (b) clockwise rotating stimuli may be produced in MSTd. Each arrow represents the activity from an efferent MT cell(s) which show a linear preference for motion in the direction of the arrow. Each cell is sensitive to linear motion and the preferred motion varies systematically across the RF. This model would also allow for changes in preferred speed across the RF.

(from Snowden, 1994).



object individually. One of the features that define objects as “separate” is that they occupy separate locations in visual space. The location of each separate object must be coded individually, within a co-ordinate frame of reference which is intrinsic to the viewer e.g. retinal-, head- or hand-centred, depending upon the task (Humphreys & Riddoch, 1994; Tipper, Lortie & Baylis, 1992; Tipper et al., 1994a). Neurones in MT (medial temporal), as well as superior colliculus (SC) and V3 are implicated in motion perception. Although, they are directionally selective, this motion is mapped in Cartesian co-ordinates and their selectivity to speed of motion suggest that their function is to provide a ‘pattern-independent’ code for speed. When applied to the dynamic IOR procedure, it seems plausible that MT cells could code the motion of each of the peripheral objects separately, regardless of the fact that two other objects in the scene are moving with it in a coherent circular pattern. SC is already implicated in the IOR effect (see section 2.4) but area MT could provide the neural representation that is the basis of inhibition of individual objects.

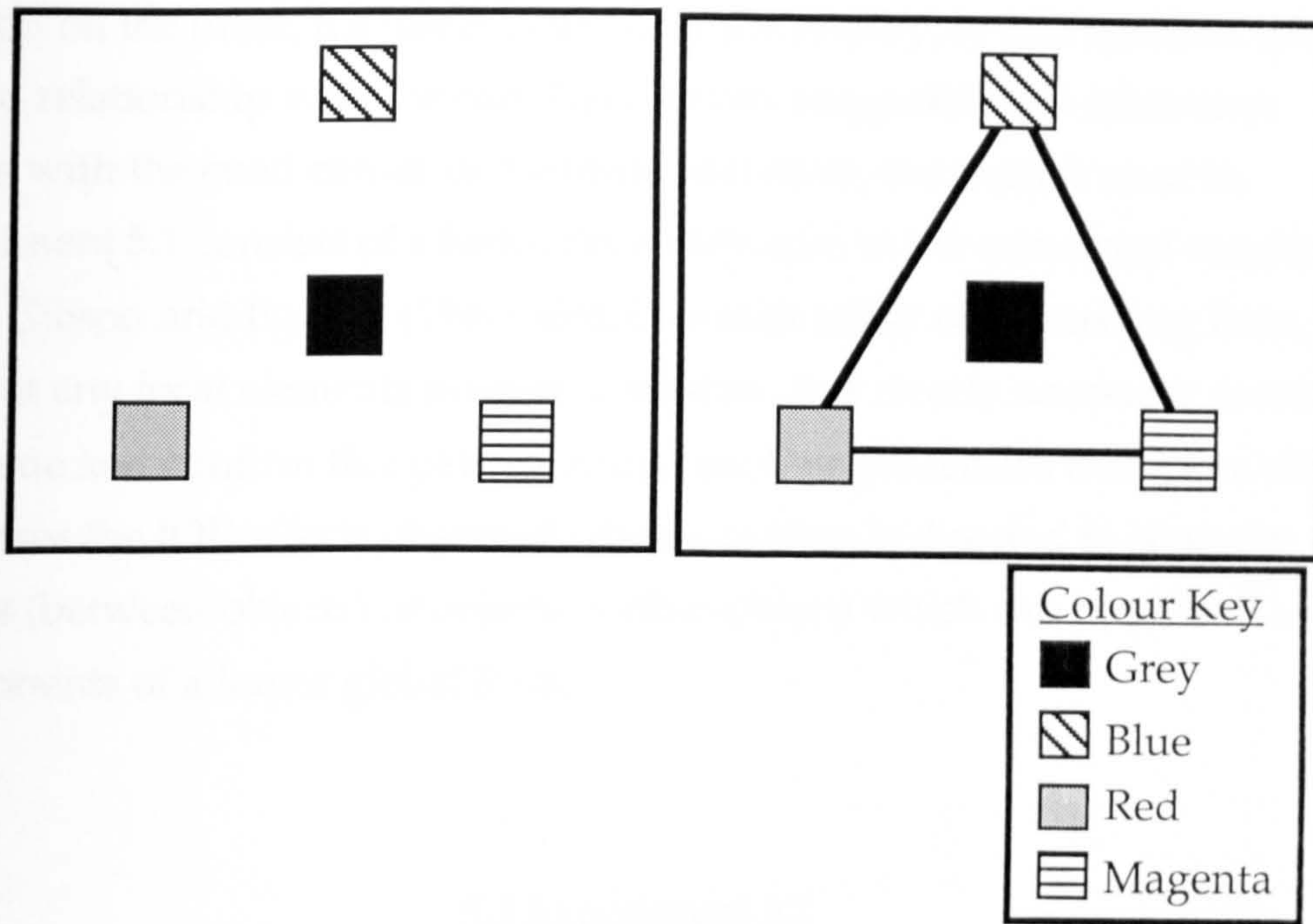
However, when objects are local elements of a larger single object, the visual system does not need to code individual locations. Rather, the visual processing system can “keep track” of the location of the global object, and subsequently recover the location of each of the elemental objects using an object-centred frame of reference. As the peripheral boxes rotate around the display in the dynamic IOR procedure, they undergo rigid transformations so that each of the component objects maintains its position within a structural description of the display. Thus, it is possible that that peripheral objects in Tipper and Weaver’s dynamic IOR procedure could be coded in an object-centered frame of reference (e.g. Biederman, 1987; Marr, 1982; Pinker, 1985). Simply linking the peripheral objects together with lines, following the logic of Behrmann & Tipper (1994; see also Humphreys & Riddoch, 1993; Luria, 1959; Tipper & Behrmann, 1996), should be sufficient to switch parsing of the dynamic IOR display into a representation which codes the display as a single global object with component local boxes. Area MST (medial superior temporal), which receives a direct projection from MT and projects to posterior parietal cortex and the pulvinar, could represent the three peripheral boxes in the dynamic IOR procedure as features of a coherent global object. Although a speculation, it is not inconceivable that this area



could represent the display as a single rotating (global) triangle that is made up of three (local) boxes. This area is thought to be divided into MSTd (dorsal), and MSTl (lateral). MST has a crude topographical organisation, with cells which are strongly directional selective and have large receptive fields (RFs). Some of the neurones, particularly in MSTd, respond strongly to rotating and frontal parallel motion as well as isotropically expanding and contracting patterns of motion. The magnitude of response of MSTd neurones are tuned for changes in angle (clockwise rotation/anticlockwise rotation) and radius (contraction/expansion) and pool responses across subsections of the RF (see Figure 5.3). Each cell receives input from several MT neurones, each with its own preference for linear motion in a particular direction (shown by the arrows). The combination of these cells gives MSTd the ability to code complex motion and object-centred information across a large part of the visual field. This area presumably would represent a dynamic display as three component objects moving in the formation of a single triangle.

The location-based IOR effect is thought to be mediated by SC and associated mid-brain structures that do not have the ability to code complex form information. There is little reason to believe that the location-based IOR effect will be affected by a change in the relationships between peripheral objects in the dynamic three-box IOR procedure (Figure 5.4). In contrast, the object-based IOR effect is mediated by cortical regions of the visual processing system (See Tipper & Weaver, in press; Tipper et al, 1997 for further discussion). Evidence from balint syndrome and neglect patients suggests that attention is mediated by cortical structures that are sensitive to object relationships and thus the object-based IOR effect should be modulated by switches between local (Figure 5.4, Left Panel) and global (Figure 5.4, Right Panel) parsing of the display. Previous work by Gibson and Egeth (1994b) using a quite different procedure, has suggested that IOR can be associated with a location within an object as well as the environmental location. In their study participants were presented with a two-dimensional drawing of an outline brick shape which was predictively cued at various corners (see also Umiltà, Castiello, Fontana & Vestri, 1995). After rotating in depth, a target was presented in a location on the brick. The subsequent target could appear in locations where the relationship between the cue and target was; the same





**Figure 5.4** Illustration of the three-box display used in the dynamic IOR procedure (left; Tipper and Weaver, in press) and the display used in Experiment 5.1 (right) to examine the effect of changing the structural relationship of objects by explicitly linking the peripheral boxes.

In the connected object display (Right Panel), it seems intuitive that the most efficient representation is in object-centred co-ordinates in which the location of the triangle is tracked, and those of the peripheral objects subsequently recovered. In contrast, although it is possible for the visual system to use the same frame of reference in the separate condition (Left Panel), empirical evidence of object-based IOR associated with an individual box suggests that a viewer-centred frame of reference is used.



location on the brick, the same location on the display, or in a location which had no relationship with the cue. Their results suggested that inhibition moves with the cued corner of the brick. However, the stimuli used in Experiment 5.1 consists of a hierarchical structure in the connected condition, while Gibson and Egeth's (1994) stimuli consist solely of connecting lines, without any local elements present. Therefore, it is clearly necessary to extend this issue and confirm this pattern within another procedure that more closely compares the IOR effects observed when attention is directed to separate objects (between-objects) or objects (within-object) which can be parsed as components of a larger global form.

### 5.3 Experiment 5.1

This experiment is designed to examine the effect of changing the structural relationships between the peripheral boxes in the dynamic three-box procedure (Weaver et al., in press). In the separate condition each of the peripheral boxes are discrete objects. In the connected condition, the peripheral objects are local elements within a larger global triangle.

#### 5.3.1 Method

*Participants.* Twenty undergraduate psychology students (five males) from University of Wales, Bangor (UWB) participated in the study for course credit. They ranged in age from 18 to 33 (mean age 22.0 years). All reported normal or corrected to normal acuity and showed normal colour vision when tested using Dvorine Pseudo-Isochromatic colour plates. All participants were naive to the purpose of the experiment.

*Apparatus.* Stimulus presentation and response time (RT) recording was carried out by an IBM compatible 486/33 microcomputer with a colour VGA monitor. Responses were collected via digital microswitches on a response box that was interfaced with the computer through the parallel printer port (see Dalrymple-Alford, 1992). RTs were computed to the nearest millisecond using Bovens and Brysbaert's (1990) TIMEX function.

*Stimuli.* The peripheral cue consisted of an enlarged coloured box ( $1.14^\circ$  horizontal  $\times$   $1.31^\circ$  vertical) with a superimposed white box ( $0.98^\circ$  horizontal  $\times$   $1.15^\circ$  vertical) with a further coloured box ( $0.41^\circ$  horizontal  $\times$   $0.50^\circ$



vertical) in the middle. The peripheral cue was presented for 86 ms and then overwritten by the original peripheral box. The central cue was identical, but always appeared at fixation.

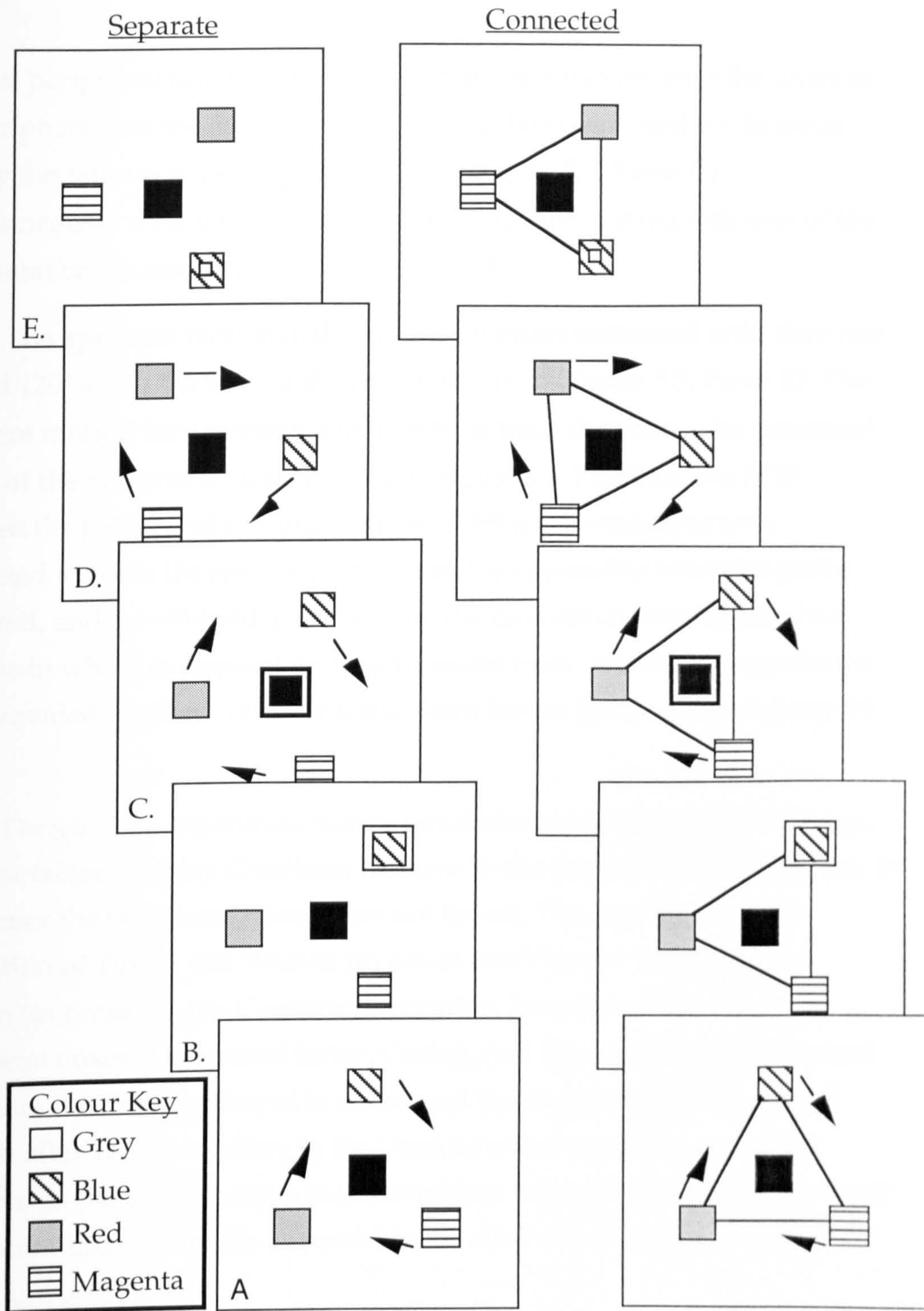
The target consisted of a small white filled box ( $0.98^\circ$  horizontal  $\times$   $1.15^\circ$  vertical) which was overlaid on one of the peripheral boxes.

*Procedure.* Each trial began with a centrally presented prompt to press the start key on the response box when the subject was ready to continue. Once the start key was pressed, the screen cleared and in all trials a dark grey box was drawn in the centre of the display surrounded by three coloured boxes (blue, red and magenta) in an imaginary circle around the central box (Figure 5.5, Panel A). In the within-object (boxes connected into a triangle) condition (50% of the trials) in addition to the four boxes, a line, 1 pixel in width, was drawn from the location of centre of each peripheral box to the location of the centre of the adjacent peripheral box, forming a triangle (Figure 1A, right panel). The peripheral boxes were overlaid on the lines, obscuring them. At a viewing distance of 70 cm (from a chin rest) the radius of the imaginary circle was  $4.4^\circ$  of visual angle. The boxes subtended  $.74^\circ \times .82^\circ$  (horizontal  $\times$  vertical).

The starting position of each of the three peripheral boxes was variable and randomly determined, with the constraint that each of the peripheral boxes was  $120^\circ$  (in polar co-ordinates) from the other two. The boxes appeared in this initial position for 1000 ms, and then began to rotate (either clockwise or anticlockwise) around the central box. The lines were updated appropriately in the Connected (within-object) condition. The apparent motion was achieved by switching of the graphics frames to produce the appearance of smooth motion of the peripheral boxes. The peripheral boxes moved by  $7.5^\circ$  (in polar co-ordinates) between each frame, with each remaining visible for 28.6 ms. Thus, 48 frames would be required to produce a full  $360^\circ$  rotation.

After three frames of movement the motion ceased and one frame later (28.6 ms) a peripheral box was replaced by a cue as shown in Figure 5.5, Panel B. The peripheral cue was presented for 86 ms and then overwritten by the





**Figure 5.5** Illustration of the stimuli and procedure used in Experiment 5.1. Three peripheral boxes were presented on grey background. In 50% of the trials the peripheral boxes were separate (Left panel) and in the remaining trials they were connected with dark-grey lines (Right panel). The peripheral (Panel B) and central cue (Panel C) were white flashes that occurred around the outside of boxes. The target (Panel E) was a filled white square that occurred inside one of the peripheral stimuli.



original peripheral box. One hundred and seventy two ms after the onset of the peripheral cue the fixation marker (central box) was cued for 86 ms in exactly the same way as the peripheral cue (Figure 5.5, Panel C).

Simultaneously with the onset of the central cue, the apparent motion of the peripheral boxes resumed (Figure 5.5, Panel D).

The apparent motion of the peripheral boxes continued until they had rotated  $120^\circ$  along the path of the imaginary circle (Figure 5.5, Panel E). The apparent motion then stopped and on 60% of trials the probe was presented in one of the peripheral boxes for 57 ms (Figure 5.5, Panel E). The SOA between the peripheral cue and target was 598 ms. Participants were instructed to press the response key as quickly as possible when the probe appeared, and to withhold a response on the catch-trials. Participants had 1000 ms in which to respond on target-present trials. A computer-produced tone provided feedback on error trials. Short breaks (30 s) occurred every 50 trials.

*Design.* The experiment used a two-factor repeated measures design. The first factor, Display Condition had two levels: Separate and Connected. In the former the peripheral boxes were not linked. This was an identical replication of Tipper and Weaver (in press) and Weaver, Lupiáñez and Watson (in press). In the Connected condition, lines linked the three peripheral boxes. The second factor, Cueing, had three levels: In the Uncued condition, the probe appeared in an uncued box that occupied an uncued location after  $120^\circ$  of rotation. In the Cued Location condition, the probe appeared in the uncued object that moved into the cued location. In the Cued Object condition, the probe appeared in the cued object that had rotated  $120^\circ$  into an uncued location.

Participants completed 40 practise trials (4 trials of each target-present condition plus 16 catch-trials) and 240 test trials. In 60 experimental trials, half of which were the Separate display, no target appeared. The remaining 180 target-present trials were made up of 60 trials for each of the three cueing conditions in the Separate and Connected displays in equal proportions.



### 5.3.2 Results

The initial 40 practice trials were excluded from the analysis. Trials with reaction times of less than 100 ms (anticipatory), greater than 1000 ms or inappropriate responses (misses and false alarms) were considered errors and excluded from subsequent analyses.

*Error Data.* The mean error percentages for all three cueing conditions for both displays are shown in Table 5.1. The error rates are very low, indicating that the participants completed the task with very little difficulty.

A 2 (Experimental conditions) X 3 (Cueing Conditions) repeated measures ANOVA was performed on the percentage error rates for the target present trials to ensure that the accuracy rate did not differ between conditions. This indicated that there was no main effect for either Display, ( $F(1,19) < 1$ ) or Cueing Conditions ( $F(2,38) = 1.5$ ,  $MSE = 3.0$ , n.s.) There was no significant interaction between these factors either,  $F(2,38) < 1$ .

A 2 (Experimental conditions) X 1 (Catch trials) repeated measures ANOVA was performed on the percentage false alarm rate in the target absent (catch trials). This indicated no significant difference between the connected and separate conditions,  $F(1,19) = 1.0$ ,  $MSE = 4.4$ , n.s.

*Response Time Data.* The mean median RTs (for correct trials) in each Cueing condition are illustrated in Figure 5. The RT data was analysed with a two-factor repeated measures ANOVA. The two independent variables were Display Condition (with two levels: peripheral boxes Separate and peripheral boxes Connected forming a Triangle) and Cueing (with three levels: Uncued, Cued Location and Cued Object).

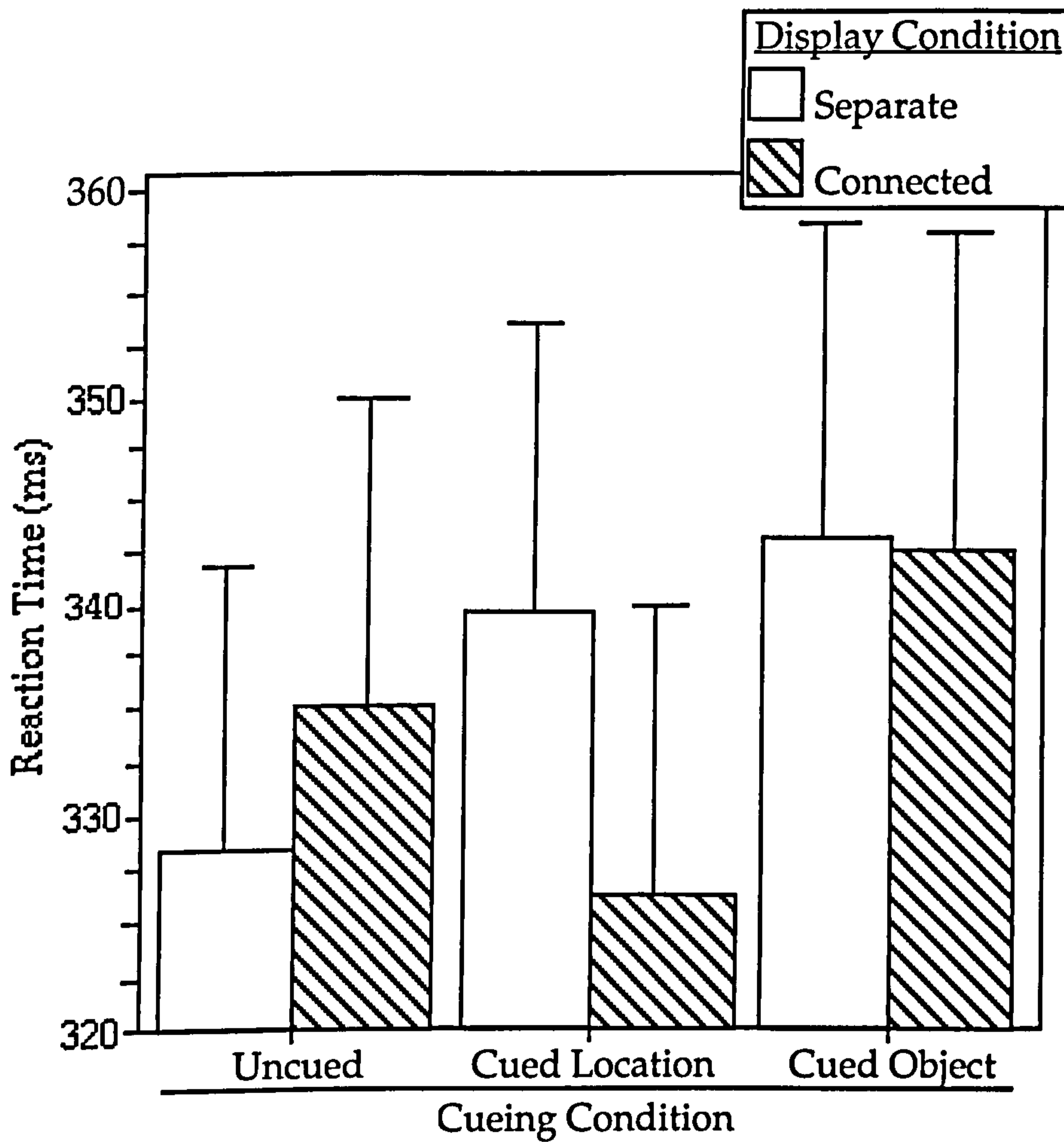
There was no main effect for the Display condition,  $F(1,19) < 1$ . The main effect for cueing was reliable,  $F(2,19) = 4.2$ ,  $MSE = 1595.0$ ,  $p < .05$ . Figure 5.6 indicates that, with the exception of cued location in the Connected condition, RTs were slower when the location/object was previously cued. Slower RTs in the Cued Location and Cued Object condition are indicative of the IOR effect.

The interaction between Display conditions and Cueing was significant,  $F(2,38) = 4.8$ ,  $MSE = 971.3$ ,  $p < .05$ . To further analyse this

**Table 5.1**

Mean error rates (%) and SE for each Cueing Condition in each Display Condition in Experiment 5.1.

	Uncued	Location	Object	Catch Trials
<u>Separate</u>				
M	0.8	0.5	1.0	2.2
SE	0.3	0.3	0.6	0.7
<u>Connected</u>				
M	0.5	0.3	1.2	1.5
SE	0.4	0.2	0.4	0.5



**Figure 5.6** Mean median RTs and standard error bars for Experiment 5.1.



interaction two separate AVOVA's were undertaken to examine first, the cueing effects for location (Uncued versus Cued location) and object (Uncued versus Cued object) frames. In the first analysis (the location-based effect) there was a significant interaction between display (connected v's separate) and cueing, ( $F(1,19) = 7.0$ ,  $MSE = 1911.0$ ,  $p < .05$ ). When the same 2 X 2 ANOVA was carried out on the object-based Cueing condition, only a main effect of cueing was observed in the object-based effect ( $F(1,19)=5.3$ ,  $MSE = 1814.5$ ,  $p < .05$ ); there was no hint of an interaction between separate/connected displays and cueing,  $F(1,19) < 1$ .

Thus, the Separate condition replicates the finding of object-based IOR as observed by Tipper and Weaver (in press; Weaver et al., in press) using a similar procedure. The pattern of data is quite different when the peripheral boxes are joined to form a larger global object (Connected condition). Although RTs to a target in the Cued Object are slower than in the Uncued condition, a trend towards a facilitatory effect is observed in the Cued Location condition.

### 5.3.3 Discussion

Analysis of the Object-Based (Uncued - Cued Object) IOR effect shows that IOR is observed, regardless of the structural relationships between the peripheral objects. These results replicate previous work examining between-object IOR (Abrams & Dobkin, 1994; Ro & Rafal, under review; Tipper et al., 1991; Tipper et al., 1994b; Weaver et al., in press). It also replicates Gibson and Egeth's (1994b) findings for within-object IOR. However, what is more surprising is that the location-based (Uncued and Cued Location) IOR effect is modulated by the relationship of the peripheral objects. In the separate object conditions, an 11 ms ( $t(19) = 3.2$ ,  $p < .01$ ) location-based IOR effect is observed when the target appears in a previously cued location. In contrast, when a location that is part of a larger object is cued a 9 ms ( $t(19) = -2.2$ ,  $p < .05$ ) facilitatory effect is observed for the detection of subsequent targets

This dramatic contrast between location-based cueing in the separated and connected displays requires replication for three reasons. Firstly, this result was not predicted, and suggests that location- rather than object-based IOR is mediated by an "object-aware" representation. As the mid-brain structures, which are thought to generate the IOR effect (see section 2.3.2), are



not capable of processing complex form information, it suggests that cortical processing is involved. This has important implications for models of IOR, including that proposed in Chapter 2. Secondly, the data observed in this study contrasts with Gibson and Egth's (1994b) observation of a significant location-based IOR effect within an object. Thirdly, it is inconsistent with the observation of both location- and object-based IOR in a similar triangle condition reported by Tipper and Weaver (in press). However, this previous study was a between subjects design, where participants only saw the connected (triangle) display. Poulton (1982) has argued that within and between subjects designs are qualitatively different. The influential companion effects he described there probably determined the results obtained in this experiment. For example, when subjects experience both separate and connected conditions randomly within the same experiment, the structural properties of the triangle may have been more salient due to the contrast when observing the three colour boxes rotating separately. Therefore Experiment 5.2 attempts to replicate and extend the observations of Experiment 5.1.

#### 5.4 Experiment 5.2

The triangle in Experiment 5.1 may have produced the subjective experience of a surface within the lines that connected the peripheral boxes. Experiment 3.1 showed that inhibitory mechanisms are sensitive to outlines that enclose regions of a display. In order to replicate and extend Experiment 5.1, ensuring that the contrast in the location-based effects between displays was not an artefact of subjective completion, a second experiment was carried out. Experiment 5.2 used an identical procedure, but the peripheral boxes in the within-object display now consisted of lines which ran from the centre of each box to the centre. This "spoke" display is shown in Figure 5.7.

##### 5.4.1 Method

As Experiment 5.2 is a replication of Experiment 5.1, only variations in the methodology are detailed below.

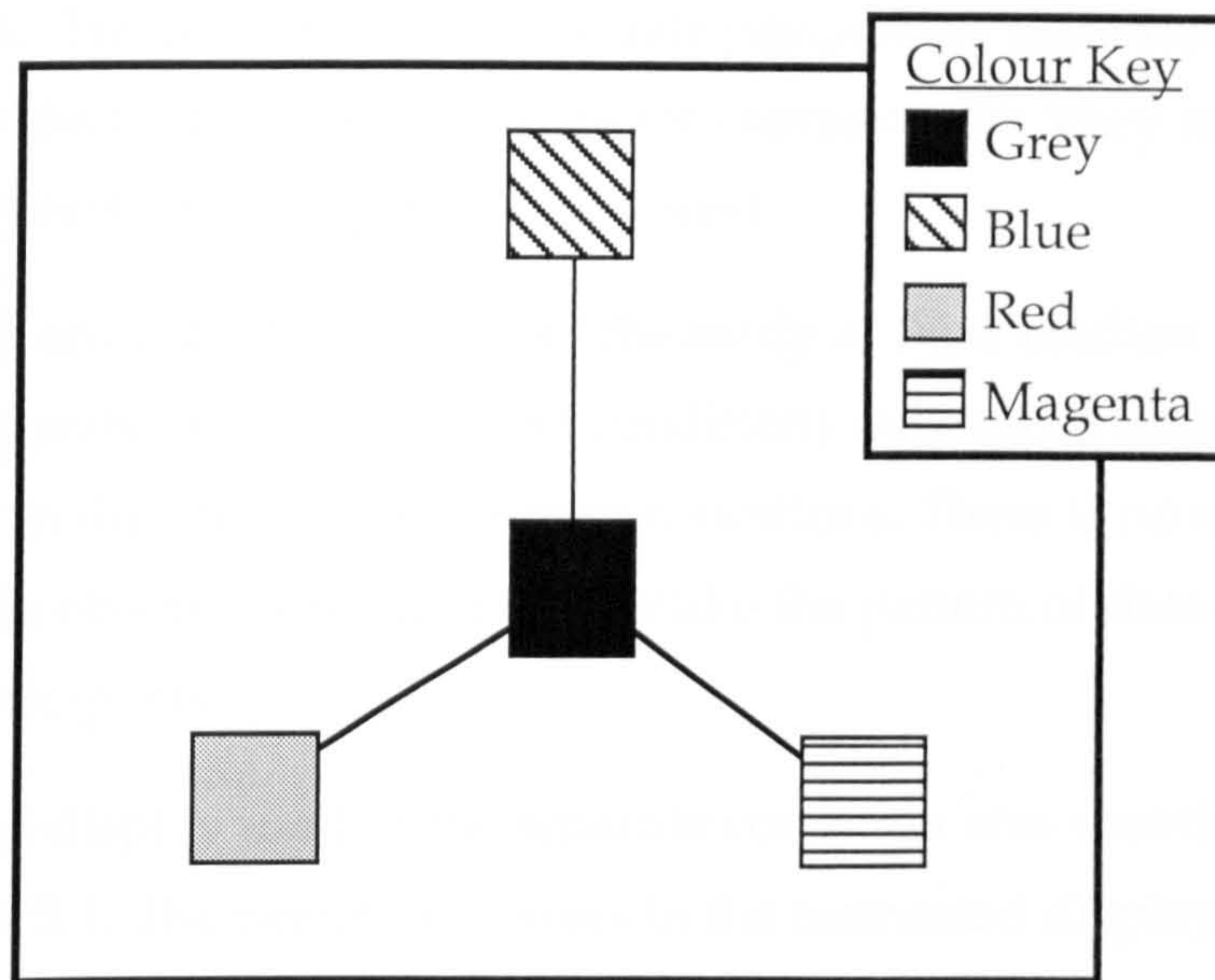


Figure 5.7 Illustration of the "Spoke" display used in the Connected condition of Experiment 5.2.



*Participants.* Twenty-one undergraduate psychology students (three male) from UWB volunteered to participate for course credit. They ranged in age from 16 to 26 years (mean age was 21.9 years).

One participant was excluded from the study as their median RT in one condition (Separate object cued object condition) were more than 2.5 SD slower than those in the other target present conditions. There is no obvious explanation for this observation and it was unlike the pattern of data for all the remaining participants.

*Stimuli.* The display used in the separate condition was identical to that in Experiment 5.1. The peripheral boxes in the connected display condition were linked by lines joining the centre of the fixation box to each peripheral object separately, producing "spokes". This display contrasts with the "wheel rim" display used in Experiment 5.1 where each peripheral box was joined to the adjacent ones. The displays are illustrated in the trial sequence in Figure 5.8.

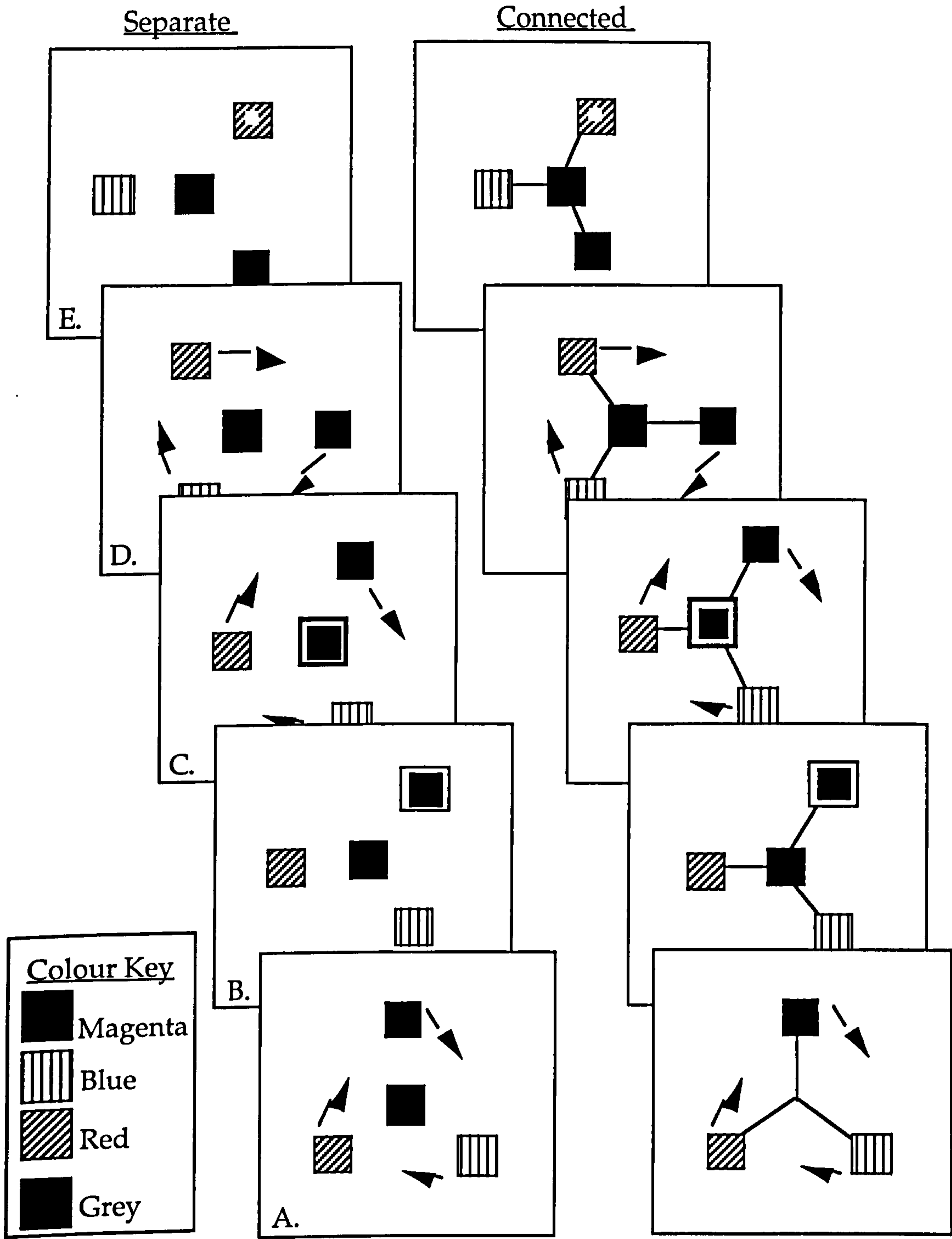
#### 5.4.2 Results and Discussion

Practice trials and those in which an error was judged to have occurred, using the criteria described for Experiment 5.1, were excluded from subsequent analysis. Percentage error rates are shown in Table 5.2 and the mean median RTs for each condition in Figure 5.9.

*Error Data.* As before, a 2 (Display condition) X 3 (Cueing condition) repeated measures ANOVA was carried out on the percentage errors for the target present trials. There were no reliable differences between either the Display conditions,  $F(1,19) < 1$  or the Cueing conditions,  $F(2,38) = 1.8$ ,  $MSE = 1.0$ , n.s. There was no interaction between Display and Cueing conditions,  $F(2,38) = 1.1$ ,  $MSE = 0.7$ , n.s. A 2 (Experimental conditions) X 1 (Catch trials) repeated measures ANOVA carried out on the false alarm rate for the target absent trials showed no significant difference between the two conditions,  $F(1,19) < 1$ .

*Reaction Time Data.* The median RTs for each condition were analysed as before using a 2 (Experimental Display: Separate, Spoke) X 3 (Cueing: Uncued, Cued Location, Cued Object) repeated measures ANOVA. The basic effects observed in this study replicate those from Experiment 5.1. There was





**Figure 5.8** The stimuli displays and trial sequence used in Experiment 5.2. In contrast to the previous experiment, the peripheral boxes were joined in a "spoke" formation by dark grey lines. These lines connected the centre of each of the peripheral boxes to the central (fixation) box. The background areas shown in white in this illustration were light grey.

no reliable main effect for Display,  $F(1,19) = 3.8$ ,  $MSE = 15678.4$ , n.s.. There was a main effect for Cueing,  $F(2,19) = 6.3$ ,  $MSE = 1924.4$ ,  $p < .01$  and the interaction between Display condition (Separate versus Connected) was significant,  $F(1,19) = 5.4$ ,  $MSE = 1499.8$ ,  $p < .01$ .

To examine this interaction, separate 2 (Experimental Display) X 2 (Cueing) ANOVA's were carried out to examine the pattern of data for objects and locations separately. As before, there was a significant main effect for Cueing in the object condition,  $F(1,19) = 11.5$ ,  $MSE = 3577.8$ ,  $p < .01$ , but no interaction between Experimental condition and Cueing. This indicates slower RTs to cued objects in both the Separate and Connected conditions. Planned means comparisons showed that there was a significant object-based IOR in both the Separate (15 ms;  $t(19) = 2.9$ ,  $p < .01$ ) and Connected (12 ms,  $t(19) = 2.2$ ,  $p < .001$ ) conditions.

The main effect for cueing locations was not significant,  $F(1,19) = 1.6$ ,  $MSE = 245.0$ , n.s. However, the interaction between the Cueing and Display conditions was highly significant,  $F(1,19) = 16.9$ ,  $MSE = 16.9$ ,  $p < .001$ . Once again, there was an inhibitory effect of cueing in the separate (15 ms;  $t(19) = 2.8$ ,  $p < .01$ ) and a contrasting facilitatory (8 Ms;  $t(19) = 1.5$ ,  $p < .05$ ) effect in the connected condition.

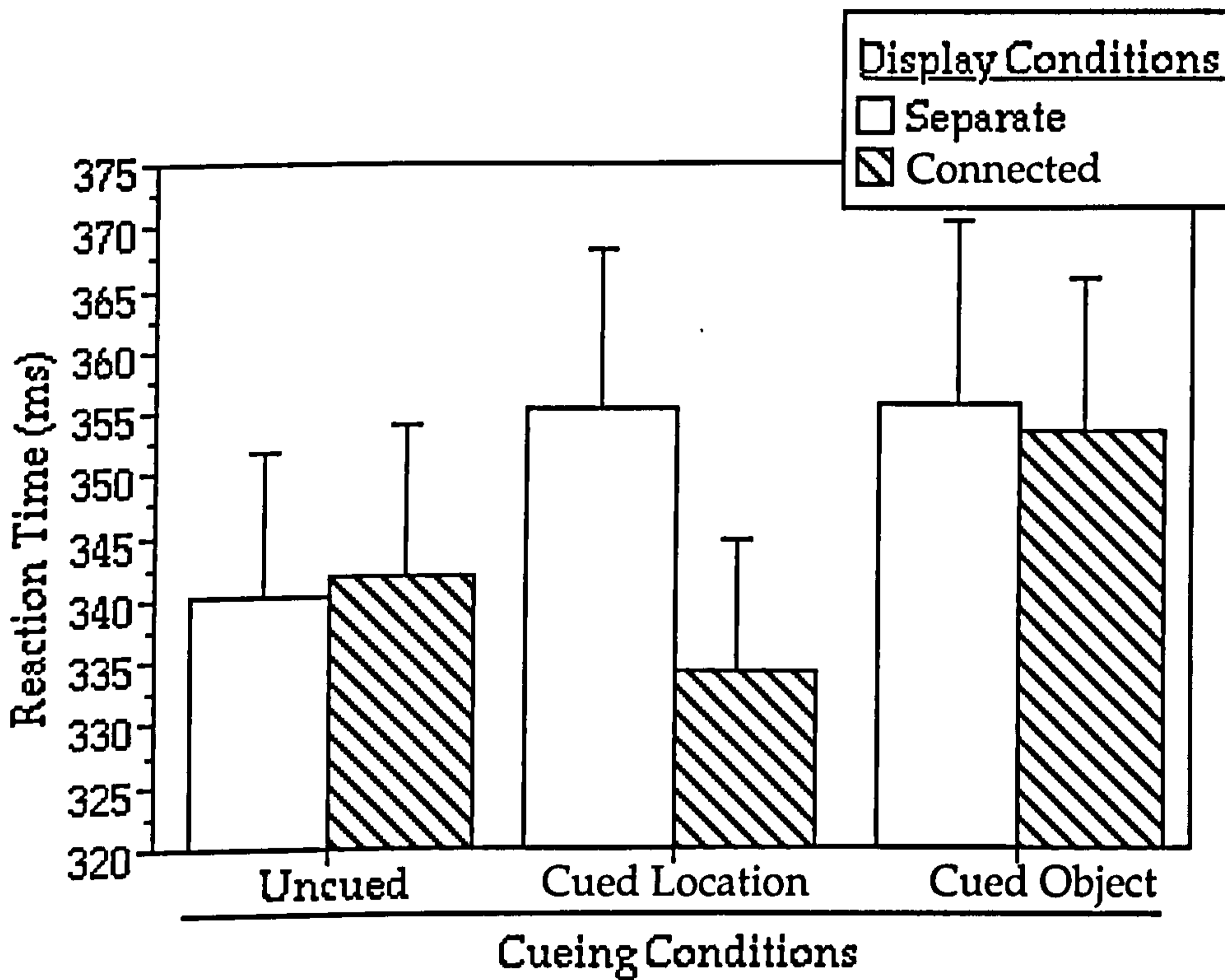
Experiment 5.2 clearly replicates Experiment 5.1. Object-based inhibition appears to move with both a separate object and with an object that is an element of a larger single (connected) object. Of most importance, the dramatic contrast in effects of cueing a location between the two Experimental Displays was replicated: in the separate condition the usual inhibition effect is observed, but in connected displays a small facilitation effect is produced.

There is a potentially crucial difference between the Experimental Displays in both Experiments 5.1 and 5.2. The connected displays are produced by the addition of lines between the peripheral and central boxes compared to the separate displays. Thus, there is a difference in the complexity of the display conditions. Although it is unclear why this should effect (only) the location-based IOR effect, a third experiment was carried out which controlled for the possible confound of complexity between the displays.

**Table 5.2**

Mean error rates (%) and SE for each Cueing Condition in each Display Condition in Experiment 5.2.

	Uncued	Location	Object	Catch Trials
<u>Seperate</u>				
<u>M</u>	0.5	0.3	0.7	1.2
<u>SE</u>	0.3	0.2	0.3	0.4
<u>Connected</u>				
<u>M</u>	0.0	0.3	0.7	0.9
<u>SE</u>	0.0	0.2	0.3	0.4



**Figure 5.9** Mean median RTs and standard error bars for each cueing condition in each display for Experiment 5.2.



## 5.5 Experiment 5.3

Experiment 5.3 replicates Experiment 5.1 but the black lines in the triangle display are added to the separate display, but without the creation of a single global object.

### 5.5.1 Method

*Participants.* Fourteen undergraduate psychology students (5 male) from (UWB) participated in the study for course credit. Their mean age was 25.4 years (range; 18 to 35 years).

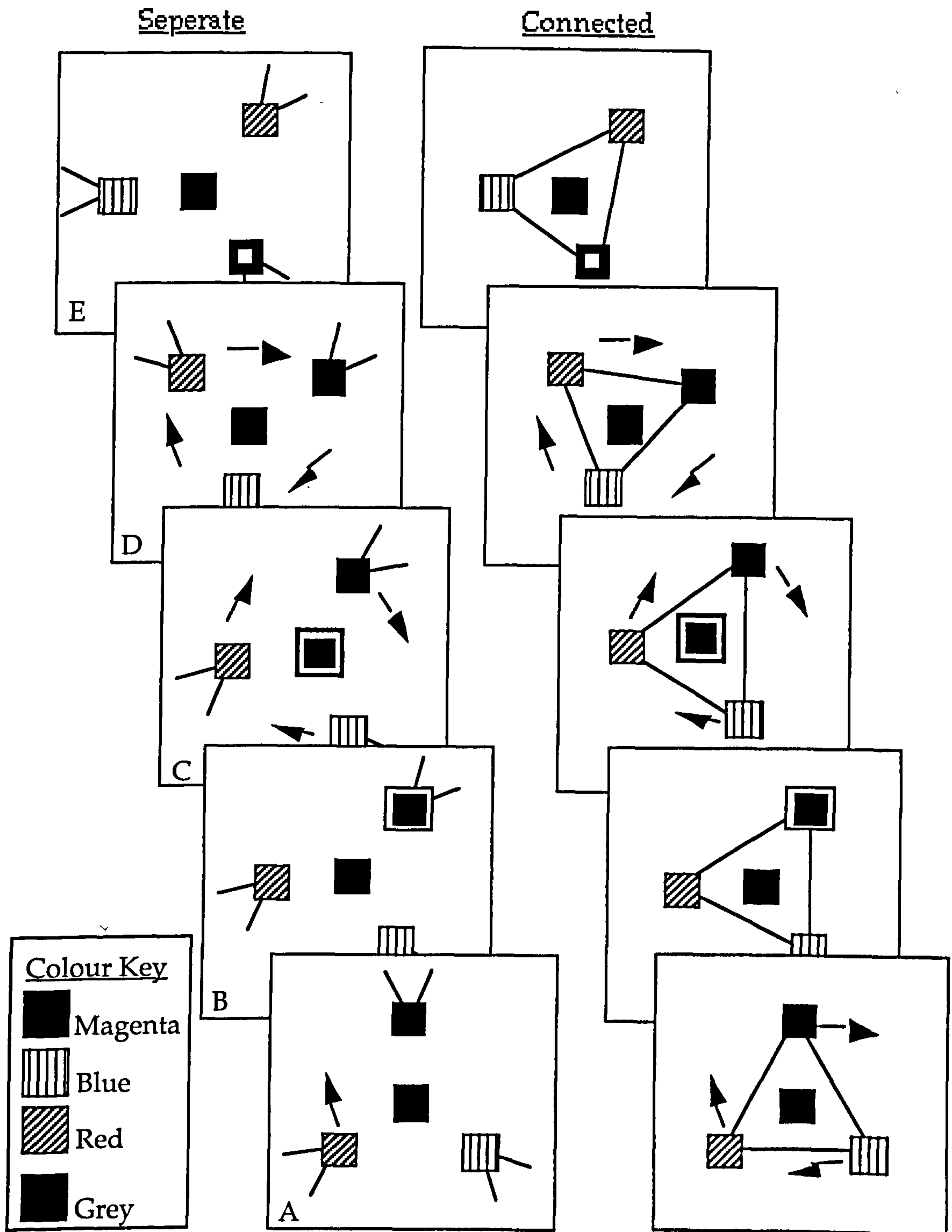
*Stimuli.* The stimuli displayed in the connected experimental display were identical to that used in Experiment 5.1. The centre of the peripheral boxes were joined to each of the adjacent boxes by means of a dark grey line ("wheel rim"). In the separate condition, identical lines were drawn, but split and rotated in location and orientation by 180°. Thus, the difference between the displays was that the peripheral boxes were associated with two lines pointing away (separate) or towards (connected) from the centre of the display in each peripheral location.

*Procedure.* The procedure was identical to Experiments 5.1 and 5.2 and a typical trial sequence is illustrated in Figure 5.10.

### 5.5.2 Results and Discussion

Trials with incorrect, slow ( $> 1000$  ms) and anticipatory ( $< 100$  ms) responses were excluded from the analysis as before. Two participants were excluded from the analysis as their mean error rate in all of the conditions was more than 8%. This is far higher than the typical error rates in this series of experiments ( $M = 0.5\%$ ,  $S.D. = 1.3\%$ ).

*Error Rate Data.* The mean error rates (in percentages) are shown in Table 5. A 2 (Display) X 3 (Cueing) repeated measures ANOVA was used to analyse the differences between the conditions. There were no reliable differences in the errors between Display,  $F(1,13) = 3.1$ ,  $MSE = 0.7$ , n.s. or Cueing conditions,  $F(1,13) < 1$ , n.s. The interaction was not significant,  $F(1,13) = 1.0$ ,  $MSE = 1.3$ , n.s. A 2 (Display) X 1 repeated measures ANOVA of the error rate percentages indicated that the difference of false alarms between the displays is not significant,  $F(1,13) = 3.9$ ,  $MSE = 1.7$ , n.s..



**Figure 5.10** Illustration of the procedure used in Experiment 5.3 which controls for a possible confound in the complexity of the display in Experiment 5.1. Note that lines were added to the separate condition (Left Panel), which radiated from each of the individual peripheral boxes. As the peripheral boxes rotated around the display the lines were redrawn so that they were oriented 180° in relation to the lines which linked the boxes in the connected display (Right Panel).

*Reaction Time Data.* The median RTs (Figure 5.) were analysed as before using a 2 (Experimental Display: Separated, Connected) X 3 (Cueing: Uncued, Cued Location, Cued Object) repeated measures ANOVA. There was no significant main effect for either Cueing ( $F(2,26) = 2.2$ ,  $MSE = 1145.4$ , n.s.) or Display ( $F(1,13) = 2.2$ ,  $MSE = 913.4$ , n.s.). Consistent with the two previous experiments, the interaction between Display Condition and Cueing was significant  $F(2,26) = 4.9$ ,  $MSE = 769.5$ ,  $p < .05$ .

Separate 2 (Display condition) X 2 (Cueing) ANOVA's were carried out for object- and location-based effects as before. There was no main effect for Experimental Displays [ $F(1,13) = .012$ ,  $MSE = 5.2$ , n.s.] for the Object analysis. The previous studies (Experiments 5.1 and 5.2) showed a main effect for cueing and the trend was in the same direction here, but the IOR effect was only marginally significant,  $F(1,13) = 3.7$ ,  $MSE = 2225.2$ ,  $p = .08$ . As before, there was no interaction between Display and Cueing,  $F(1,13) < 1$ ,  $MSE = 33.0$ , n.s. Planned means comparisons indicated that there was a significant object-based IOR effect in the Separate (14 ms;  $t(13) = 2.9$ ,  $p < .01$ ) and the Connected (11 ms;  $t(13) = 2.3$ ,  $p < .02$ ) display conditions.

As before, there was no main effect for Displays, ( $F(1,13) = 4.3$ ,  $MSE = 1089.4$ , n.s.) or Cueing in the Location analysis,  $F(1,13) = 1.5$ ,  $MSE = 936.4$ , n.s. However, the critical interaction between Display and Cueing conditions was significant,  $F(1,13) = 9.3$ ,  $MSE = 1330.9$ ,  $p < .01$ . Experiment 5.3 replicates the two previous ones as there is an (18 ms,  $t(13) = 3.9$ ,  $p < .001$ ) inhibitory effect in the separate condition and trend towards a contrasting non-significant facilitatory effect (2 ms;  $t(13) = 0.3$ , n.s.) in the connected condition.

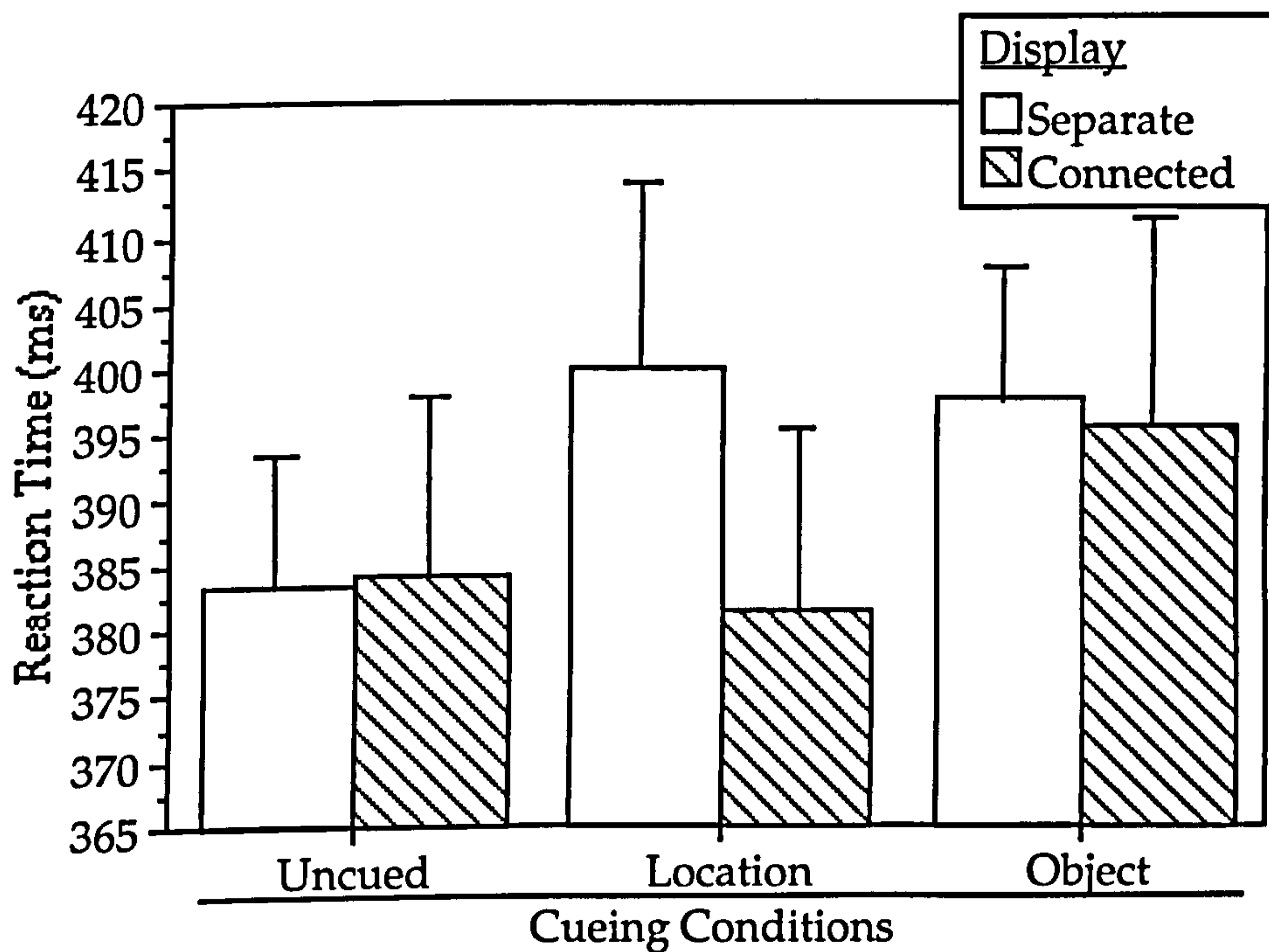
Even when the complexity of the stimulus displays are held constant, there is a qualitative difference between the separate and connected experimental displays when the target appears in a cued location. In the former case, location-based IOR is observed which is consistent with previous reports in the literature. In contrast, when the peripheral objects are connected as features of a single object, location-based facilitation is observed. In both displays, normal object-based IOR effects (Separate: 14 ms,  $t(13) = 3.1$ ,  $p < .01$ , Connected: 11 ms,  $t(13) = 2.4$ ,  $p < .05$ ) are observed.



**Table 5.3**

Mean error rates (%) and SE for each Cueing Condition in each Display Condition in Experiment 6.3.

	Uncued	Location	Object	Catch Trials
<u>Seperate</u>				
<u>M</u>	0	0.5	0.2	0.4
<u>SE</u>	0	0.3	0.2	0.3
<u>Connected</u>				
<u>M</u>	0.5	0.7	0.5	1.3
<u>SE</u>	0.3	0.5	0.3	0.6



**Figure 5.11** Mean median RTs (ms) and SE of cueing conditions in Experiment 5.3

### 5.6 Omnibus Analysis (Experiments 5.1 - 5.3)

Experiments 5.1, 5.2 and 5.3 show the same pattern of data. In order to increase the power of the analysis, the data was combined and analysed using a 3 (Experiment: Experiment 5.1, Experiment 5.2 and Experiment 5.3) X 2 (Display: Separate, Connected) X 3 (Cueing Conditions: Uncued, Cued Location, Cued Object) mixed design ANOVA. The variable Experiment is a between subjects factor while Display and Cueing Condition are repeated measures.

There was a main effect for Experiment which reflected reactions times which were slowest in Experiment 5.3 and fastest in Experiment 5.1,  $F(2,51) = 4.4$ ,  $MSE = 81659.7$ ,  $p < .05$ . As this is a between subjects comparison, the main effect is probably due to sampling errors and is of no theoretical importance. In addition, there were no significant interactions between Experiment and any other factor indicating that the pattern of effects are consistent across experiments.

There was a main effect for Display,  $F(1,51) = 6.5$ ,  $MSE = 2371.2$ ,  $p < .05$ , as participants were slower to detect the target when the three boxes were separate, compared to when they were joined together with lines. This is consistent with previous literature which suggests that shifts of attention are slower between objects compared to within objects (e.g. Duncan, 1984). There was also a main effect for Cueing,  $F(2,51) = 10.9$ ,  $MSE = 4243.9$ ,  $p < .0001$ . The only interaction which was significant was a highly reliable interaction between Displays and Cueing,  $F(2,102) = 14.0$ ,  $MSE = 3057.4$ ,  $p < .001$ . Planned means comparisons indicate a significant location-based IOR (13 ms,  $t(51) = -5.1$ ,  $p < .001$ ) and object-based IOR (14 ms,  $t(51) = -5.2$ ,  $p < .001$ ) in the separate condition. There is also a significant object-based IOR in the connected condition (10 ms,  $t(51) = -3.5$ ,  $p < .001$ ) but a significant facilitatory location-based effect (6 ms,  $t(51) = 2.1$ ,  $p < .05$ ). These are illustrated in Figure 5.12.

## 5.7 Discussion

Experiments 5.1 - 5.3 have been concerned with examining the effects of structural relationships of objects on inhibitory mechanisms. The effects of connecting the peripheral objects together in Experiments 5.1 - 5.3 produces a consistent change in the pattern of IOR effects. Each of these experiments showed that object-based IOR can be associated with a specific object in both connected and separate display conditions. The object-based IOR effect was robust across all experiments and was not affected by changes in the structural relationships of the peripheral objects. However, the location-based cueing effect varies qualitatively with changes in the structural relationships of the objects in the display. The cued locus was inhibited in a between-objects (separate) form of representation. However, when a location in a display where shifts were within-object (connected) location-based IOR was not observed. Thus, Experiments 5.1 - 5.3 did dissociate the location- and object-based IOR effects (Table 5.4). A boundary condition for the observation of the location- and not the object-based IOR effect was identified.

The crucial difference between the separate/connected displays is that an additional level of structure is imposed on the display in the connected condition. The peripheral boxes in the connected display are unambiguously local elements of a larger single triangle while they are parsed differently, presumably as separate objects, in the separate display. It is clear from this series of experiments that the (location-based) inhibition generating regions of the visual system are influenced by structural relationships. The location-based IOR effect is observed when processing resources are moved between objects but is not triggered when they are moved within a (global) object. However, it is inconsistent with the notion that the location-based IOR effect is generated exclusively by midbrain structures, as they do not have the ability to process complex form information. Tipper and Weaver (in press) used an identical display to that in the connected condition in Experiment 5.1 and 5.3, but in a between subjects design experiment. They failed to observe the abolition of location-based IOR effects in the connected displays. The contrast between separate and connected displays from trial-to-trial appears to be critical. An "influential companion effect" (Poulton, 1982) appears to emphasise the contrast between the display conditions. The unpredictability of the structural relationships between the peripheral objects from trial-to-trial



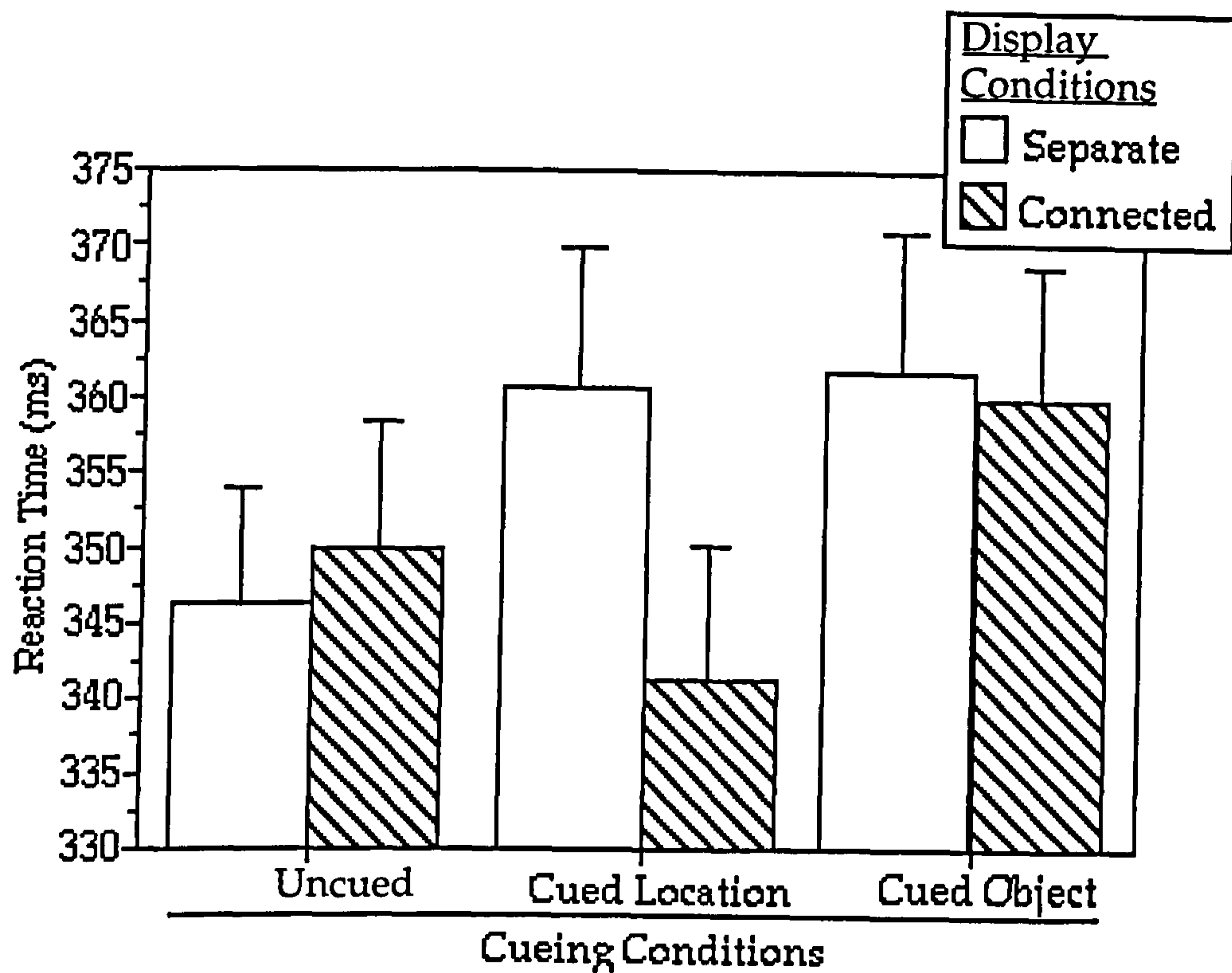


Figure 5.12 Mean median RTs with bars indicating one SE for each Experimental and Cueing Condition, collapsed across Experiment 5.1 - 5.3.

Table 5.4

Summary of the IOR effects observed in Experiments 5.1 - 5.3.

	Object+ Location IOR	Object- based IOR	Location-based IOR
<u>Between Subjects Exp.</u>			
Separate IOR procedure (e.g. Weaver et al, in press)		✓	✓
Connected (Tipper & Weaver, in press)		✓	✓
<u>Within Subjects Exp. (5.1-5.3)</u>			
Separate		✓	✓
Connected		✓	✗

prevents the location-based inhibitory mechanism “settling” to a local level of analysis, as it does in the Tipper and Weaver study.

It appears that the object-based IOR mechanism in Experiments 5.1 - 5.3 is mediated by a representation that is either “unaware” of structural changes and thus does not code the distinction, or is able to “ignore” them. As Gibson and Egeth (1994) showed that object-based IOR could be observed when a portion of a line drawing of an object was cued and rotated around the display, it seems unlikely that the representation which mediates object-based IOR is “unaware” of structural information. Rather the object-based IOR effect appears to be generated by a mechanism which associates inhibitory effects with individual elemental objects (viewer-centred frame of reference) in this task, rather than switching between viewpoints. In Experiments 5.1 - 5.3, the targets always appeared within an individual box and object-based inhibitory effects occurred at that level. This is consistent with Robertson, Egly, Lamb and Kerth’s (1993) report that when a local identification target occurred more frequently than a global one, local identification was facilitated and global identification was slowed. Thus, consistent with excitatory attentional effects, object-based inhibitory mechanisms can be directed to a particular level of a structural description.

In the previous experiments, object-based IOR was associated with an individual peripheral object, regardless of whether it was separate or an element of a larger single object. Changing the structural relationships between the peripheral objects had an affect on the location- but not the object-based IOR effect. This is inconsistent with the notion that the peripheral boxes are grouped together as they undergo rigid apparent motion.

The following experiment examines the role of individuating the peripheral objects on the inhibitory effects using a converging procedure. Kahneman and Treisman (1984) proposed that the visual system constructs abstract object files (or tokens) for individual real-world objects, and these are updated as the objects move or change. They specifically stated that the maintenance of the integrity of an object file is achieved via spatiotemporal (e.g. trajectory), not object dimension (e.g. colour, shape), characteristics of the object in the visual scene. There is some evidence to support the idea that spatiotemporal rather than object dimension characteristics are critical for

object-based attentional effects (Driver & Baylis, 1989; e.g. Kahneman et al., 1992; for review see Kanwisher & Driver, 1992; Pylyshyn & Storm, 1988; Tipper et al., 1990). However, it seems counter-intuitive that providing the visual system with object dimension information which helps to individuate and track the previously attended peripheral object does not modulate object-based inhibition in the dynamic IOR procedure. The previous experiments reported in this chapter showed that the visual system individuated the peripheral objects, even when they are connected to form a single object. Additionally, it was predicted in Chapter 2 and observed in Chapter 4 that the saliency of objects modulated the observed object-based IOR effect.

The following experiment tests whether presenting peripheral boxes, which were differentiated in both shape and colour, compared to a display of undifferentiated boxes, modulates the object-based IOR effect. Thus, in the former condition the visual system had more object dimension information available to individuate the previously attended peripheral object from the distractors and track it as it moved around the display. This should have no effect on the location-based IOR effect that is associated with (unchanged) spatial information. However, modulating the object-dimension information could produce one of two alternative affects on the object-based IOR effect. If Kahneman and Treisman (1984) are correct, there should be no effect on the object-based inhibitory mechanism. However, increasing the salience/information available to individuate the peripheral objects may initially increase the magnitude of the object-based IOR effect (see also Chapter 4). Both inhibitory effects should decrease with practice (Experiment 3.4). However, as colour and shape information is task-irrelevant (see section 4.4.1 the effect of practice on the object-based inhibitory effect should be larger.

#### 5.8 Experiment 5.4

The methodology of this experiment is the same as that described for Experiment 5.1, with the following exceptions.



### 5.8.1 Method

*Participants.* Thirty (8 male) undergraduate psychology students from University of Wales, Bangor participated for course credit. The mean age of participants was 21 years (range: 18 to 35 years). They were randomly assigned to one or other experimental condition.

*Stimuli.* All participants viewed one of two displays (Same/Different) throughout the session. Both displays consisted of three peripheral stimuli surrounding a central stimulus, which acted as a fixation marker, presented on a light grey background. The peripheral shapes made up the three corners of a triangle and the starting position of the individual peripheral stimuli varied randomly from trial to trial. Each of the stimuli on the display subtended 0.8 degrees by 0.9 degrees visual angle at a viewing distance of 65 cm from the display.

Same Condition Four dark grey objects appeared on the display which were identical in size and shape to those reported by Tipper and Weaver (in press) and Weaver, Lupiáñez and Watson (in press) (Figure 5.13, Panel A).

Different Condition The four shapes presented on the display varied in shape and colour. In all of the displays the central object was a dark grey cross. The three peripheral objects were a square, a circle and a triangle. One of the objects was magenta, another blue and the third red. The colours were randomised between trials so that a colour did not become associated with a shape.

In both of the displays the peripheral and central cue consisted of a white flicker which appeared for 86 ms. The flicker was created by making the relevant object slightly larger (by 3 pixels), superimposing a smaller white object and centring an even smaller coloured object on top of that. The target consisted of a white flicker which was the same shape, but slightly smaller (by 2 pixels) than the object on which it appeared.

*Design.* Three factors were manipulated in a mixed design. The first factor, Type of Stimuli, had two levels and was manipulated between subjects. One group of participants viewed the Same stimuli display, in which all the objects in the display were identical grey boxes. The remainder of the

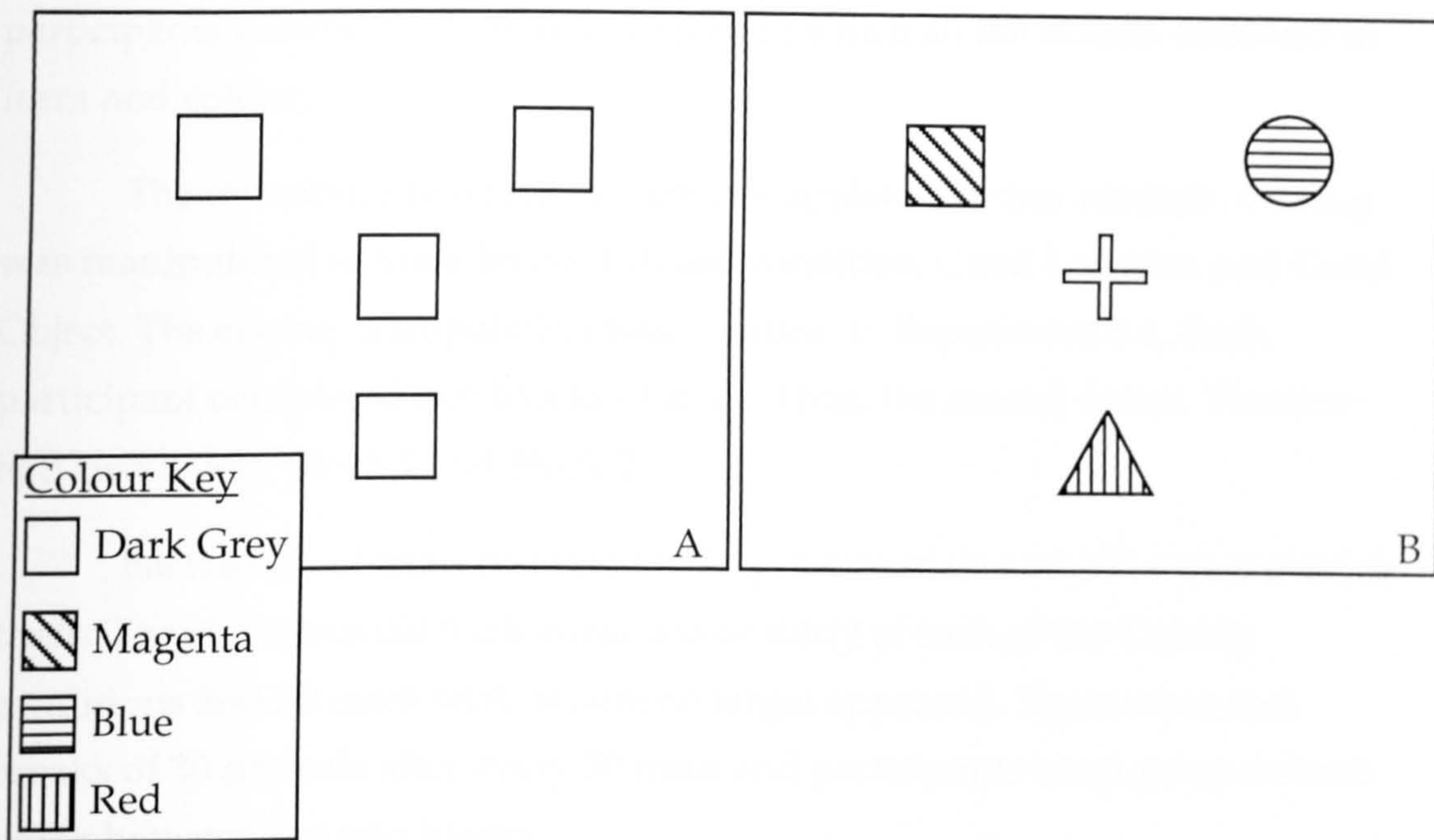


Figure 5.13 Illustration of the displays used in the same (Panel A) and different (Panel B) Types of Stimuli conditions of Experiment 5.1. In both cases, the background was light grey.

participants viewed the Different display in which all the objects different in form and colour.

The remaining two factors were manipulated within subjects. Cueing was manipulated at three levels: Uncued condition, Cued Location and Cued Object. The cueing manipulation was identical to Experiment 5.1. Each participant completed two blocks of trials. Thus, the second factor, Practice had two levels; Block 1 and Block 2.

Each block of trials consisted of 20 practice trials and 180 experimental trials. The experimental trials consisted of thirty of each of the Cueing conditions and 60 catch trials where no target appeared. There were rest breaks of 30 seconds after every 50 trials and participants were given a short break between the two blocks.

### 5.8.2 Results

Trials with inappropriate responses (false alarms and missed targets), anticipatory (less than 100 ms) or very slow (more than 1000 ms) were excluded as errors.

*Error Rate Data.* A 2 (Practice: First block, Second block) X 2 (Type of Stimuli; Shapes, Grey) X 3 (Cueing; Cued Location, Cued Object, Uncued) mixed design ANOVA was carried out the percentage error rate for each participant in each Cueing condition (Table 5.5). Practice and Cueing were repeated measures and Type of Stimuli was between subjects. There was no main effect for Type of Stimuli [ $F(1,30) < 1$ ], Practice [ $F(1,30) < 1$ ] or Cueing [ $F(2,60) < 1$ ]. There was no two-way interaction for any of the variables in the study and the three-way interaction was also insignificant.

A 2 (Practice) X 2 (Type of Stimuli) mixed design ANOVA was carried out on the percentage false alarms in the catch trial conditions for each participant. There were no main effects for either Practice ( $F(1,30) < 1$ ) or Type of Stimuli,  $F(1,30) = 1.1$ ,  $MSE = 2.5$ , n.s. There was no interaction between these two factors,  $F(1,30) < 1$ .

*Response Time Data* A 2 (Type of Stimuli; different, same) X 2 (Practice; First Block, Second Block) X 3 (Cueing; Uncued, Cued Location, Cued Object)



**Table 5.5**

Mean Error Rate (%) in the first and second block of Experiment 5.4. N = 15 in each Type of Stimuli condition.

Different				Same			
Uncued	Cued Object	Cued Location	Catch Trials	Uncued	Cued Object	Cued Location	Catch Trials
0.6	0.6	0.4	0.8	0.4	0.0	0.6	0.9
0.2	0.6	0.4	0.6	0.6	0.6	0.2	1.4

**Table 5.6**

Mean median Response Times (ms), Standard Error of RTs for each Cueing condition in the first and second block of Practice in Experiment 5.4. N=15 in each Type of Stimuli condition.

Blocks		Different			Same		
		Uncued	Cued Object	Cued Location	Uncued	Cued Object	Cued Location
1	M	345	360	364	303	312	308
	SE	(13.5)	(13.9)	(14.8)	(14.3)	(16.7)	(15.6)
2	M	324	334	332	291	295	297
	SE	(13.0)	(12.6)	(14.1)	(7.9)	(8.2)	(8.4)

mixed design ANOVA was carried out on the median RT data of correct trials for each participant in each condition (Table 5.5). Type of Stimuli was a between subjects comparison, while Practice and Cueing are repeated measures.

A main effect was found for the Type of Stimuli [ $F(1,28) = 5.9$ ,  $MSE = 13594.1$ ,  $p < .05$ ], as RTs were faster to targets in the same display. The absence of main effect in error rates between the displays suggests that this is not due to a speed/accuracy trade-off. However, this is a between participants comparison, so it may be due to either a sampling difference or a difference in the difficulty of the task (see discussion).

There was a significant main effect for Practice [ $F(1,28) = 14.8$ ,  $MSE = 1193.5$ ,  $p < .001$ ] reflecting decreased RTs to targets with experience of the task (Mowbray & Rhoades, 1959). There was also a main effect for Cueing [ $F(2,56) = 10.8$ ,  $MSE = 252.2$ ,  $p < .001$ ] indicating that target detection is influenced by its relationship to the peripheral cue. This effect is due to slower RTs to targets appearing in Cued Locations and Cued Objects compared to the Uncued condition. This is consistent with the cueing effects in the previous experiments. Cueing did not interact with either Experiment [ $F(2,56) = 1.5$ ,  $MSE = 165.5$ , n.s.] or Practice [ $F(2,56) = 1.1$ ,  $MSE = 226.3$ , n.s.] and three-way interaction between Type of Stimuli, Practice and Cueing was not significant,  $F(2,60) = 1.8$ ,  $MSE = 123.4$ , n.s.

Experiment 3.4 and the observations of Weaver et al (in press) suggest that both the object- and location-based IOR effects would decline with practice. It was predicted that manipulating the amount of object dimension information between the Same and Different displays would have an affect on the magnitude and/or the robustness of the object-based IOR effect with practice. Although an effect of practice on the location-based IOR effect was predicted, it was suggested that this would not vary between displays. Separate analyses of the effect of practice on the Location- and Object-based IOR effects were carried out. In each case a 2 (Practice; First Block, Second Block) X 2 (Type of Stimuli; Different, Same) X 2 (Cueing; Cued, Uncued) mixed design ANOVA was performed on median RTs of correct trials from the Different and Same groups.

*Location-based IOR.* There is a significant main effect for experiment as RTs were slower in the Different compared to the Same condition,  $F(1,28) = 5.5$ ,  $MSE = 8843.8$ ,  $p < .05$ . RTs decreased with Practice [ $F(1,30) = 13.0$ ,  $MSE = 585.2$ ,  $p < .01$ ] and a highly significant location-based IOR effect was observed,  $F(1,28) = 29.1$ ,  $MSE = 249.4$ ,  $p < .001$ .

Critically, the interaction between Practice and Cueing was not significant [ $F(1,28) = 1.9$ ,  $MSE = 205.4$ , n.s.] and there was no hint of a three way interaction between the two Types of Stimuli condition, Block and Cueing,  $F(1,28) < 1$ . There was a significant location based-IOR effect

*Object-based IOR.* The same analysis was carried out for the median RTs for the Cued Object and Uncued conditions. Consistent with the Location-based IOR analysis RTs in the Different display were slower compared to the Same condition,  $F(1,28) = 5.6$ ,  $MSE = 9093.8$ ,  $p < .05$ . RTs declined with Practice, [ $F(1,28) = 14.5$ ,  $MSE = 743.5$ ,  $p < .001$ ] and a significant object-based IOR effect was observed,  $F(1,28) = 12.5$ ,  $MSE = 472.0$ ,  $p < .01$ .

The interaction between Practice and Cueing was not significant,  $F(1,28) = 2.5$ ,  $MSE = 360.5$ , n.s.. Critically, the three way interaction between Type of Stimuli, Practice and Cueing was significant,  $F(1,28) = 4.7$ ,  $MSE = 76.4$ ,  $p < .05$ . The Stimulus displays did modulate the effects of practice on the object-based IOR effect, although they had no effect on the location-based IOR effect.

A 2 (Practice; first, second) X 2 (Cueing; uncued, cued object) repeated measures ANOVA on of the Same condition indicated that there was an 5 ms object-based IOR effect [ $F(1,14) = 4.3$ ,  $MSE = 416.0$ ,  $p = .05$ ] but it did not interact with practice. The same analysis of the Different condition showed a main effect for Cueing [ $F(1,14) = 8.3$ ,  $MSE = 2613.6$ ,  $p < .01$ ] and practice,  $F(1,14) = 18.7$ ,  $MSE = 10613.4$ ,  $p < .001$ . In contrast to the Same condition, the interaction between cueing and practice was also significant,  $F(1,14) = 4.4$ ,  $MSE = 540.0$ ,  $p < .05$ . Initially a highly significant 19 ms object-based IOR was observed ( $t(14) = 4.7$ ,  $p < .001$ ), which disappeared in the second half of the experiment (7 ms,  $t(14) = 1.8$ , n.s.).



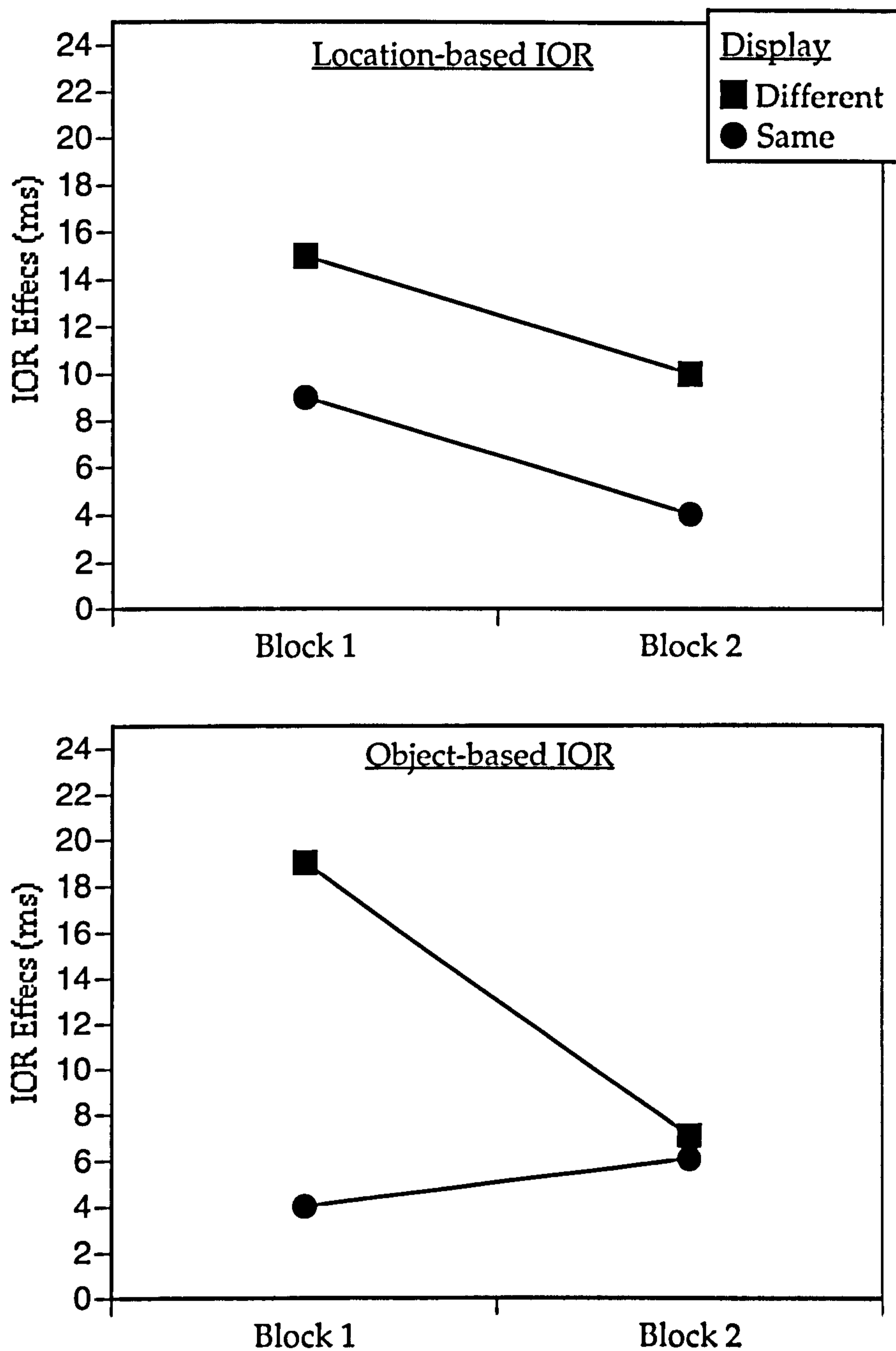


Figure 5.14 Location- (Cued Location-Uncued) and Object-based (Cued Object-Uncued) IOR effects in each block (180 trials) of Experiment 5.4. The interaction between practice and the cueing was significant for the object-based, but not the location-based effect.

### 5.8.2.1 Discussion

Overall, the results of this experiment are clear. Consistent with the prediction, changing the amount of object dimension information had no effect on the location-based IOR effect. This mechanism is blind to featural (but not structural) information about objects in the visual scene. Even in the first block, the appearance of the display had no impact on the location-based IOR effect. When a 2 (Cueing; Cued, Uncued) X 2 (Display (Same, Different) ANOVA was carried out on the data from the location condition in the first block alone, there was a significant location-based IOR effect,  $F(1,28) = 19.2, p < .001$ ). This did not differ between displays,  $F(1,28) = 1.2, n.s.$

In contrast, providing the visual system with extra object dimension information did increase the magnitude of the object-based IOR effect. When the same analysis was carried out on the object-based cueing condition, there was also a main effect for Cueing,  $F(1,28) = 9.7, p < .01$ ). However, this effect decreased with practice, as evidenced by a significant two-way interaction between Cueing and Display,  $F(1,28) = 9.7, p < .01$ ).

The observation that object dimension (shape and colour) changes modulate attentional effects in this experiment is inconsistent with Kahneman and Treisman's (1984) notion that spatio-temporal factors alone mediate object-based attentional effects. It also contrasts with the finding that facilitatory cueing effects are modulated only by the characteristics of the peripheral cue.

Although Müller and von Mühlénen (1996) suggested that the dynamic object-based IOR is fragile and hard to observe, this effect has always been observed using this procedure. A significant object-based IOR effect was observed in the same condition of this experiment, and on every occasion in the previous experiments in this chapter. Weaver et al (1996) and Tipper and Weaver (in press) report observing this effect consistently in their experiments and there are several unpublished studies from this laboratory which also show an object-based IOR effect. The object-based IOR effect has been observed in several independent laboratories, using different procedures (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b). Even Müller and von Mühlénen (1996) report observing the effect in unpracticed participants. The second block of the different condition is the first occasion in which

significant object-based IOR effects have not been observed using the procedure reported here.

Experiment 5.4 used a between subjects design, so participants were not aware that they were receiving relatively more or less object dimension information compared to the other experimental group. Thus, the differential effects of practice on the object-based IOR effect are automatic and not dependent on the relative quantity of object dimension information in the display.

### 5.9 General Discussion

The studies in this chapter have been concerned with examining the effect of changes of the visual stimuli on the object- and location-based inhibitory effects. It has been shown that manipulating the experimental stimuli has differential effects on the inhibition associated with previously attended spatial regions and objects. This is consistent with the notion that the object- and location-based IOR effects are the products of separate mechanisms. Changing the structural relationships between peripheral objects in the visual scene, and in turn the type of representation in which they can be coded, can abolish the location-based IOR effect (Experiments 5.1 - 5.3). Changes in the relative saliency of the peripheral objects modulates the effect on object-based IOR effects alone. Chapters 3 and 4 together provide direct evidence that the object- and location-based IOR effects can be dissociated. The experiments reported in this chapter confirm this observation as each inhibitory mechanism is subject to different boundary conditions.



## Chapter 6

### *Physiological Basis of Location- and Object-based IOR Effects*

#### 6.1 Summary

Previous research suggests that IOR is mediated by the retinotectal pathway to the midbrain (Rafal et al., 1989; Rafal et al., 1988). Rafal, Calabresi, Brennan and Sciollo (1989) reported a temporal/nasal hemifield asymmetry in the IOR effects in a static procedure under monocular conditions. However, when Experiment 3.2 was replicated under monocular conditions there was no evidence for a retinotectal hemifield asymmetry. Rather, a visual field asymmetry was observed in the IOR effect and this was due to the benefit in the object+location-, compared to the location-based IOR effect, being observed exclusively in the left visual field. There was no asymmetry in the location-based IOR effect. Although the physiological basis for the object-based IOR hemifield asymmetry is unclear, the effect was consistent with a previous report of visual field asymmetries in the IOR effect (Handy et al, 1995) and was replicated in two separate experiments.

## 6.2 Introduction

In the previous chapter it was observed that location-based IOR effects are modulated by the structural relationship between the peripheral objects in the dynamic IOR procedure (Experiments 5.1- 5.3). This result was surprising as the mid-brain structures which were thought to mediate the location-based IOR effect are very limited in their capacity to process form information. IOR is generally thought to be mediated by the retinotectal pathway which carries visual input to the superior colliculus of the midbrain (for brief review see Rafal, 1996). The midbrain structures have the capacity to control and co-ordinate eye-movements around a visual scene and perform simple visual form processing. The retinotectal pathway leads directly to the superior colliculi (SC), which are implicated in representing multi-modal (visual, auditory, tactile) stimuli in a series of co-registered spatial representations. Evidence that patients, with insults to the dorsal midbrain, exhibit distinctive deficits in the allocation of visual attention (e.g. Posner et al., 1982; Rafal et al., 1989) suggests that the SC and associated structures are involved in the movement of visual attention, particularly in response to exogenous visual events.

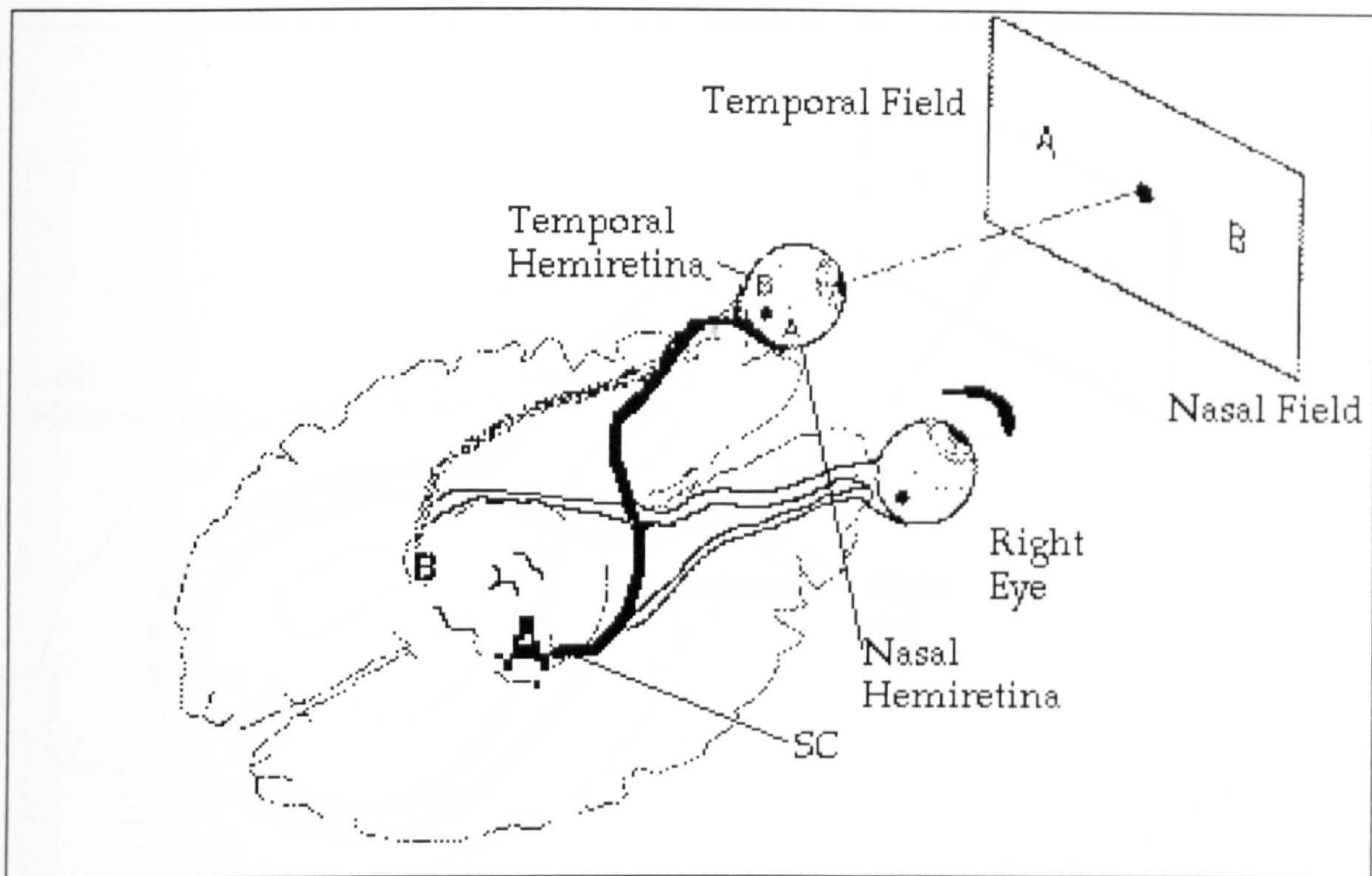
Evidence that the SC is directly implicated in the IOR effect is provided by a study that examined the effect of progressive supranuclear palsy (PSP) on the generation of inhibition. PSP is a progressive degenerative disorder that affects midbrain structures, producing many Parkinson's-like deficits. Uniquely, it also involves the SC and adjacent peritectal regions, and results in the distinctive paralysis of voluntary eye movements, particularly in the vertical plane. When a group of PSP patients completed a traditional static IOR procedure, Posner, Rafal, Choate and Vaughn (1985) found evidence for inhibitory effects on the uncompromised horizontal meridian, but none on the compromised vertical plane. In contrast, a control group with Parkinson's disease, which does not implicate the SC, showed normal IOR on both meridians. Thus, the SC appears to play a unique role in the inhibitory mechanism of visual processing.

Separate, and parallel, geniculostriate and retinotectal pathways carry visual information from the retinae to cortical and subcortical regions respectively. The retinotectal pathway receives predominantly crossed fibres from the contralateral eye. Furthermore, these projections are asymmetrically represented so that each eye receives more information from its temporal

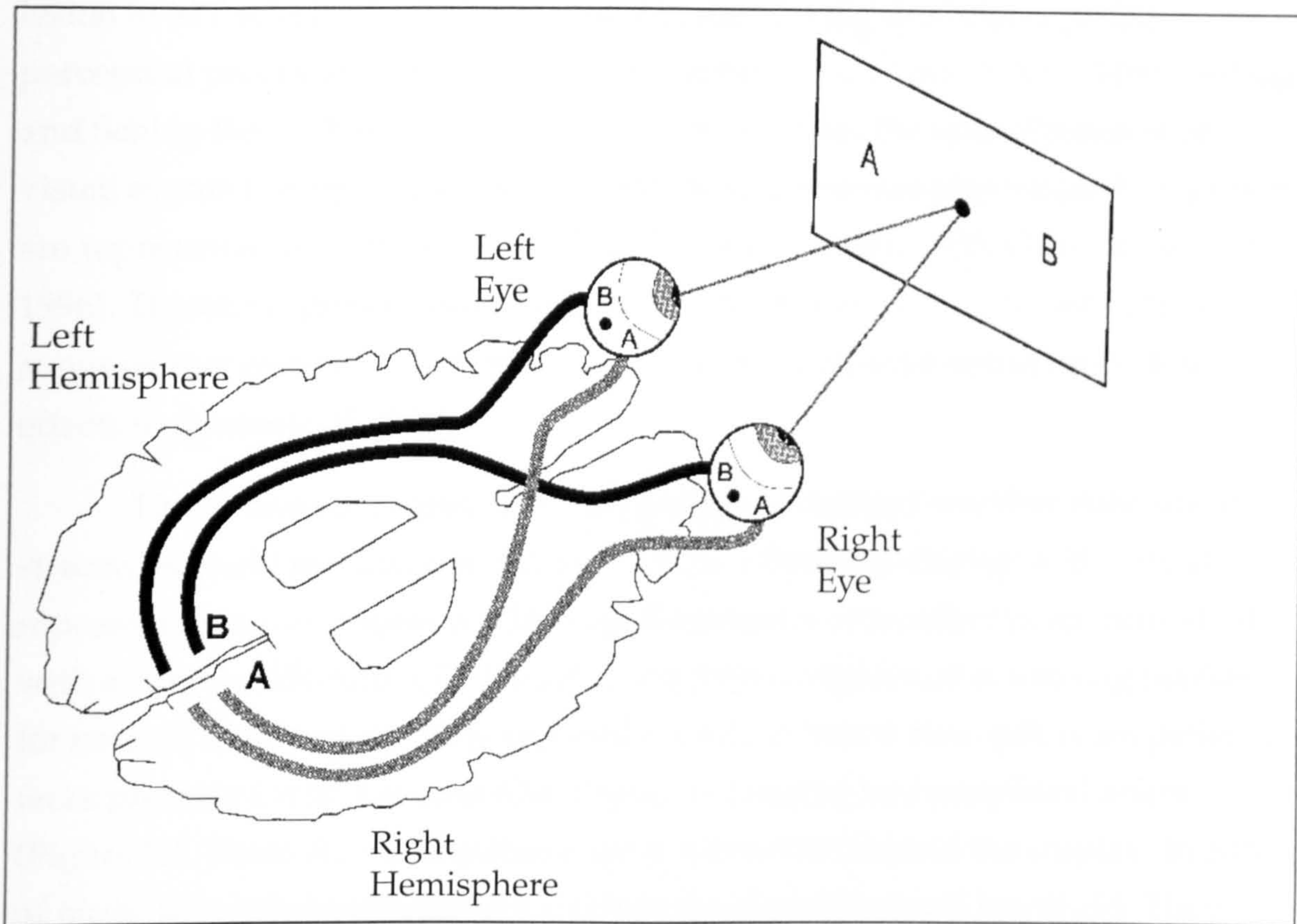
hemifield. Costs and benefits of orienting attention are greater in the temporal, compared to the nasal hemifield when attention is summoned by an uninformative peripheral cue under monocular conditions (Rafal et al., 1991) (Figure 6.1). In contrast, the geniculostriate pathway carries both crossed and uncrossed fibres, so that the visual cortex of each hemisphere receives bilateral projections that represent the contralateral visual field of each eye (Figure 6.2). Rafal, Calabresi, Brennan and Sciolto (1989) exploited the lateralised neuroanatomical arrangement of the retinotectal pathway to discriminate which of the two alternative pathways mediates IOR. They observed a larger IOR effect for cues that appeared in the temporal, compared to the nasal, hemifield and concluded that IOR is mediated by the retinotectal pathway. This temporal/nasal hemifield asymmetry has subsequently been replicated in infants (Simion et al., 1995). As young infants (< 4 months) do not have an encephalised geniculostriate pathway all vision is mediated via the retinotectal pathway. The observation of IOR in newborns (< 1 day) (Valenza, Simion & Umiltà, 1994) and young infants (Clohessy, Posner, Rothbart & Vecera, 1991; Hood, 1993; Simion et al., 1995) provides converging evidence that IOR can be mediated by the retinotectal pathway. Finally, Danziger et al (1997) have shown that an IOR effect can be observed in the absence of a geniculostriate contribution in the blind field of a patient with hemianopia (F.N.).

There is some evidence that suggests that the object-based IOR effect is generated by cortical regions of the brain. Observation of object-based IOR associated with a moving object in dynamic displays (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b; Tipper, Weaver, Jerreat & Burak, 1994b; Weaver, Lupiáñez & Watson, in press; section 5.3) requires sophisticated motion analysis which SC is not capable of without a cortical contribution (Goldberg & Wurtz, 1972; Gross, 1991; Schiller, 1972). Lesions to the SC, in patients with PSP, does not impair object motion perception as long as the middle temporal (MT) visual area, and the cortical regions which feed it, are intact (see also section 5.2). This is consistent with animal studies of the role of SC in perceptual processing (Graham, Berman & Murphy, 1982; Newsome, Wurtz, Dursteler & Mikami, 1985). In contrast, Zihl and colleagues have shown that a discrete





**Figure 6.1** Illustration of the visual pathways of the sub-cortical retinotectal pathway and the geniculostriate pathway to the visual cortex. In contrast to the geniculostriate pathway, which has binocular afferents, the retinotectal pathway is dominantly monocular and has a greater representation from the temporal hemifield. This asymmetry is represented in the above figure by the larger "A" in the contralateral SC.



**Figure 6.2** Illustration of the organisation of the cortical visual pathway which results in stimuli presented in the left visual field (A) being projected to the right visual cortex and stimuli presented in the right visual field (B) being projected to the left visual cortex. Eyes are fixated on the central dot. Taken from Ivry and Robertson (1998).



lesion to MT selectively abolishes object motion perception although other perceptual processes were unaffected (e.g. Zihl, Von Cramon & Mai, 1983). Schlag and Schlag-Rey (1983) have noted that the SC encodes the spatial location of visual events (for the control of eye movements), whereas object-based properties are represented by cortical regions (e.g. Olson & Gettner, 1995; Olson & Gettner, 1996). Therefore, present knowledge of the physiology of motion perception suggests that cortical contributions are required to observe object-based IOR effects in dynamic displays.

Tipper and colleagues (1997) empirically examined whether subcortical structures could mediate object-based IOR in a dynamic display or if cortical representations are required. Although the absence of an effect in an individual with a corpus callosum (CC) section is not direct evidence, it is a strong marker, for cortical involvement. They reported a study in which two split brain patients were presented with a typical IOR display containing two peripheral boxes (Figure 2.2, Panel A), which subsequently rotated 90° around the display. In 50% of trials, the peripheral boxes rotated into the opposite visual hemifield. They predicted that if object-based IOR is mediated by sub-cortical structures, this effect would be “carried” by the previously attended object into the opposite visual hemifield. However, if cortical structures were required, this cueing effect would be abolished when the previously cued object rotated into the opposite visual hemifield, as the sectioned CC prevented visual information being carried from one hemisphere to the other. As expected, object-based IOR was observed when the object remained within the visual field. Critically, they observed an object-based facilitatory, but not inhibitory, cueing effect when the previously cued object rotated into the opposite visual hemifield. The absence of an object-based IOR effect indicates that the inhibitory mechanism relies on cortically mediated structures. It also suggests that object-based facilitatory effects are mediated by a subcortical pathway e.g. cortico-pontine-cerebellar route (Glickstein, 1990), which do not require the involvement of the CC, and abolishing the inhibitory effect allows the underlying facilitatory effect to be observed (see section 2.2 for further discussion and Experiments 5.1 - 5.3 for converging evidence). The most parsimonious interpretation of the literature is that both object- and location-based inhibition effects are produced by the SC, but the location-based effect is generated by midbrain structures which receive their



input from the retinotectal pathway and the object-based IOR effect relies on cortical structures receiving geniculostriate pathway afferents.

Experiment 6.1 tests the notion that the IOR effects are generated by structures that receive their input via two separate visual pathways from the retinae. Experiment 3.3 was replicated under monocular and binocular conditions. If the location-based IOR effect is mediated by the retinotectal pathway leading directly to the midbrain, a temporal/nasal hemifield asymmetry should be observed in the location (no apparent object present) condition, but only in monocular conditions. It is suggested that the object-based IOR effect is the product of cortical inhibitory mechanisms that receive retinal input via the geniculostriate pathway. The literature concerning cortical asymmetries is far less clear. Egly, Rafal, Driver and Starreveld (1995) tested a split-brain patient on a modification of the rectangles pre-cueing procedure (Egly, Driver & Rafal, 1994; see chapter 4) and concluded that object information is only represented in the LH. This would predict a larger object+location-based IOR effect in the RVF in both monocular and binocular conditions.

### 6.3 Experiment 6.1

#### 6.3.1 Method

Experiment 6.1 is a replication of Experiment 3.3 with the following exceptions in experimental detail.

*Participants.* Eighteen (3 male) participants volunteered to take part in the experiment. The 9 undergraduates from the School of Psychology, UWB received a course credit and the remainder received £3. Their mean age was 21.8 years (range; 18 to 31 years). All were right handed, had normal or corrected-to-normal acuity and were naive to the hypothesis of the experiment.

*Apparatus and materials.* The study was carried out on a 486-66 IBM compatible computer in a dimly lit room. The stimuli were presented on a 14' colour VGA monitor and stimulus display and response collection was controlled by MEL 1.0. All participants sat approximately 70 cm from the display, and were restrained in a chin rest to ensure that their heads were centred on the display. Responses were collected via micro-switches on a response box, which was interfaced with the computer via the printer port.

The participant's eyes were patched using surgical gauze and tissue that was fixed in place with surgical tape. All participants reported that they had no vision through the eye patch. Those who wore spectacles, placed these over the patch and wore them as normal.

*Design.* The experiment used a repeated measures design in which four variables were orthogonally manipulated. The independent variables were: Eye patch (left covered, right covered, binocular (i.e. neither covered)), Type of Stimuli (Object+Location (apparent object present); Location (apparent object absent)), Target Location (left visual field (LVF), right visual field (RVF)) and Cueing (Cued, Uncued). The Eye-patched condition was blocked and the order of levels randomised for each subject. The remaining variables were randomised from trial to trial and completely crossed.

Each participant completed sixteen practice trials and 114 experimental trials in each of the Eye conditions. During the experimental trials they completed twelve trials for each of the combinations of variables and 18 catch trials in which no target appeared. The practice trials were randomly selected from the same pool of trials. Once they completed all of the trials for one eye-patch condition they were asked to remove the eye patch and replace it with a fresh one on the other eye (if appropriate).

### 6.3.2 Results and Discussion

The data from the practice trials and those with inappropriate responses (false alarms and misses) were discarded from subsequent analysis. As there were only 12 trials in each condition for each visual hemifield, median RTs are an inappropriate summary of the data. As an alternative trimmed mean RT was calculated for correct responses. Trimming was accomplished by removing trials more than 2.5 standard deviations from the preliminary mean. These trials accounted for less than 1% of the data.

*Reaction Time Data.* The trimmed mean RTs for each condition were submitted to a 3 (Eye patch: Binocular, Left-covered, Right-covered) X 2 (Type of Stimuli: Object+Location, Location) X 2 (Target Location: left, right) X 2 (Cueing: cued, uncued) repeated measures ANOVA. This indicated that the only reliable main effect was for cueing [ $F(1,17) = 41.4$ ,  $MSE = 4322.4$ ,  $p < .001$ ], with longer RT's to cued (355 ms) compared to uncued (313 ms) targets. This is consistent



with the IOR effect. Eye-patch,  $F(2,34) < 1$ , Target Location,  $F(1,17) < 1$  and Type of Stimuli,  $F(1,17) < 1$  had no reliable effects on RTs.

There was an interaction between the magnitude of the observed IOR effects and the eye patched,  $F(2,34) = 9.4$ ,  $MSE = 308.7$ ,  $p < .0001$ . The largest cueing effect was observed in the Right Covered condition (48 ms) and the least in the left covered condition (33 ms). There was a 41 ms IOR effect observed in the binocular condition. There is no theoretical reason why the amount of IOR should vary with eye condition and it is probably an artefact of the blocked design.

Consistent with the experiments reported in Chapter 3, there was a reliable effect of the Type of Stimuli on the Cueing effect,  $F(1,17) = 4.7$ ,  $MSE = 320.6$ ,  $p < .05$ . This experiment replicates the observation that more IOR is observed when attention is oriented away from a region which is occupied by an object compared to an unmarked region. There was a 44 ms IOR effect ( $t(17) = 18.2$ ,  $p < .001$ ) in the Object+Location condition, compared to a 37 ms IOR effect ( $t(17) = 15.2$ ,  $p < .001$ ) in the location condition. There was no hint of a three-way interaction between Eye-patch, Type of Stimuli and Cueing,  $F(2,34) < 1$ , n.s. The benefit in the IOR effect in the object+location condition was observed in each of the Eye Patch conditions.

More IOR was observed for regions in the left (53 ms;  $t(17) = 10.6$ ,  $p < .001$ ), compared to the right (32 ms;  $t(17) = 6.5$ ,  $p < .001$ ) visual field,  $F(1,17) = 8.5$ ,  $MSE = 1335.6$ ,  $p < .01$ . This asymmetry occurs in each of the Eye Patch conditions, as indicated by the absence of a three-way interaction between Eye condition, Target Location and Cueing,  $F(2,34) < 1$ , n.s.. However, there was a marginally significant three-way interaction between Target Location, Type of Stimuli and Cueing,  $F(1,17) = 4.0$ ,  $MSE = 963.8$ ,  $p = .06$ . This interaction is illustrated in Figure 6.3. There was a benefit in the magnitude of the IOR effects in Object+Location condition (61 ms;  $t(17) = 10.1$ ,  $p < .001$ ) compared to the Location condition (41 ms;  $t(17) = 6.9$ ,  $p < .001$ ) in the LVF. However, this benefit was absent in the RVF (Object+Location: 28 ms  $t(17) = 4.7$ ,  $p < .001$ ; Location: 33 ms  $t(17) = 5.5$ ,  $p < .001$ ). None of the other interactions were significant.

Rafal et al's (1989) study suggests that there should be a temporal/nasal hemifield asymmetry in the monocular conditions in this experiment. However,



there is no hint that the four-way interaction between Eye-patch, Type of Stimuli, Target location and Cueing in the previous analysis,  $F(2,34) = 1.9$ ,  $MSE = 344.9$ , n.s. If an asymmetry is present it will be small, and possibly hidden in the previous analysis by the binocular condition. Therefore the analysis was repeated on the data from the monocular conditions only. Again, there was no hint of the predicted hemifield asymmetry,  $F(1,17) = 2.6$ ,  $MSE = 484.0$ , n.s. Rafal et al (1989) marked the peripheral cue/target regions of the display with outline boxes, which confounds the object- and location-based IOR effects (see Chapter 3). Therefore, and in a final attempt, the analysis was repeated on the data from the object+location condition alone, which is equivalent to the traditional static IOR procedure. Once again, there was no hint of this asymmetry,  $F(1,17) < 1$ .

It seems fairly clear that this experiment fails to find any evidence for Rafal et al's reported temporal/nasal hemifield asymmetry in either the object+Location or location-based IOR effects. With the exception of Rafal et al's report and a single replication in 50 hour old infants (Simion et al., 1995) this asymmetry has been very elusive. Anecdotally, several laboratories have attempted to observe the retinotectal neuroanatomical asymmetry with no success. The anatomical asymmetry is much less pronounced in primates than cats (Perry, Oehler & Cowey, 1984; Williams, Azzopardi & Cower, 1995) but the absence of an encephalised geniculostriate pathway in infants requires retinotectal involvement. The boundary conditions under which the temporal/nasal hemifield asymmetry is observed, when both retinotectal and geniculostriate pathways are intact, is unclear at present. Failure to observe the asymmetry in this experiment does not exclude the possibility that the retinotectal pathway can be involved in mediating IOR effects (see General Discussion).

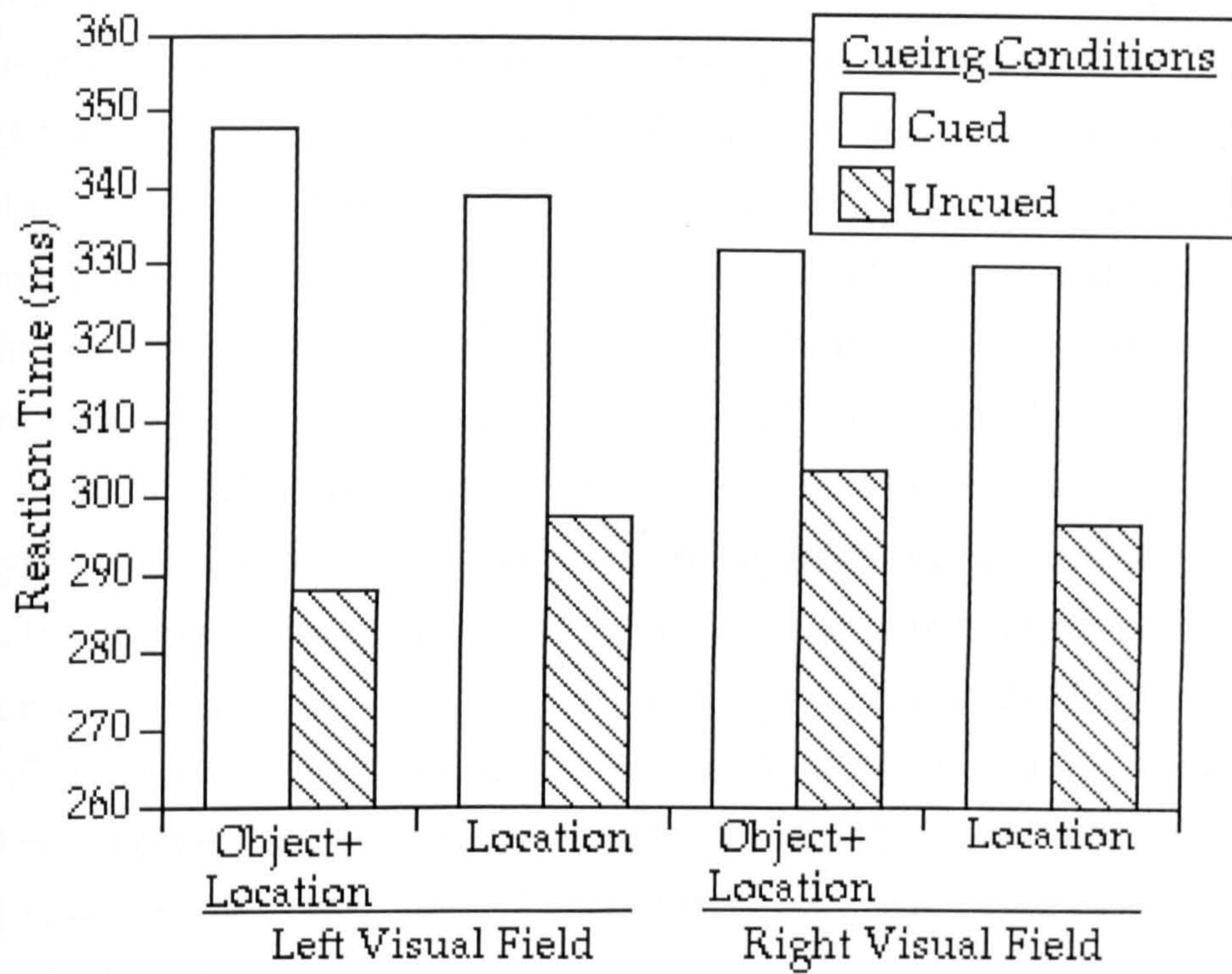


Figure 6.3 Mean Median RT's for each of the cueing conditions, varying with the Type of Stimuli in the left and right visual field in Experiment 6.1.



It is clear that there was an unpredicted cortical visual hemifield asymmetry present in this experiment, with larger IOR effect in the LVF (50 ms;  $t(17) = 9.4, t < .001$ ) compared to the RVF (32 ms;  $t(17) = 6.0, p < .001$ ). This contrast has previously been reported by Handy, Jha, Kingstone and Mangun (1995) in a threshold-level orientation discrimination task in two separate experiments that investigated the time-course of IOR. However, as Handy et al confounded the location- and object-based IOR effects by marking the peripheral regions with an outline box, they were unable to detect the cause of their visual field asymmetry. The data in this experiment suggests that their visual field asymmetry occurs in the object-based IOR effects; similar location-based effects are observed in both the LVF (40 ms;  $t(17) = 6.2, p < .001$ ) and RVF (35 ms;  $t(17) = 5.4, p < .001$ ), but there was a larger object+location-based IOR was present in the LVF (59 ms;  $t(17) = 9.0, p < .001$ ) compared to the RVF (28 ms;  $t(17) = 4.3, p < .001$ ). This is consistent with object-based IOR effects only being mediated by the right hemisphere (RH).

This unpredicted contrast is curious for two reasons. Firstly, when Egly, Rafal, Driver and Starreveldt (1995) specifically examined hemispheric laterality in location- and object-based facilitatory attentional orienting, they suggested that, while both hemispheres guide location-based attention, object-based effects are associated only with the left hemisphere (LH). This predicts an absence of hemispheric asymmetries in the location-based IOR effect in this experiment but that an object-based effect would only be observed in the RVF. Although the location-based IOR effect is consistent with this notion, the object-based effect shows the opposite pattern.

Secondly, although participants may identify targets in the LVF faster, due to a general alerting advantage of the RH (Posner, Inhoff, Friedrich & Cohen, 1987), previous studies have reported a RVF advantage in facilitatory cueing effects in precueing procedures involving both luminance detection (Egly & Homa, 1984; Gawryszewski, Riggio, Rizzolatti & Umiltà, 1987; Hughes & Zimba, 1985) and choice discrimination tasks (Anzola, Bertolini, Buchtel & Rizzolatti, 1977; Umiltà & Nicoletti, 1985). Reuter-Lorenz, Kinsbourne and Moscovitch (1990) suggest that the cortical hemispheres generate a contralateral spatial attentional bias and, when an orienting conflict is introduced, the rightward bias of the left hemisphere is relatively stronger. However, only Handy et al's (1995)



and this experiment have explicitly examined visual field asymmetries in the IOR effect and indicate that inhibitory cueing effects show the opposite bias.

As the visual field asymmetry in the object-based IOR effect was unpredicted, and potentially important in understanding the relationship between the inhibitory and facilitatory attentional effects, it is important to replicate it. Thus, a second experiment was conducted in which visual field asymmetries were examined only in the binocular condition. Dropping the monocular conditions allowed for an increase in the number of trials in each condition. Additionally, a between subjects design was used, which compared the effects of Type of Stimuli in the LVF and RVF in separate groups of participants, reducing any possible companion effects (Poulton, 1982).

## 6.4 Experiment 6.2

### 6.4.1 Method

Experiment 6.2 is a between-subjects version of Experiment 3.1. Thus, only inconsistencies between the two experiments will be reported here.

*Participants.* Thirty-seven undergraduate students (12 male) from the School of Psychology, UWB, participated for course credits. The mean age of the participants was 23 years (range from 18 to 36 years). The participants reported normal or corrected to normal acuity and normal depth perception. All participants reported seeing the Kanizsa illusion clearly in the debriefing session at the end and were naive as to the purpose of the experiment. One of the participants was excluded from the study due to self-reported epilepsy in his youth, with associated motion perception deficits.

The participants were randomly assigned to one of two display conditions. These conditions consisted of either modally completed boxes on the horizontal condition, or on the vertical axis.

*Apparatus.* The study was conducted in a darkened room. Subjects were seated at a table 70 cm in front of a 14 inch colour monitor with their heads resting on a chin rest. The VDU was adjusted so that they were looking directly at

the centre of the screen. Responses to the target were collected via the 'h' key on the attached keyboard (debounce rate = 4 ms).

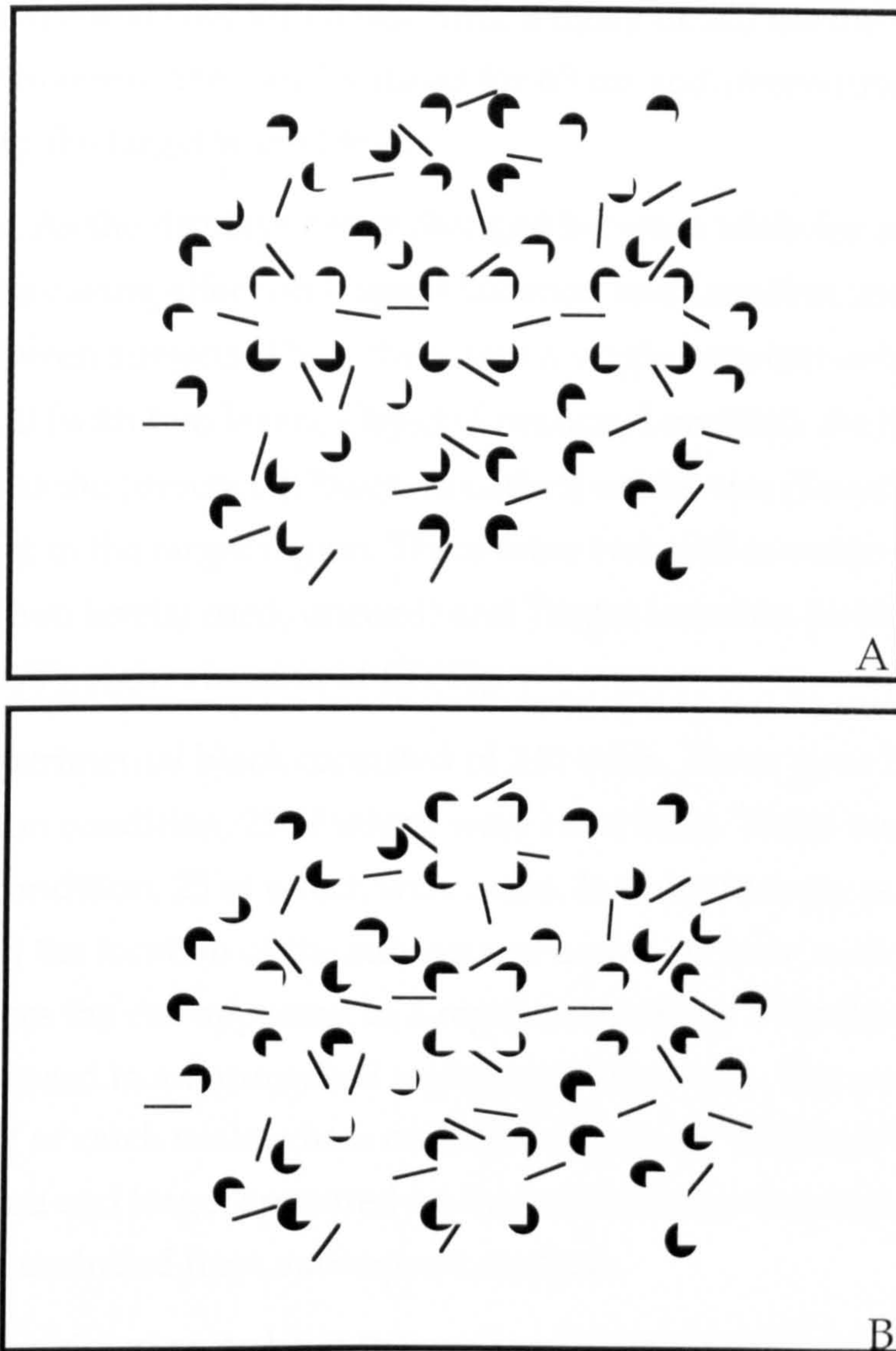
*Stimuli.* The black 'pacmen' and lines and the peripheral cues and target were identical to Experiment 3.1. The horizontal and vertical extent of the display was 18 cm X 14 cm (subtending 14 degrees visual angle by 11 degrees visual angle when viewed 70 cm from the display) (Figure 6.4).

As before, three apparent (illusory) squares (i.e. Kanizsa squares) which subtended  $2^\circ$  visual angle appeared when the inducer 'pacmen' were appropriately oriented. An apparent object always appeared in the centre of the display. However, one group always observed Kanizsa objects flanking the central object on the horizontal axis of the display (Figure 6.4, Panel A) and the other group viewed misaligned inducers in the same region (Figure 6.4, Panel B). In both cases, the cues and targets appeared 5 degrees from the centre of the fixation box.

*Procedure.* The display was described to the participants who were told that "grey squares" would appear shortly after the beginning of the trial. There was no reference to the "Kanizsa illusion". They were told that the three squares would appear on either the horizontal or vertical axis, depending on which group they were assigned to. The participants were instructed that they were to perform a target detection task, and that the target would appear above, below left or right of the centre of the display with equal probability.

The participants initiated each trial by pressing the space bar. At the start of each trial black circles and lines appeared on a light grey background. After 1120 ms the display was overwritten so that one quarter of each circle was removed, resulting in the appearance of 'pacmen'. For the Object+Location group of participants, the apparent objects (Kanizsa squares) always appeared on the horizontal axis (Figure 6.4, panel A) whereas no object appeared on the vertical meridian due to misaligned inducers. For the vertical axis group, the horizontal meridian was occupied by misaligned inducers, and the vertical meridian by Kanizsa squares (Figure 6.4, panel B). After 1120 ms the (peripheral) cue was presented for 83 ms and then overwritten, followed after 500 ms by a cue in the





**Figure 6.4** Illustration of the displays used in Experiment 6.1. Panel A shows the stimuli which were presented to the Object+Location group. Panel B depicts the Location display, which was shown to the other group. Note that unlike the experiments in Chapter 3 in which the Display varied within subject, this was a between subject factor in this experiment.



central square (central cue) for 83 ms. After a delay of 520 ms the target appeared equiprobably in one of the four locations for 83 ms and overwritten. The SOA from the cue to the target was 1186 ms.

*Design.* As the displays never changed between trials for an individual participant, the cueing effect on Object+Location and Location trials were compared between subjects. Thus, there was a single between-subject factor, Type of Stimuli (with two levels; Object+Location, Location). As before, Type of Stimuli refers to the presence (Object+Location) or absence (Location) of an apparent object in the target region. There were two within-subjects factors, Cueing (with two levels; cued, uncued) and Target Location (with two levels, left visual field (LVF), right visual field (RVF)).

The experimental block consisted of 240 trials. There were 50 trials in the Object+Location condition, 25 of which were cued trials. There were 50 trials in the Location condition, 25 of which were cued. In order that the peripheral cue did not predict the location of the subsequent target, 80 filler trials were presented where the cue appeared in a region marked by a Kanizsa square and the target appeared in an unmarked region and vice-versa. The remaining 20% of trials consisted of catch trials where no target appeared. The filler trials and those in which the cue and target appeared on the vertical axis were not of interest in this study and excluded from subsequent analysis.

Each participant completed twenty practise trials before commencement of the experimental trials. These were randomly selected and replaced from the experimental block. There were three equally spaced 30 s rest-breaks during the experimental trials.

#### 6.4.2 Results and Discussion

The response latencies in trials with incorrect responses, anticipatory (less than 100 ms) or very long (greater than 1000 ms) were designated as error trials and were excluded from subsequent analysis. This resulted in less than 1% of trials being excluded and no analysis was carried out.

*Reaction Time Data.* The mean median RTs for the cued and uncued trials for each of the Type of Stimuli conditions is shown in Figure 6.5. The median RT data was subjected to a 2 (Type of Stimuli; Object+Location,

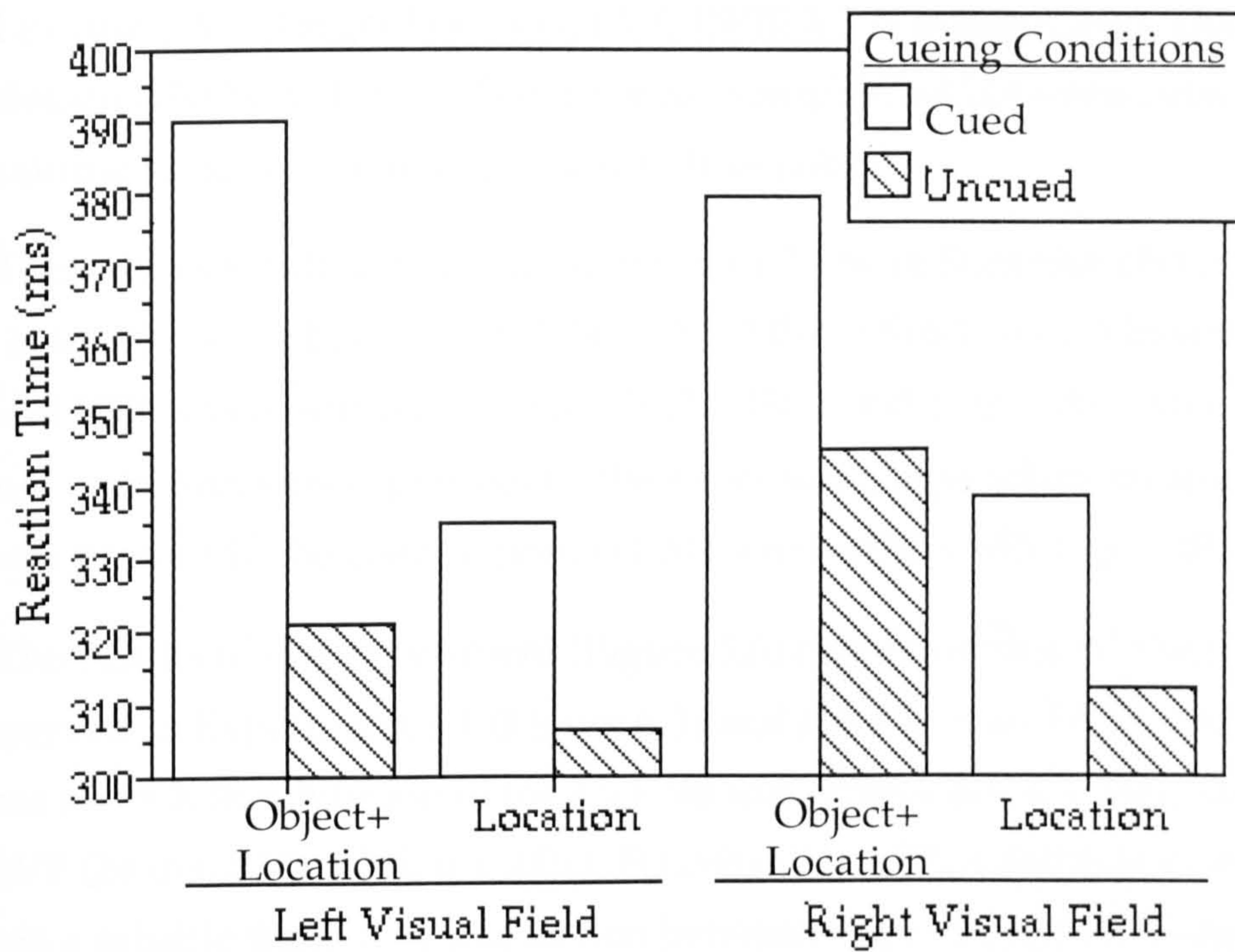


Figure 6.5 Mean median RT's for targets appearing on the horizontal axis of Experiment 6.2

Location) X 2 (Target Location; LVF, RVF) X 2 (Cueing; Cued, Uncued) mixed design ANOVA. Type of Stimuli was manipulated between-subject while the remaining factors were manipulated within-subject.

This analysis indicated no main effect for Type of Stimulus [ $F(1,34) = 3.2$ ,  $MSE = 14465.1$ , n.s.] or Location [ $F(1,34) = 2.3$ ,  $MSE = 514.1$ , n.s.]. However, significant IOR was observed [ $F(1,34) = 59.7$ ,  $MSE = 895.1$ ,  $p < .001$ ] and consistent with previous experiments, the effect was larger when an apparent object was present in the cued region,  $F(1,34) = 6.0$ ,  $MSE = 895.1$ ,  $p < .05$ .

The results of this experiment (Figure 6.5) clearly replicated the pattern of data observed in Experiment 6.1 (Figure 6.3) and Handy et al (1995). Overall there was more IOR inhibition in the LVF (45 ms,  $t(34) = 6.6$ ,  $p < .001$ ) compared to the RVF (24 ms,  $t(34) = 3.6$ ,  $p < .001$ ),  $F(1,34) = 5.2$ ,  $MSE = 560.8$ ,  $p < .05$ . Again, there was a reliable three-way interaction between Type of Stimuli, Target Location and Cueing,  $F(1,34) = 4.2$ ,  $MSE = 559.8$ ,  $p < .05$ . This reflects the same asymmetry observed in the previous experiment. The location-based IOR effect is similar in size in both visual fields, (LVF: 27 ms,  $t(34) = 3.7$ ,  $p < .001$ ; RVF: 25 ms,  $t(34) = 3.9$ ,  $p < .001$ ). However, more object+location IOR was observed in the LVF (68 ms,  $t(34) = 6.7$ ,  $p < .001$ ) compared to the RVF (34 ms,  $t(34) = 4.4$ ,  $p < .001$ ).

### 6.5 General Discussion

Experiment 6.1 failed to show evidence for the predicted temporal/nasal hemifield asymmetry in monocular conditions. However, larger IOR effects are observed in the LVF compared to the RVF and this asymmetry was present in the object- but not location-based IOR effects. The location-based IOR effect was similar in magnitude in the LVF and RVF. However, there was a benefit in the magnitude of the object+location-based IOR effects in the presence of an apparent object in the LVF, but not the RVF. This asymmetry was replicated in Experiment 6.2. The method of coding of trial conditions made it possible to re-examine the data from Experiment 3.4 to observe if the same visual field asymmetries were present there also. This analysis showed that the pattern of data repeated that observed in Experiments 6.1 and 6.2, although the three-way interaction was only marginally significant,  $F(1,9) = 3.8$ ,  $MSE = 757.6$ ,  $p = .08$ .



Previous studies have suggested that midbrain structures, particularly SC, are involved in mediating inhibitory effects. In section 6.2 it was predicted that evidence of a temporal/nasal asymmetry in the location-based IOR effect in monocular conditions should be observed in Experiment 6.1. There was no hint of this effect. The absence of evidence for the involvement of the retinotectal pathway does not preclude the SC from playing a unique role in generating the (location-based) IOR effect. The retinotectal pathway is not the only available route for visual stimuli to the midbrain structures involved in orienting. SC is part of a complex network that projects to and receives input from cortical visual areas, as well as other extrageniculate pathways (Figure 6.6). Projections from the SC are relayed to the cortex via the lateral posterior-pulvinar complex of the pulvinar. In turn the SC receives indirect projections from the frontal eye fields (FEF), which are implicated in voluntary eye movements, and posterior parietal cortex (PPC), which are involved in oculomotor activity and reflexes (Figure 6.6). The midbrain structures including SC are responsible for the output of a complex system which involves both cortical and subcortical regions of the brain. There is a possibility that the location- and/or object-based IOR effect could be generated by cortical (as well as or instead of subcortical) structures which feed down to the SC. Abrams and Dobkin's (1994) observation that the location-based IOR effect has a perceptual, in addition to an eye movement, component suggests that cortical structures may be involved in addition to midbrain structures as neurones in SC do not show attentional characteristics. Additionally, the observation that the location-based IOR effect was sensitive to changes in object structure (Chapter 5) is consistent with the notion that this effect is generated by cortical not midbrain structures, as the latter do not have the capacity to perform the complex form analysis required to interpret object relationships in hierarchical structures.

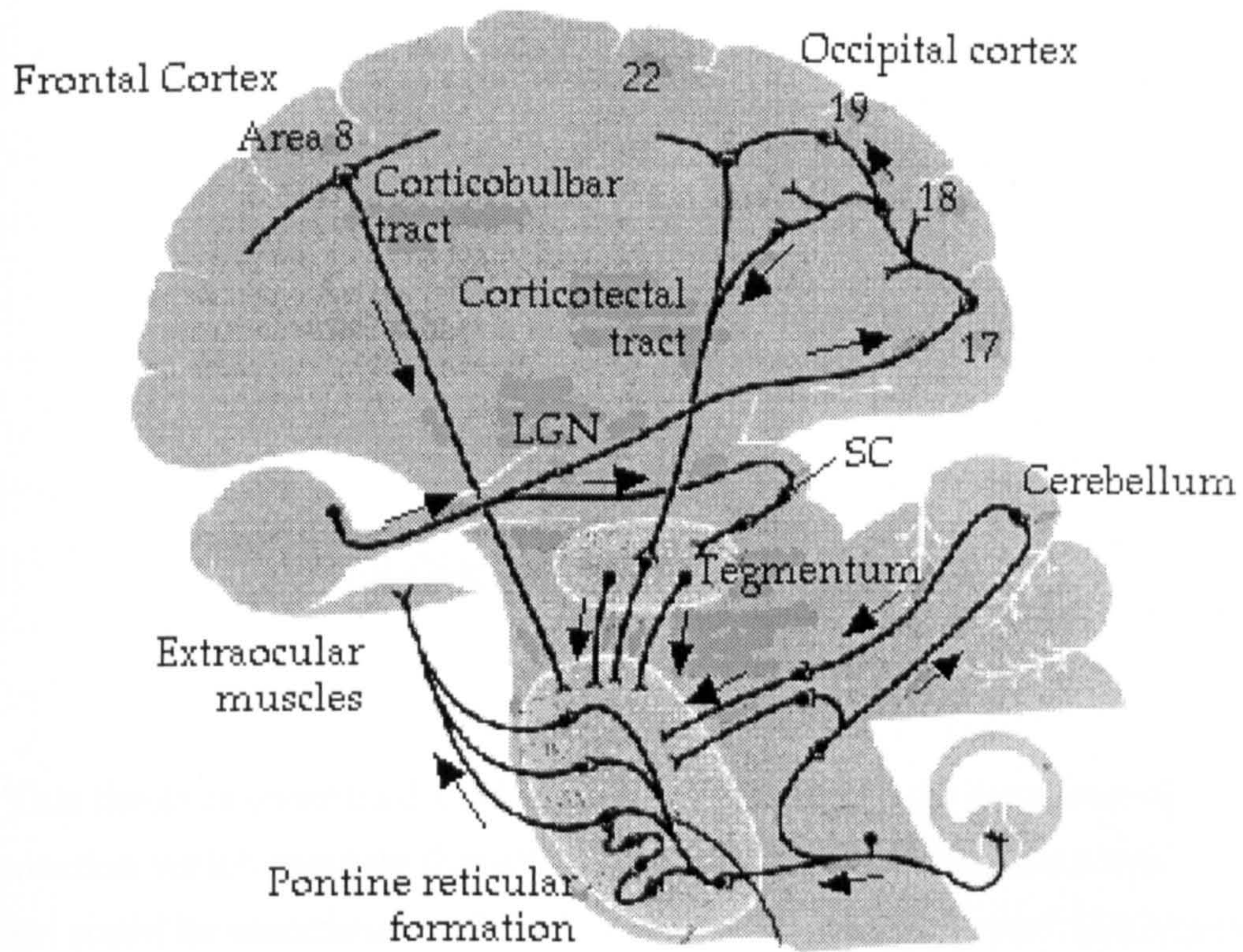
It is not completely clear why the object-based IOR effects are only (indirectly) observed in the LVF. As section 0 briefly discussed, the observation of object-based cueing effects in the LVF rather than the RVF is inconsistent with Egly et al's (1995) suggestion that objects are represented only in LH. It is also inconsistent with the observation of larger object-based facilitatory cueing effects in the RVF compared to the LVF. However, the contrast between the experiments in this chapter and those which examine facilitatory cueing effects provide converging evidence that the excitatory and inhibitory effects of an

uninformative peripheral cue are independent (e.g. Experiments 5.1 - 5.3, Gibson & Egeth, 1994a; Tassinari et al., 1994; Tipper et al., 1997). Indeed, Tipper et al (1997) not only suggest that the excitatory and inhibitory cueing effects are independent mechanisms, but also that they are mediated by different neural structures.

The observation of object-based IOR effects in the LVF which are absent in the right is consistent with a body of literature in which laterality effects arise from asymmetries in the processing of spatial frequencies; the LH appears to be specialised for processing high frequency information, whereas the RH processes lower frequency information (Sergent, 1982; see Ivry & Robertson, 1998 for a review). Thus, the RH is better than the LH at picking up the overall shape of objects, and this has been confirmed in studies using Navon figures in which global shapes are the result of the appropriate arrangement of smaller forms (Figure 1.10). This raises the possibility that the result obtained in the experiments reported in this chapter are an artefact of the use of Kanizsa objects which require integrating information across the wide area occupied by the Kanizsa inducers, or the relatively large cues and targets utilised in these studies. Further work is required to replicate and extend this finding to outline objects in the visual scene.

The experiments in this chapter confirm Handy et al's (1995) report that there are visual field asymmetries in the IOR effect. They extend it to show that it is specifically due to an asymmetry in the object-based IOR effect and this provides converging evidence that (a) location- and object-based IOR effects are the products of separate and independent mechanisms and (b) that these inhibitory effects are confounded in procedures that use a traditional static IOR procedure (Figure 2.2).





**Figure 6.6** The neural centres and projections which are known to be involved and affect the motor output to the ocular muscles (adapted from Kandel & Schwartz, 1985)



## Chapter 7

### *Final Discussion and Conclusions*

This thesis re-examined the IOR effect, with a focus on the forms of representation which mediate this effect. Tipper et al (1994b) showed that inhibition could be associated with both a previously cued location and object in a single display and suggested that these effects are confounded in the traditional static IOR procedure. The observation of separate object- and location-based IOR effects in dynamic displays has subsequently been replicated in several independent laboratories (Abrams & Dobkin, 1994; Gibson & Egeth, 1994b). However, there was only indirect evidence that object-based IOR effects were present in static IOR procedures and that the object- and location-based IOR effects are confounded in static displays. Müller and von Mühlénen (1996) suggested that pure object-based IOR effects are only observed in dynamic displays, and questioned the generality and utility of this effect. This thesis explicitly examined these issues.

#### 7.1 The generalisability of object-based IOR effects

The use of a dynamic procedure to dissociate object- and location-based IOR effects (Tipper et al., 1991; Tipper et al., 1994b) exploits the most common means of de-coupling these forms of representation in normal subject populations. Tipper and colleagues maintained that the object-based IOR effect is the result of the presence of an object in the precued peripheral region of the display (Tipper & Weaver, in press; Tipper et al., 1994b). However, it was a possibility that the pure object-based IOR effect is triggered by motion in the visual scene, and is not observed in static displays (e.g. Müller & von Mühlénen, 1996). Most of the studies which examine the

inhibitory effect of an exogenous peripheral cue on subsequent target detection or discrimination use a static display in which peripheral locations are marked by objects. The effects observed in these studies are usually interpreted as the product of a single spatial-based mechanism. Therefore, it was an important issue to: (a) confirm whether object-based effects in dynamic displays generalise to static displays, and (b) whether object- and location-based IOR effects are confounded. All of the experiments reported in this thesis investigated object-based IOR effects in simple target detection tasks, with non-predictive cues and where the objects visible in the display are never relevant to the response. Thus, Müller and von Mühlenen's challenge to confirm the existence of the object-based IOR effect in static displays was responded to in the situation which was least likely to show evidence of the effect.

Chapters 3 and 4 report the use of procedures that partially dissociate the location- and object-based IOR effects in static displays. In one condition the peripheral cue and target shared both object and location identity. In a second condition the cue and target shared only location (Chapter 3) or object (Chapter 4) identity. In each case, the IOR effect was larger in the Object+Location condition compared to when only location or object identity was common to the peripheral cue and target (Table 7.1). The experiments in Chapter 3 demonstrate that the presence of an (apparent) object in the cued region is sufficient to observed object-based IOR effect. The benefit of the presence of an object on the observed IOR effect was shown to be robust. Evidence for the object-based IOR effect in static displays was observed in every appropriate experiment (Chapters 3, 4 and 6), including after over 1800 trials (Experiment 3.4) and in monocular viewing conditions (Experiment 6.1). The object-based effect does generalise to static displays and this observation is replicable. It is more appropriate to refer to the inhibitory effect observed in the traditional IOR procedure as an object+location-based IOR effect and requires the re-assessment of the IOR literature in the light of this confound.

The second question concerned the relationship between the inhibitory effects in experimental conditions that confound these effects. Tipper et al (1994b) first suggested that the location- and object-based IOR effects operate additively when peripheral regions are marked by objects in static displays



(see section 2.4). Taken together, the experiments in Chapter 3 and 4 provide a complete dissociation of the object- and location-based IOR effects in static displays. Therefore, it is possible to examine the magnitude of the inhibitory effects, comparing an unconfounded (location: Chapter 3; object: Chapter 4) effect with the confounded Object+Location IOR effect from the same experiment. This comparison is shown in Table 7.1 where the unshaded cells are observed data, and the size of the unobserved (shaded cells) is calculated by subtracting the observed (location or object IOR effect) from the object+location IOR effect. If the object- and location-based IOR effects interacted, the confounded object+location-based IOR effect would be qualitatively larger than the separate effects. However, the similarity of the magnitude of the IOR effects suggests that this is not so. The magnitude of the effects is broadly consistent with Tipper et al's (1994b) notion that they operate additively. However, the general observation in this thesis that the magnitude of the IOR effects are modulated by task demands requires caution in drawing any firm conclusions. It would be necessary to conduct an experiment in which pure object-, location- and confounded object+location-based IOR effects are observed directly within the same display to confirm this proposal.

Of more general interest, the confounding of inhibitory effects in the static IOR procedure suggests that location- and object-based effects may be confounded in Posner's precueing procedure in general. This is potentially very problematic as the precueing procedure has been extensively used to examine "spatial" attention effects. However, any conclusion that is to be drawn from the data in this thesis, relating to facilitatory effects in the precueing procedure, must be treated with great caution. Object-based excitatory effects are often absent in unpredictable exogenous spatial cueing tasks in which the objects are irrelevant to the response compared to the same procedures/stimuli where the response is object-contingent (e.g. Vecera & Farah, 1994). Jonides (1981) found evidence that facilitatory cueing effects are modulated only by the physical characteristics of the cue, and not any task-irrelevant stimuli. In contrast, object-based inhibitory effects are modulated by the presence/absence of objects in the cued region (Chapter 3). The data



**Table 7.1**

A summary of the IOR effects compared across a variety of procedures that would be expected to show pure object- or location-based IOR or a confounded (object+location) effect. The unshaded boxes for Experiments 3.1, 3.2 and 4.1 show observed data. The remaining effects (shaded) are calculated by subtracting the pure from the confounded IOR effect.

	Object+Location	Location	Object
<u>Posner &amp; Cohen (1984)</u>			
• Object+Location	45 ms		
<u>Wright &amp; Richards (1996)</u>			
• Location		21 ms	
<u>Weaver et al (1998)</u>			
• Moving Boxes		15 ms	23 ms
• Boxes	57 ms	-	-
<u>Experiment 3.1</u>			
• Object+Location	41 ms	-	19 ms (41- 22)
• Location	-	22 ms	
<u>Experiment 4.1</u>			
• Object+Location	41 ms	28 ms (41 - 13)	-
• Object			13 ms

from Experiments 5.1 - 5.3 and Tipper et al (1997) support the notion that excitatory and inhibitory effects of exogenous cues are the product of separate mechanisms. All of these factors suggest that conclusions concerning inhibitory cueing effects are not necessarily generalisable to excitatory effects in the same type of procedure. However, just as the IOR literature has confounded object- and location-based effects, it is possible that Posner's precueing paradigm, more generally, suffers from this problem. Further work is required to specifically examine the forms of representation which mediate the excitatory effects of exogenous cues.

### 7.2 The robustness of object-based IOR effects

The second issue Müller and von Mühlénen (1996) raised concerned the utility of the object-based IOR effects. A particular concern was the effect of practice on the dynamic object-based IOR effect. They claimed that the dynamic object-based IOR is less robust over a large number of trials than the static object+location-based IOR effect. Briefly reviewing the IOR literature indicated that the effect of practice on the object+location-based IOR effect is known to be modulated by the saliency of the peripheral cue (Lambert & Hockey, 1991) and temporal certainty (Lupiáñez et al., under review). Thus,



Müller and von Mühlhausen's (1996) comment is simplistic, at best. Several experiments in this thesis directly or indirectly examined the effect of practice on the IOR effects. Broadly, the results were consistent with Weaver et al's (in press) observation that both location- and object-based IOR effects decrease with practice.

In Experiment 3.4, although the object+location- and location-based IOR effects decreased in magnitude early in the experiment, significant effects were still observed in the last block of trials. This is consistent with the observations of Weaver et al (in press) using a different procedure. However, the effect of practice on the confounded object+location- and location-based IOR effects were similar. There was no evidence that the (indirectly) observed object-based inhibitory contribution was particularly fragile. In contrast, the pure object-based IOR effect was shown to be fragile over a relatively small number of trials in Chapter 4. However, this interpretation is qualified by the observation that the robustness of the pure object-based IOR effect was modulated by the saliency of the task-irrelevant objects in the display. In Chapter 5, when manipulating the quantity of object dimension information (colour and shape) using a dynamic display, the effect of practice was observed on the object- but not the location-based IOR effect. Increasing the amount of object dimension information available increased the saliency, as well as the differentiability, of the peripheral objects. In contrast to Chapter 4, increasing the saliency of objects resulted in a larger practice effect. Thus, the saliency of objects in the display does appear to modulate the robustness of the object-based IOR.

Weaver et al (in press) suggested that practice effects on the inhibitory mechanisms which generate the IOR effects are subject to habituation. Repeated presentation of (an irrelevant) visual stimuli can lead to a decreased responsivity which is a fundamental means "of how organisms adjust to the environment" (Domjan & Burkhard, 1993). Consistent with this idea, increasing the saliency of the peripheral cue and fixing the temporal interval between the visual events in the procedure increases habituation and hence practice effects (for further discussion see Lupiáñez et al., under review; Weaver et al., in press). The practice effects observed in the experiment reported here, which had a fixed SOA and a very salient peripheral cue, are



consistent with the literature. The practice effects observed in Chapter 4 and Experiment 5.4 are more complex because they are modulated by the response-irrelevant background objects, rather than the characteristics of the peripheral cue and target. Indeed, this is the first report that task-irrelevant objects in the display have any role on practice effects at all.

### 7.3 Form of representation which mediates the location-based IOR effect

Chapter 1 presented evidence that object-based attentional effects are sensitive to object structure and Experiment 5.1 - 5.3 attempted to generalise this to the inhibitory effects. When a hierarchical structure was imposed on the display, it was predicted that this would modulate the spread of object-based IOR across the global object, but have no effect on the location-based effect. Surprisingly, there was no effect on the object-based IOR effect, but the location-based effect was abolished and replaced by a facilitatory cueing effect. Together with Experiment 5.4, these experiments confirm that the object- and location-based IOR effects are independent, with different boundary conditions. Additionally, the observation that the location-based inhibitory effect was replaced by an excitatory one, provided evidence for a dual process notion of the facilitatory and inhibitory effects of an exogenous cue (see section 2.2). More problematically though, the observation that the location-based IOR effect is modulated "object-aware" representation is inconsistent with the notion that the location-based IOR is mediated by mid-brain structures of the brain.

The final chapter attempted to replicate Rafal et al.'s (1989) report of a temporal/nasal asymmetry, which characterises the involvement of the retinotectal pathway in the object+location-based IOR effect. However, the observed data failed to show any evidence for a temporal/nasal asymmetry and was consistent with both effects being modulated by cortical rather than subcortical structures. There was more IOR observed in the left visual field, and this was due to an asymmetry in the inhibition that was associated with the presence of an apparent object. This is fundamentally different to the reports of larger facilitatory cueing effects in the right visual field and Egly, Rafal, Driver and Starreveldt's (1995) suggestion that this may be due to an asymmetry in the representation of objects. Although the physiological basis of this visual field asymmetry in the object-based inhibitory effects is



presently unclear, it does provide another contrast between the excitatory and inhibitory effects of exogenous cues.

In summary, evidence was found for both location- and object-based IOR effects in static displays, and that these effects are confounded in static displays. The observation that these separate inhibitory mechanisms are subject to different boundary conditions raises concerns about the interpretation of much of the current IOR literature. The necessary re-consideration of the literature will require further work, using dynamic displays, apparent objects or other means yet to be developed to dissociate object- and location-based inhibitory effects. There are several issues arising from the work in this thesis that are particularly important. The first is to examine the physiological basis of the object- and location-based IOR effects. Only by unequivocally demonstrating that different regions of the perceptual-motor system are involved in generating the IOR effects will it be possible to confirm the main findings of this thesis. The combination of ERP, which has good temporal resolution, and fMRI or similar imaging techniques, with good spatial resolution, would provide extremely useful converging evidence for identifying the cortical and sub-cortical areas involved in generating the two IOR effects.

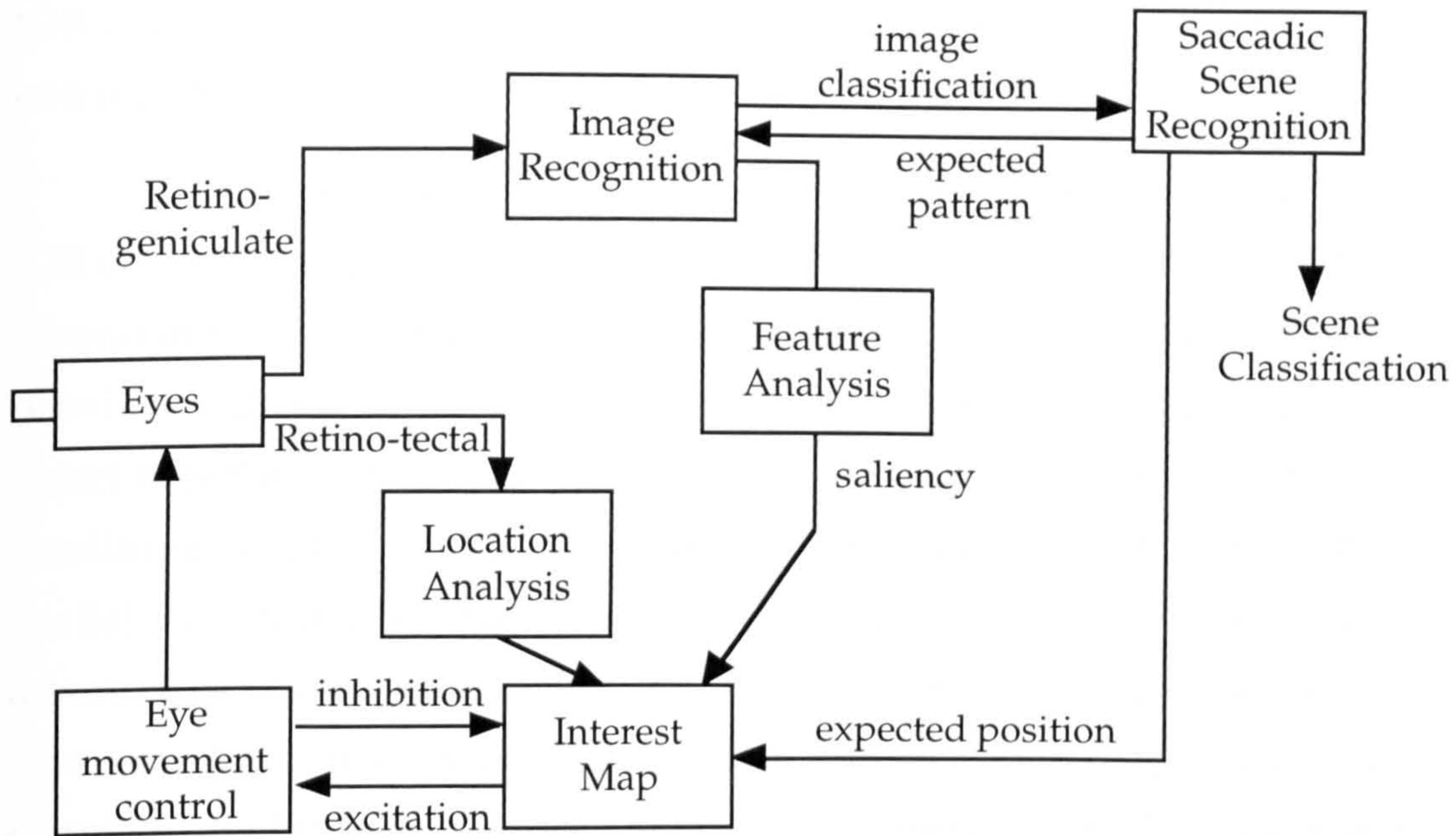
Secondly, in order to clarify the generality of the inhibitory mechanisms in visual processing it would be useful to re-examine the role of the location- and object-based IOR effects in perceptual and response components of RT studies. In Chapter 2, a schematic model of inhibition in the human visual system was proposed (Figure 2.7). This was based on a saccadic camera control system from the machine vision literature, which is analogous to the saccadic eye movement system in the human visual system. This model suggested that an "inhibition of return" mechanism is essential to prevent perseverance of re-orienting of the processing resources (saccadic camera/ eye movements) to recently fixated locations. It was suggested that the addition of a second "bottom-up" input to the interest map from an object processing system would produce behaviour that is consistent with separate object- and location-based effects in empirical studies. This cortical object-based component would prevent repeated attentional capture by particularly salient objects in the visual scene. However, the evidence that the location-

based IOR effects are generated by an object-aware region of the “where” pathway requires cortical processing.

A reconsideration of the schematic model of inhibition as described in Figure 2 illustrates this point. There are two possible modifications that can be made to the model to incorporate the notion that the location-based IOR effect is generated by cortical regions of the brain. The first is to simply move the location-based pathway so that it is a product of input from the retinogeniculate pathway and is located in the “cortical area” of the schematic diagram. However, there is some evidence of “object unaware” spatial inhibitory effects (see section 2.3.4). The observation of evidence for both “object aware” and “object unaware” spatial inhibitory effects fits with Abrams and Dobkin’s (1994) report that location-based IOR effect is generated by both perceptual (presumably cortical) and motor (subcortical) components. This suggests that the “tagging” of recently cued locations is carried out in two different loci in the brain.

Therefore the modified version of the model of IOR simply adds a third bottom-up input to the interest map, in addition to the midbrain location- and cortical object-based IOR mechanisms (Figure 7.1). This third input is termed “object-aware” location-based to differentiate it from the midbrain “object-unaware” location-based pathway. It is possible that either superior parietal region (SPT; Turnbull, Carey & McCarthy, 1997) or the human homologue for the supplementary eye fields of the macaque (Olson & Gettner, 1996) are the neural substrate for the “object-aware” location-based representation. Further work is required to test whether the location- and location-based IOR effects are separate in the same way as the location- and object-based effects have been found to be in this thesis. Evidence from cross-modal studies of IOR suggest that there is a larger motor component involvement in auditory IOR, which is probably mediated purely by the SC and other midbrain structures, than visual IOR which may be motor or attentional (Spence & Driver, 1998b). One possible difficulty with the task of dissociating “object-aware”-location- and “object-unaware” location-based





**Figure 7.1** Illustration of the revised version of the model of IOR which was proposed in section 2.5.3.2. A fourth input to the interest map has been added to allow for the evidence of an “object aware” spatial representation which mediates cortical location-based IOR. In order to encompass evidence that the IOR effects in the pre-cueing procedure do exhibit “motor” features the original location-based input remains. The grey area represents the structures that are thought to be part of the midbrain complex.



IOR effects is that different tasks may show varying contributions from the two inputs.

In the course of these studies examining the object- and location-based IOR effects in target detection tasks in static displays we have observed several important differences between the effects. While the data does not provide evidence for Müller and von Mühlenen (1996) statement that the object-based IOR effect is trivial, the object-based effect is subject to boundary conditions which as predicted are related to the saliency of the object. The spatial inhibitory effect has to be carefully “designed out” in order to observe a pure object-based effect, by controlling spatial distance (e.g. Chapter 4). However, the boundary conditions of the object-based inhibitory effect are closely related to factors which are related to perseverance of re-processing object information which captures attention. Thus, while it is important to know about visually important objects in the visual scene e.g. new objects, once they have been “looked” at (covertly or overtly), it is important not to return to them again. The influence of habituation (or activation) has been incorporated into the model by the “expected location/object” input into the interest map. Thus the activation levels on the interest map are determined by information that certain spatial regions or objects “look interesting”, predictions that a predictable visual event is about to happen in a region of the display and a “memory” that processing resources have recently been allocated to a particular region of the visual scene. Processing resources are allocated to regions of the visual scene on the basis of the relative influence of each of these factors. Inhibition of return may help selection of visual (and other modality) information in a much more efficient, stimulus-related manner than the more primitive habituation influence.

#### 7.4 Summary

In summary, the experiments in this thesis are consistent with the notion that inhibition is associated with previously cued locations and any objects which occupy them. These effects are confounded when peripheral regions are marked with objects, as in the majority of IOR procedures in the literature. There is converging evidence that the inhibitory mechanisms are separate and independent and are characterised by different boundary conditions. It is unclear whether inhibition that is associated with a spatial

region is the product of a single mechanism, or the combined contribution of a perceptual “object-aware” and a motor “object-unaware” mechanism. Additionally, there is converging evidence that inhibitory and excitatory effects are separate effects, and only when the former is abolished is the latter observed. The inhibitory mechanisms that underpin the IOR effects may have evolved to guide efficient visual processing as it probes the visual scene. Inhibiting previously processed environmental stimuli prevents perseverance of “attentional capture” and complements low-level automatic habituation effects, which take time to develop and may not be flexible enough in real-world, real-time situations.



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## Appendix 1

In Chapter 2, Janßen's (1996) model of a saccadic camera control system was briefly described, with particular interest in the "inhibition of return" function which prevents the camera repeatedly returning to a previously fixated region. Janßen's saccadic control system was developed to carry out learn and recognise complex scenes or objects by means of directed fixations of the camera. The saccadic control and recognition subsystems are embedded in a camera system which controls the behaviour of the camera including focus control, tracking and vergence. This part of the system is not pertinent to the issues in this thesis. There are two elements of the system which are of interest here; (a) the method which Janßen uses to define the saliency of objects in the visual scene (See Chapter 4) and (b) the representation which mediates the "inhibition of return" and excitatory mechanisms which is the input to the camera system.

In everyday speech, an object is salient when it is "obvious" to the viewer and is observed in an unambiguous way. It is difficult to quantitatively measure the salience of an object, although the term is widely used in the psychological literature. There is little evidence that the human visual system can extract relational properties among features in early, pre-attentive stages of processing (e.g. Treisman & Gelade, 1980). Rather selection may be based on saliency measures defined by local differences in contrast, colour, size etc. (Engle, 1974; Sagi & Julesz, 1985). Generally, salience in the experimental psychology literature is estimated by subjective means (e.g. Chapter 4). However, the machine vision literature has had to develop quantitative methods which are suitable to implement within working systems. A related issue to the definition of saliency as a basis of selection is the problem of segmenting objects from their background. Segmentation involves both top-down and bottom-up processing, but it is possible to



'decide' which elements in a scene are part of an occluder and occluded without knowing the identity of the objects. Although saliency and segmentation are considered separately in the psychological literature, machine vision systems often solve these problems at a single stage.

Janßen (1996), like many similar systems, used a modified Gaussian function to define salient regions in the camera input. This modified non-linear filtering definition provides a measure which incorporates local distinctiveness and invariance across views and temporal changes (Haralick & Shapiro, 1993). Gaussian functions are often used as a measure for local distinctiveness across a region (Marr & Hildreth, 1980). This function works by pooling intensity within a circular region, so that intensities from the central region are weighed more strongly than from the periphery. Individual "blurred" channels are created by independently convoluting the original image with Gaussian filters of various widths (e.g. Figure 4.5). Intensity changes, which are present in each channel, are located relative those in 'neighbourhood' regions and thus an edge detected. Marr and Hildreth's method used the second derivative of each of the channels, which is known as the Laplacian operator, and located the zero-crossings at different spatial scales. Retinal ganglion cells are thought to operate in a similar manner to Marr and Hildreth's convolution. (See Humphreys & Bruce, 1989).

Janßen's (1996) system used a similar approach to detect local distinctiveness. He used a two-dimensional approximation of the three-dimensional Gaussian transformation, and computed it at several ( $n$ ) different scales of the image. This function  $S_p$  was zero for all points lying in a plane or on an edge, while it was high for local peaks of contrast. This modified saliency measure  $S_p$  was computed as the sum of the absolute Gaussian curvatures,  $S$ , of the  $n$  single scales:



$$S_p = \sum_{i=1}^n S_k^{(i)}$$

where

$$S_k = \left| \frac{\delta I(x, y)}{\delta x} \frac{\delta I(x, y)}{\delta y} + \frac{\delta I(x, y)}{\delta(x+y)} \frac{\delta I(x, y)}{\delta(x-y)} \right|$$

This produced a saliency measure which was sensitive for broad image structure and was stable under a variety of viewing conditions. This saliency measure,  $S_F$  was used to drive the levels of activation on the interest map. A principle components analysis (PCA) was carried out on which drove feature-specific selection. This calculated the most salient features in the visual scene by calculating the most salient region in the most salient region of the visual scene.

Figure 4.5 illustrates the application of a Gaussian to each of the displays used in Experiment 4.1. Scale drawings of each of the displays were prepared (left panel) and then blurred with a Gaussian filter. Blobs of opposing contrast are observed at this low spatial frequency at the location of the edges. The important point to notice is that the two displays (Outline (top) and Physical Rectangles (bottom)) which show object-based IOR, the regions across which the object-based IOR spreads group together. However, the Apparent Object display (middle) where the object-based IOR does not spread, the contrast discontinuities group with the inducer edges, and not those of the apparent object surface. This suggests that spatial frequency plays a critical role in the observation of pure object-based IOR spreading across the surface of an object (see also Campion & Latto, 1985). Experiment 4.1 follows the trend towards testing phenomenological hypotheses (subjective experience of saliency) by objective experimental techniques (e.g. Davis & Driver, 1994; Davis & Driver, 1998; Shipley & Kellman, 1992).

In Janßen's (1996) model, the metrics of the camera movement is determined by the location of a peak, and acts as a salience map (see section 1.1.1.1). The camera is directed to its next spatial location using a winner-



takes-all process for the highest peak at any instant of time (see also Tsotsos et al., 1995). The interest map is defined as a system consisting of two different linear differential equations; a target map which registers the most “interesting” regions of the scene and an inhibitory map, which memorises the locations which have been gazed at. Therefore the locations of activity peaks on the interest map is a product of “attentional capture” and a memory trace for having oriented to that location recently. As the metrics of the map are spatial, the camera orienting is characteristic of the location of the target, and is independent of other target characteristics. However, observation that characteristics including saliency of the objects in the visual scene are not accounted for in the original schematic model. Modification of the interest map, perhaps following a similar system to that proposed by Logan (1996) would be more appropriate.

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