The influence of complex distractors in the remote distractor effect paradigm

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Abstract

This thesis reports six experiments that examine the influence of complex distractors in the Remote Distractor Paradigm. Experiment 1 examined whether linguistic distractors modulated the RDE in any systematic way under bilateral target presentation. This was found not to be the case, but all types of linguistic distractors produced prolonged saccades for central versus peripheral distractor location. Non-linguistic distractors produced equivalent saccade onset latencies for central and peripheral presentation and these were significantly shorter than those produced for all types of linguistic distractors. This unexpected finding was investigated in Experiment 2, which showed that repeated presentation of a distractor resulted in shorter saccade latencies at central presentation, compared to those distractors that changed on every trial. This was termed the 'constancy' effect. Experiments 3 and 4 employed only repeated non-linguistic distractors under different target presentation conditions. Under bilateral target presentation peripheral distractors produced longer saccade latencies and greater RDE magnitudes compared to central distractors. Under unilateral target presentation RDE magnitudes for peripheral distractors were of a similar order to those produced by Walker *et al.*, (1997). This replicated for linguistic and non-linguistic distractors, and for repeated and changing distractors in Experiment 5. Thus repeated distractors result in shorter saccade onset latencies compared to changing distractors at central presentation, and RDE magnitudes of a similar order to those obtained for central and peripheral distractors in the Walker *et al.*, (1997) study only occur under unilateral target presentation. In Experiment 6 a difference was obtained between two different types of linguistic distractors for saccade onset latencies and RDE magnitudes at an intermediate distractor location, and the 'constancy' effect was reproduced for same category repeated and changing distractors. Taken together the findings show that saccade onset latencies and RDE magnitudes can, under some circumstances be modulated by higher-level cognitive factors.

Declaration

I hereby declare that this thesis has been composed by myself and that the research reported herein has been conducted by myself.

November, 2003

Valerie Brown

Statement of Copyright

Acknowledgements

The completion of this thesis has been a long, arduous and sometimes lonely process. I have been challenged intellectually, physically and emotionally and in the process I have somewhat neglected my children, my partner, my family and myself. I apologise to all of these people for not always having sufficient time to spend with them. That being said, I would very much like to acknowledge the continued and enduring support of all those mentioned above, and also the support of my two supervisors, John Findlay and Simon Liversedge, both of whom have provided consistent, sustained and very helpful advice throughout. I am looking forward to taking them out for a pint in due course.

On a final note, my partner Simon warrants a special mention since he has been a rock of support to me along this journey. He has in fact not only put up with me when, I am quite certain, no one else would have, he has also continuously and lovingly encouraged me to keep going.

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Table of Contents

List of Tables

Table 8: Experiment 6. The mean percentage of errors for each type of distractor at each distractor presentation location.

Table 9: Experiment 6. Mean saccade onset latencies (with standard deviations in parentheses) for each Distractor Type, at each Eccentricity for Changing and Constant distractors.

Table 10: Experiment 6. Mean RDE magnitudes (with standard deviations in parentheses) for each Distractor Type.

List of Illustrations

Figure 7: Experiments 3 and 4. The mean saccade onset latencies for each of the two distractor eccentricities and for the baseline no distractor condition for Experiment 3 (bilateral target) and Experiment 4 (unilateral target). Error bars denote 1 standard error from the mean.

Figure 8: Experiment 6. The mean saccade onset latencies for each of the three DistractorTypes at each of the three Eccentricities in Experiment 6. Error bars denote one standard error from the mean.

Figure 9: Experiment 6. The mean saccade onset latencies for each of the three Distractor Types, at each of the three Eccentricities, for both Changing and Constant distractors in Experiment 6. Error bars denote one standard error from the mean.

Figure 10: Experiment 6. Supplementary analyses. The mean saccade target onset latencies for central distractors and for the single target condition. Targets were positioned at 4 degrees and at 8 degrees. Data is shown for each of the three Distractor Types at each of the three Eccentricities for both Changing and Constant distractors.

Figure 11: Experiment 6. The mean saccade onset latencies separated by saccade target eccentricity for each of the three Distractor Types at each of the three Eccentricities for both Changing and Constant distractors in Experiment 6.

Chapter 1

General Introduction

Information about the external world arrives via our sense organs. Receptors in each of the sense organs code the arriving information and pass it to the brain for perceptual analyses in order that behavioural responses can be generated. The transformation from sensory information to perception, and from perception to action, has been studied in detail and indeed is what much of Psychology is about. In the case of visual information the receptive organ for sensory information (the eye) does not however sit still waiting around for stimulation to which it can respond to, but rather it actively seeks out information in the form of saccadic orienting. This is an example of active vision, whereby it is recognised that we interact with our environment as active perceivers, not as passive receivers (Findlay & Gilchrist, 2003). Several hundreds of thousand times a day the eyes move in a series of fast movements (saccades) and pauses (fixations). These fast movements redirect the eyes to new locations in the visual field and the accompanying pauses allow detailed analysis, by the fovea, the very high acuity area of the eye, of whatever is being visually inspected when the eye pauses to fixate. This is known as saccadic orienting and it is interesting to note at this point that saccadic orienting appears to be an inherent behaviour, which allows optimal sampling of the visual environment. Indeed in the absence of eye movements, for example in the case of congenital opthalmoplegia saccadic orienting is achieved by the head, which behaves very much like an eye, revealing patterns of movement in reading (and many other robust vision research paradigms) which mimic those found for eye movements during the same tasks

(Gilchrist, Brown & Findlay, 1997). The processes and mechanisms involved in saccadic orienting have been studied in detail and much is now known about the mechanisms involved in the control of eye movements. Many questions however remain to be answered, not least in the area of how the saccadic orienting system interacts with, or is influenced by higher-level cognitive or attentional factors.

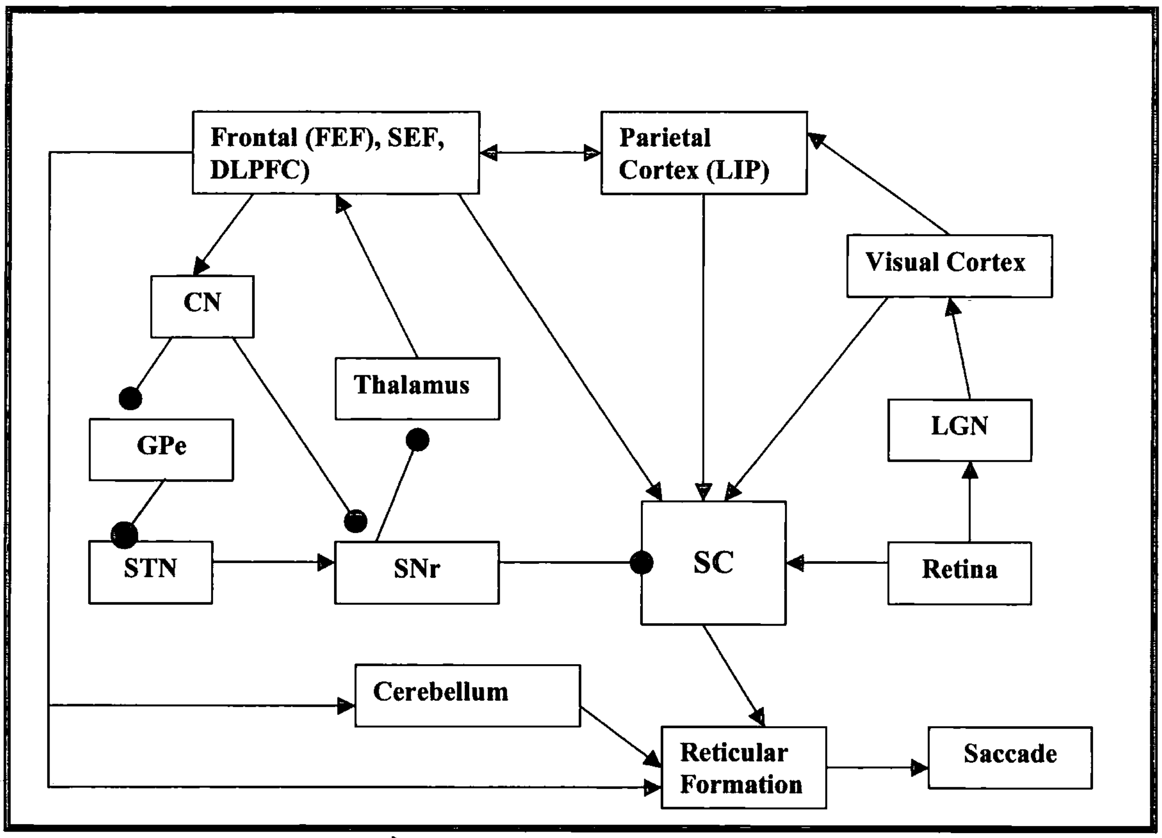
The experiments reported in this thesis are designed to address the sensitivity to various factors of one aspect of low level oculomotor behaviour, namely the decision of when to move the eyes. Throughout the thesis a robust eye movement research paradigm will be employed. The Remote Distractor Effect (RDE, Walker, Deubel, Schneider, & Findlay, 1997) paradigm measures eye movement onset latencies to targets presented at varying locations within the visual field. The targets are presented on their own or with an accompanying remote distractor, the location of which can be varied in relation to the target. The latency increase for the distractor present trials, compared to the single target trials is known as the RDE magnitude. It has been shown that saccadic onset latencies (the time it takes to make an eye movement to a target from the time the target is presented) in the RDE paradigm are increased if a remote distractor is presented simultaneous with the target. To date no assessment has been made of the effects of complex, task irrelevant distractors on the magnitude of the RDE. For example, what would be the effects of presenting distractors, which are thought to initiate automatic processing (i.e. linguistic distractors) on saccadic onset latencies? This was the starting point for the experiments conducted in this thesis.

This introductory chapter will provide some background to the research topic for the experiments in this thesis, which falls under the broad heading of visual cognition (how human visual and cognitive processes interact). A brief account of the neural circuitry underlying the eye movement system will be presented, with some emphasis placed upon recent studies investigating the inhibition of eye movements. Following this, the nature of saccadic eye movements will be explained in the context of their relationship with visual attention. An outline of two models of saccade generation will be provided with an explanation of how each of these attempts to account for findings from experiments using the RDE paradigm to examine the oculomotor control system. A full description will be given of the Remote Distractor Effect and some justification as to why it is interesting to consider within this paradigm distractors that induce complex cognitive processing will be given.

1.1: The neural circuitry for eye movements.

In order to provide a full description of oculomotor behaviour it is important that the many behavioural findings from experimental work on eye movement generation, along with the factors that influence this behaviour, map onto the neurophysiology of the saccadic control system. Therefore, an overview of the neural circuitry involved in eye movement control is described below. This includes a description of the processing in the saccade brain stem generator, the role of the superior colliculus (SC) and the function of some higher-level brain areas, such as the frontal eye fields (FEF) involved in saccade generation, target selection and saccadic inhibition.

A large and accumulating body of literature from saccadic orienting studies, and evidence from a wealth of broad areas of research including brain imaging and clinical studies, neurophysiological and neuroanatomical studies has revealed a network of subcortical and cortical structures involved in the control of eye movements. Munoz (2002) outlines an overview of the neural circuitry of saccadic eye movements and describes the critical nodes and some of their proposed functions in the 'start, stop, start' sequence associated with saccadic orienting. Munoz suggests that the evidence gathered from a variety of different types of studies points to the notion that specific functions of eye movement control are likely to be distributed across different brain areas, rather than being localised to one area. It is now known that there is a network of cortical and subcortical regions involved in the generation of saccades. These include the frontal and the parietal cortices, the superior colliculus, the thalamus, the basal ganglia, the cerebellum and the brainstem reticular formation (see Wurtz & Goldberg, 1989; Schall & Thompson 1999; Munoz, Dorris, Pare, & Everling, 2000; Scudder, Kaneko, & Fuchs, 2002) for detailed reviews of aspects of the circuitry). A wide variety of recording and experimental techniques have been used in studies with humans and animals which has resulted in a large body of data from which the role of the various brain areas involved in both visual fixations and saccade generation has been described. Experiments with humans have recently used a variety of functional imaging techniques where changes in either the metabolism of oxygen or the blood flow in different brain areas has been correlated with different aspects of eye movement behaviour. Additionally, since the saccade generation system can be disrupted by psychological and neurological disorders, patients with any of these and those with discrete lesions to a specific brain area have also been studied. Techniques used in animal studies have additionally used single cell recordings, lesion studies, electromicrostimulation and neuronal activation or deactivation using transmitter substances (Munoz, 2002). Since the saccadic orienting system is so important in the visual selection process it is important to know something about the mechanical workings of it. Briefly, to date, the following, summarised from Munoz (2002) outlines what is known about how the eye actually moves, the role of the Superior Colliculus (SC) in controlling eye movements, the role of higher-level brain areas in the network and recent work looking at how saccades are inhibited voluntarily and involuntarily. Figure 1 is taken from Munoz (2002) and shows a schematic of the neural circuitry for eye movement generation.



Excitatory Connection

Inhibitory Connection

Figure 1. Circuitry connecting brain areas involved in saccadic eye movements. Abbreviations: CN, caudate nucleus; DLPFC, dorsolateral prefrontal; FEF, frontal eye field; Gpe, globus pallidus external; LGN, Lateral geniculate nucleus; LIP, Lateral intraparietal area; SC, superior colliculus; SEF, supplementary eye field; SNr, substantia nigra pars reticulata; STN, subthalamic nucleus.

There is a sophisticated control system in the brainstem which sends coded signals to the oculomotor muscles resulting in a pattern of muscle excitation consisting of high frequency bursts of activity which reposition the eye, and this is followed by tonic activity which keeps the eye in its new position, but a complete understanding is still to be developed. Three orthogonal pairs of extraocular muscles synergistically act to control eye movements. These muscle pairs are innervated by motorneurons (MN) located in the brainstem (see Leigh & Zee, 1991 for details). During saccades MN show a step pulse pattern of discharge. That is to say, there are bursts of action potentials for the on direction for saccades (the pulse) followed by pauses in activation for the off direction for saccades. Additionally there is a tonic component of the discharge, (the step), following a saccade which keeps the eye in its eccentric orbital position. The types of cells that are involved in this sequence include Excitatory (EBN) and Inhibitory (IBN) burst neurons, which discharge bursts of action potentials for the on direction for saccades, and which are silent during fixations. Omnipause neurons (OPN) pause for saccades in all directions and discharge tonically during fixations. Long-lead burst neurons (LLBN) project to the EBN and the IBN in order to provide the burst input. These neurons have a low frequency build up before the burst, and discharge a high frequency burst for saccades directed to the opposite hemifield.

The generation of a saccadic eye movement therefore requires that the OPN becomes silent whilst the LLBN produces the necessary amount of activity for the EBN and IBN to send a saccade command to the MN. Following the saccade the OPN become tonically active once again which inhibits any activity in EBN or IBN from disrupting fixation. This is what happens when a saccade is produced, but how does the brain know when and where to stop? Several brain structures project to the premotor circuitry in the brainstem and there is some understanding of how these projections are coordinated to control the actions of the saccadic burst generator (see Scudder *et al.*, 2002 for detailed review).

It appears that the oculomotor system is 'ballistic' in that it has to work out the patterns of muscle innervation in advance from its knowledge of the target location, since if it had to wait for visual signals to tell it when it had reached the target it would have overshot it long before such signals would have arrived (Carpenter, 2000). Recent work suggests that this is achieved by communication between a structure at the top of the brainstem (the superior colliculus (SC)) and the brainstem itself. Visual information in the SC is combined with internal feedback signals about what commands are being sent to the oculomotor muscles. According to Carpenter, the 'SC is like a mini theatre and here a kind of drama is played out whereby the presumed position of the eye is plotted in two dimensions, and a command is issued to stop the evolving movement at the moment that it seems to be on target – a bit like in the gun aiming computers in "World-War II battleships" (From:www.cai.cam.ac.uk/people/rhsc/oculo.html).

Indeed there is much neurophysiological evidence to suggest that the role of the SC is critical for the control of eye movements. The SC is a midbrain structure that has direct inputs to the saccadic burst generator. The superior colliculi form the rostral two bumps (one on each side) on the dorsal aspect of the midbrain. The caudal two bumps are the inferior colliculi and together they (inferior and superior colliculi) comprise the tectum or roof of the midbrain. In contrast to the inferior colliculus, which is an auditory structure, the superior colliculus is usually described as a visual reflex centre. It is highly laminated (layered) and receives direct projections from the retina as well as projections from several other brain areas. It is also a site for the convergence of multisensory information (see Stein and Meredith, 1993 for review), and despite the differences in sensory coding systems for the different types of multisensory information, the same motor system is used to localise a target. The top or dorsal-most three layers receive visual information primarily from two sources, i.e., the retina (retinocollicular) and the visual cortex (area 17, corticotectal). Neurons in the top layers are organised into a visual map of the contralateral hemifield. In contrast to the exclusively visual nature of the superficial layers, the intermediate and deep layers receive projections from many functionally different areas of the brain. These inputs are both "motor" and "sensory". Since the latter category includes visual, auditory and somatosensory inputs, the superior colliculus is not exclusively related to visual function. Instead, it plays a role in helping orient the head and eyes to all types of sensory stimuli.

Neurons involved in the generation of saccades are located throughout the intermediate layers of the SC. Several types of premotor cells are located here (Munoz & Wurtz, 1995a, 1995b) and these neurons increase their discharge prior to and during saccades. Neurons in the intermediate layers of the SC are organised into a retinotopically coded motor map specifying saccades into the contralateral visual field. Signals related to visual fixation and saccade initiation interact dynamically across the motor map within the SC (Munoz & Fecteau, 2002) and "local interconnections are used as the substrate for motor programs to compete. Outputs from these interactions are passed to the brainstem premotor circuitry to help guide behaviour" (Munoz, 2002 pp 93). Munoz and Wurtz identified 3 main types of collicular neurones on the basis of presaccadic activity. Fixation cells are localised in rostral pole region of the superior colliculus and show a sustained response to a fixation stimulus. Build up cells are located throughout rest of collicular map and show a gradual rise in activity after the onset of a peripheral saccade target. This activity is related reciprocally to activity in the fixation cells. Build up cells are involved in the preparation to make a saccade. Burst cells are located throughout the rest of the collicular map and show a sudden burst in activity just prior to saccade onset. It is suggested that these cells may encode the metrics of the saccade. Both premotor neurons and fixation neurons project to the brainstem premotor circuitry to provide signals specifying when and where a saccade will be made (Munoz, 2002).

Other inputs to the saccadic burst generator, which may be important for maintaining the accuracy of saccades, arise from the cerebellum. Enderle (2002) describes a model in which inputs from both the SC and the cerebellum are important in the control of eye movements. In the model saccade initiation is achieved by inputs to the burst generator from the SC and saccade termination is achieved by inputs from the cerebellum. An important point to make here is that although the SC plays a critical role in eye movement control, it does not operate in isolation, but as part of a network.

In addition to the brainstem neural machinery, which is designed to get the eye on a designated target, there are higher-level centres in the brain involved in the presaccadic process of deciding the next saccade target. This is not surprising given that in day to day life we are often confronted with a selection of targets for saccades, and it appears that the potential target selection process is completed in part by the frontal part of the cerebral cortex, the posterior parietal cortex and the basal ganglia (Munoz, 2002), which all have projections to the brainstem, cerebellum and the SC.

There are units in the frontal cortex whose firing seems to reflect the processes of choosing and discriminating between targets. Work on saccadic reaction times in humans seems to suggest that the brain runs a kind of race between signals representing different possible targets, with more probable or likely targets starting nearer the finishing post than less likely or probable targets (Carpenter, 2000). An important question in the sensory motor transformation literature relates to how the signals from the different visual areas in the brain are combined to guide action. Most models of visual attention incorporate a saliency map in which there is topographical representation of the visual field and on which locations of potential targets are registered (Treisman, 1988; Cave & Wolfe, 1990; see also Findlay & Walker, 1999). Activation in the saliency map is derived from both bottom up processes (stimulus driven properties and elementary features of the image) and top down influences (observer goals and expectations). Evidence from the anatomical and physiological data suggest that the frontal eye fields (FEF) may be regarded as implementing a saliency map (Schall & Thompson 1999). The FEF both receives and sends information to other brain areas involved in the production and control of saccades and it has direct inputs into the SC and the brainstem. Damage to the FEF results in impaired saccade generation and different types of neurons in the FEF have been shown to reflect different types of selection for visual salience or behavioural responses. The lateral intraparietal area of the posterior parietal cortex (LIP) has also been associated with a salience map.

The SC receives direct inputs from the Frontal cortex, the visual cortex and LIP and so these higher-level areas can influence the premotor processing and ultimately behaviour (Munoz, 2002). Visual inputs important for both saccade generation and fixation travel initially to the visual cortex via the retina and the lateral geniculate nucleus. Projections via the dorsal stream of extrastriate cortex project to areas of the posterior parietal cortex that are involved in sensory-motor transformations and attentional processing (see Andersen, Snyder, Bradley, & Xing, 1997; Colby & Goldberg, 1999; Glimcher, 2001 for detailed review). It has been suggested that (LIP), which lies at the sensory-motor interface, may play an important role in decision making. Frontal cortical motor areas include the frontal eye fields (FEF), the supplementary eye fields (SEF), and the dorsolateral prefrontal cortex (DLPFC). Area LIP projects directly to FEF and SEF (see Schall, 1997; Schall & Thompson, 1999 for a review). The FEF, SEF and DLPFC are interconnected and all project to the SC, the cerebellum and the brainstem reticular formation. All three have been shown to have a role in fixation control.

It has been suggested that the different classes of saccades, (voluntary and involuntary), may be mediated by different cortical areas that are involved in the control of saccadic eye movements (Pierrot-Deseilligny, Rivaud, Gaymard & Agid, 1991; Gaymard, Ploner, Rivaud, Vermersch, & Pierrot-Deseilligny 1998). The visual and posterior parietal cortices may provide the main input to the SC for visually guided saccades. Additionally, the brain has evolved mechanisms to suppress saccades during fixation that are either unwanted or reflexive. Both the suppression of reflexive saccades and the generation of voluntary saccades are controlled to some extent by the direct and indirect (via the basal ganglia) projections from the FEF to the SC.

Although much is now known about the neural circuitry for the generation of voluntary (endogenous) and involuntary (exogenous) saccades, the neural mechanisms of saccadic inhibition are not yet clearly understood, although it has been suggested that a critical function of the DLPFC may be the voluntary suppression of reflexive or unwanted saccades (Munoz, 2002). Munoz highlights the importance of the concept of saccadic inhibition and points to evidence from Stampe and Reingold (2002) which suggests that, in addition to voluntary suppression of saccades, there may be a low level oculomotor mechanism for saccadic suppression. Clearly the inhibition of unwanted saccades is an important part of saccadic orientation. In order to operate effectively with our environment it is necessary not only to be able to select and process relevant visual information, but also to ignore irrelevant information. It is important therefore to have some background knowledge for the inhibition of saccades, since the experiments in this thesis will require participants, on some trials, to inhibit a saccade to a designated distractor in favour of making a saccade to a designated target. Two paradigms which have been use to investigate saccadic inhibition are described below.

1.2: Saccadic inhibition

The countermanding paradigm has been used to investigate the inhibitory control of voluntary action. In this paradigm two types of trials are randomly mixed in an experimental block of trials and participants are requested to either respond as quickly as possible to the presentation of a target (go task), or to inhibit a response to the target whenever a stop signal is presented (stop task). The stop signal can occur at varying delays after target presentation. The ability to successfully inhibit a response depends on the stop signal delay (SSD), which is the time delay between the presentation of the go and the stop signals. Inhibitory behaviour using the countermanding task has been looked at for different kinds of manual responses (see Logan, 1994 for a review) and more recently oculomotor control has been studied both in monkeys and in humans, using visual targets and visual stop signals (Hanes & Schall, 1995, 1996; Hanes, Patterson & Schall, 1998; Logan & Irwin, 2000; Stuphorn, Taylor & Schall, 2000). In the eye movement countermanding task the stop signal is frequently the reappearance of the fixation point (the spatial location of this has been varied), but more recently both auditory stop signals (Colonius, Oyzurt & Arndt, 2001) and a combination of visual and auditory stop signals (Cabel, Armstrong, Reingold & Munoz, 2000) have also been used. What the results from these and other countermanding studies demonstrate is that saccades can be inhibited voluntarily, but not always. Furthermore there is a pattern of neuronal activity in the FEF for the presentation of a stop signal that is restricted to fixation and movement neuron activity. Visual response neurons do not show this pattern.

Hanes & Schall (1995) used the oculomotor version of the countermanding paradigm to investigate the ability to control eye movement in the monkey. Monkeys (Macaques) were trained to make a saccade to the appearance of a peripheral target unless they received a stop signal to withhold the saccade. The stop signal for this experiment was the reappearance of the central inter-trial fixation spot. The stop signal reaction time is an estimate of how long it takes to cancel the planned movement and it has been shown that in monkeys this averages 100ms (Hanes &

Schall, 1995), and is slightly longer for humans (Hanes & Carpenter, 1998). Hanes & Schall, (1995) point out that the speed of the stopping process in their experiment was very fast with the foveal stop signal producing a visual response latency of 50ms. Given the 100ms stop signal reaction time this means that the movement was actually cancelled in just 50ms. They suggest that the presentation of a flash of light in the fovea directly activated the gaze fixation system (e.g. Munoz & Wurtz, 1993. Thus the inhibition of saccades can be achieved voluntarily when a signal to stop the saccade to a peripheral target, is presented at central location. Moreover, in the Hanes and Schall (1995) study neuronal activity in the FEF showed that movement related activity, which began to grow towards the trigger threshold, failed to reach threshold and decreased quickly once the stop signal was presented and a movement was cancelled. Additionally movement related activity differentiated between execution and inhibition of the movement before the stop signal reaction time had elapsed. The pattern of results was observed in all cells with movement related or fixation related activity but was not observed in neurons with only visual responses. The results demonstrate that stop signals (at least those at central presentation) have a direct effect on the movement and the fixation neurons in the FEF, and that the countermanding paradigm can be used to investigate in detail the neuronal control of gaze.

However, saccades cannot always be inhibited, and the latencies from these stop failure trials have also been investigated. Further work has been carried out on countermanding saccades with humans using both nonfoveal and/or auditory stop signals (Colonius, Ozyurt & Arndt, 2001; Ozyurt, Colonius & Arndt, 2003). In a study using three human participants (Colonius *et al.*, 2001) it was found that the overall mean saccade onset latencies were significantly reduced for stop failure trials (where participants could not inhibit a saccade) compared to control trials (where no stop signal was presented) for two of the participants, but not for the third participant. It was also found that auditory stop signals presented centrally were no more effective than those presented in the periphery. Varying the spatial distance between auditory stop and visual go signals had no significant effects on mean saccadic reaction times and stopping performance, nor on saccadic amplitudes. What this suggests is, firstly that erroneous saccades to the target produce faster saccadic reaction times compared to saccades to targets when no stop signal is presented, and, that the location of the stop signal (central or peripheral) and the modality of the stop and go signals (visual or auditory) had no influence on the ability to inhibit a saccade.

The explanation for the finding of no difference between different spatial locations for the stop signal, suggests that the inhibition mechanism either has no access to, or simply makes no use of, location information. They suggest that to successfully inhibit a saccade requires only detection of the stop signal, not localisation of it and their findings are in agreement with those of Asress and Carpenter (2001). It was concluded that information from different parts of the visual field is equally effective in countermanding saccades.

According to Logan (1994) performance in the countermanding task is dictated by the outcome of a race between the process that generates the movement and the process that inhibits the execution of the movement. According to the race model (Logan & Cowan, 1984) a delay in the presentation of the stop signal will decrease the chances of successful inhibition. This is because the probability of the stop process winning the race will decline with holding up its starting time.

An interesting observation from the stop signal studies was investigated further by Ozyurt, Colonius and Arndt, (2003). This was, that for some participants, short SSD's produced saccadic reaction times (for the stop signal failure trials) that were longer than would have been predicted by the model. Hence it was hypothesised that if this increase could be shown in any way to result from the stop signal having some sort of inhibitory effect upon the go signal, then this would mean that the race model's assumption of independence between the processing of the go and the stop signals, would have been violated.

The authors developed a paradigm which enabled the recording of a sufficiently large number of data points for the short SSD's and the auditory stop signal could appear either at the location of the target or in a mirror symmetrical position on the opposite side of the display. Visual targets were presented at either the left or the right side of the midline of the display at an eccentricity of 15 degrees. The stop signal in this experiment was held constant throughout a block of trials so that participants were aware of where it would be presented in each block of trials. Thus within an experimental block, visual stimuli were presented randomly to either the right or the left of the display, but auditory stimuli were presented at only one of the two locations. It was argued that this manipulation would allow the examination of whether there was a generalised spatial attention shift with participants monitoring more closely the expected side where the stop signal would appear. It would therefore be expected that a difference should be observed between the expected and the non-expected sides for the go signal trials, where no stop signal is presented. Additionally, it was suggested that a specific spatial effect might be seen where a stop signal would be more effective the closer (spatially) it was presented to the go signal. It was suggested that this was analogous to the distinction between foveal and peripheral presentations in the purely visual set ups reported in previous experiments (e.g. Hanes & Schall 1995; 1996). A comparison of the mean saccadic reaction times for expected versus non expected stop signal locations in the go trials showed no significant effects, which suggests that prior knowledge of the location of the stop signal has no effect upon saccade latencies. This finding is similar to Walker, Kentridge and Findlay's (1995) findings for an RDE study where an instruction to attend to the side of the display that the target would appear at did not modify saccade latencies to the target.

The experiment was designed to test the independence assumptions of the race model. One of the predictions is that smaller mean saccade latencies will be observed for the stop signal failure trials compared to the control condition means. However two of the participants in the study showed significantly larger mean stop failure reaction times compared to the control condition and moreover, according to the model stop failure RT's should increase with an increase in SSD and for these two participants the opposite pattern was shown with stop failure RT's decreasing with SSD. Additionally the estimates of SSPT decreased quite substantially over SSD, whereas it should have remained more or less invariant. Together these violations of the race model for short SSD's support the hypothesis of an inhibitory influence between go and stop signal processing, but as yet it is not clear why this violation should apply specifically to trials with very brief SSD's. What is important here is that there is some suggestion that the race model cannot explain all the data from the countermanding studies.

Saccadic inhibition as described by Stampe and Reingold (2002) is different to the voluntary saccadic inhibition investigated in the countermanding studies. Here saccadic inhibition is a phenomenon that occurs as a result of brief changes to a display. Recent work by Reingold and Stampe (2003a; b) using the saccadic inhibition paradigm which was introduced to measure the effects of changes in visual input on saccade production (Reingold & Stampe, 1997; 2000; 2002; 2003a; b) has shown that inhibition of saccades may be a low level oculomotor response to transient display changes, and this effect occurs for both voluntary and involuntary saccades. What this means is that in a given task (e.g. reading or visual search), when a transient change is made to the display for a period of 33ms, which participants are instructed to ignore, the number of saccades produced (normally 3 or 4 per second) is reduced and this decrease in saccadic frequency is time locked to the presentation of the transient image, and occurs as quickly as 60 to 70 ms after the onset of the transient image. It was suggested that this is a reflexive oculomotor low-level effect and the latency of the effect is close to the limits imposed by delays in the visual and saccadic systems (Stampe & Reingold, 2002).

The authors have documented the profile of saccadic inhibition and this appears to be time locked to the onset of the transient display change. In the first 50ms following a display change the proportion of saccades remains constant. After about 60 or 70 ms there is a decrease in the proportion of saccades produced which results as a dip in the distribution (saccadic inhibition). Following this there is an increase in saccadic frequency, which is above the initial level, and forms a peak in the distribution. The proportion of saccades returns to initial levels following this peak (Stampe & Reingold, 2002). This saccadic inhibition has been shown to occur for complex visual tasks such as reading and visual search (Reingold & Stampe, 1997, 2000, 2002; 2003a; b) and also in more typical paradigms used to study saccadic behaviour such as the gap effect and the antisaccade task (Reingold & Stampe, 2002).

The authors of these studies proposed a neurophysiological model to account for saccadic inhibition findings suggesting that the short latency of saccadic inhibition implies that it is a result of input from the early stages of the visual processing system, with the SC being put forward as the locus of control (Reingold & Stampe, 2003b). However, despite the different findings from studies using different paradigms to look at saccadic inhibition (countermanding task, saccadic inhibition paradigm, RDE paradigm) the precise neural pathways and structures underlying inhibition still remain to be fully specified. Reingold and Stampe speculate that the reason for having such a mechanism may be that the suppression of saccades is necessary in the event of the arrival of new visual information, which may need to be processed. Since there is reduced availability of visual information (Burr, Morrone, & Ross, 1994) and saccadic suppression when saccades are being produced (Deubel, Schneider & Bridgeman, 1996) it may be that the visual system automatically inhibits the production of saccades for a short period when new visual information is detected, in order to be able to process that new information.

Two paradigms investigating saccadic inhibition have been reported. The findings from the countermanding studies showed that voluntary saccadic inhibition may be mediated by activity in the FEF, and it is not affected by the spatial location of a signal to stop a saccade. Additionally, the suggestion that the outcome of the countermanding task resulted from a race between two independent processes was shown to be inadequate. The findings from the Reingold & Stampe studies on voluntary and involuntary saccadic inhibition are important in that the authors argue that the saccadic inhibition effect has implications for studies that incorporate brief changes to displays. They offer, for example, an interpretation of findings from experiments investigating double target onset studies which suggests that the observed increases in saccade latencies for these experiments (Ross & Ross, 1980; Walker *et al.*, 1995) may be determined by both the timing delays between target and distractor onsets, and, the saccadic latency distributions for the single target conditions in these studies (Reingold & Stampe, 2002).

The relevance of the discussion on saccadic inhibition to the experiments in this thesis is that although participants are not required to explicitly inhibit a saccade in the experiments, it is possible that for some experimental conditions i.e. when a peripheral target is presented with a peripheral distractor, participants may have to inhibit a saccade to the distractor in favour of making a saccade to the target. Additionally, the experiments in this thesis will involve the presentation of abrupt changes to the displays, and therefore the findings from the Reingold and Stampe studies on saccadic inhibition may also be relevant and may offer a possible explanation for any changes observed in saccade onset latencies between the different conditions in the particular paradigm employed. Current knowledge concerning saccadic inhibition therefore has implications for behavioural studies that employ transient display changes.

In summary, the above discussion has illustrated that both the generation of saccades, and possibly the inhibition of saccades, are under the control of many interconnecting lower and higher level brain areas. Clearly, much is now known about how the neural circuitry operates for the production of saccades, and how fixation is maintained between saccades. Although less is known about the neural correlates for saccadic inhibition, this is clearly an important aspect of the saccade generation system.

Another important aspect of the eye movement system is that it is constrained in the amount of information that can be processed in detail at any one time. It is common to divide the retina into three areas, which are labelled foveal, parafoveal and peripheral respectively. Typically foveal vision is regarded as the central two degrees of vision surrounding the fovea; parafoveal vision is defined as three degrees either side of this and peripheral vision is outside this parameter (Liversedge & Findlay, 2000). This is a working definition, which is useful for the purpose of saying where a particular stimulus was presented in the visual field, but it should be pointed out that there is a steady decline in acuity from the central part of the fovea outwards and the definition is therefore an arbitrary one in terms of function (Liversedge & Findlay, 2000). However it does serve to illustrate that there are limitations to how much detailed information can be processed in a single fixation. Therefore the process of selecting which portion of the visual field should be sampled in detail intuitively suggests that there should be a strong relationship between attention and eye movements and this is what will be discussed in the next section.

1.3: Eye movements and attention

An important aspect of the saccadic orienting system is that it is selective. That is, in everyday life where we are confronted with a wealth of, often dynamic, visual information, it is necessary for us, not only to be able to select the information that is relevant to our goals, but also to ignore information that is irrelevant. This selection process enables us to interact adaptively with our environment (Godijn & Theeuwes, 2003), and attention plays an important role in the visual selection process.

Eye scanning patterns in higher level cognitive tasks has shown that in the case of text reading (e.g. Rayner, 1998) there is an ordered stereotypical pattern of scanning, and in the visual search literature (Treisman & Gormican, 1988), searching for a target is to some extent dependent on the featural relationship between targets and distractors. Such work serves to illustrate that saccadic orienting is not a random process and also that we can attend to, and extract information from, stimuli whilst we are not directly fixating it. Moreover we make use of this information in guiding our saccades (Wolfe, Cave & Franzel, 1989).

Typically, the orienting of attention involves shifts of the eyes, head and even the whole body, in order to align the fovea with new areas of interest for detailed analyses. Overt orienting allows the redirection of the fovea (the central two degrees) to a new location in the visual field for detailed visual inspection, whereas covert orienting facilitates the processing of selected objects in the parafovea (up to five degrees outside the fovea) or in the periphery (outside the parafoveal area) without shifting the eyes (Godijn & Theeuwes, 2003). Since, the fovea occupies only the two central degrees of the retina, it is intuitively necessary that we should covertly process parafoveal and peripheral information prior to making saccades (Kean & Lambert, 2003).

Since the goal of both visual attention and visual orienting is to facilitate the selection process it is not surprising that a strong link has been proposed between attention and eye movements. It has been suggested that saccadic eye movements and visual attention are subserved by the same neural circuitry (Rizzolatti, Riggio, Dascola & Umilta, 1987; Rizzolatti, Riggio & Sheliga, 1994). Additionally there is much neurophysiological data to support the link between the attentional and eye movement systems (e.g. Kustov & Robinson, 1996). It has also been proposed that a shift of attention corresponds to the programming of an eye movement, and that this programming of an eye movement occurs also in shifts of covert attention, but under these circumstances the eye movement is not executed (e.g. Posner, 1980). However, agreement with this view has been contested (e.g. Klein & Pontefract, 1994) and many studies in the literature provide evidence for the position that whilst attention can be shifted without an accompanying eye movement, an eye movement is always preceded by a shift of attention to the location of the saccade target (e.g. Deubel & Schneider, 1996 amongst others).

Covert attentional shifts are shifts of attention to areas in the parafoveal or peripheral visual field that are not accompanied by eye movements (Posner, 1980) and this type of attentional allocation has been studied extensively by Posner and colleagues using the spatial cueing task (e.g. Posner *et al*, 1978). That there is an intimate link between saccadic orienting and covert attention in everyday life has been demonstrated by many studies on reading (see Rayner, 1998 for a review), although it may be argued that the stereotypical scanning patterns observed in reading are a result of the specific task demands for that particular activity. In contrast to covert attentional shifts, overt attentional shifts, are accompanied by eye movements. Two quite different processes have been identified as being capable of effecting shifts in attention (both for covert and for overt shifts in attention).

These are, the endogenous orienting mechanism which requires conscious direction and is therefore under voluntary control, and the other is the exogenous orienting mechanism which is independent of conscious control and is responsible for attention shifts that are involuntary, or without conscious intent. There is some neurophysiological evidence to support the two separate orienting systems. For example, the superior colliculus has been shown to be involved in exogenous shifts of attention, whereas some of the frontal brain areas have been shown to be associated with endogenous orienting (e.g. Robertson & Rafal, 2000).

There are temporal differences between the two systems in terms of their execution of attentional shifts, with the consciously controlled endogenous system being slower to respond than the rapidly operation exogenous system, which has been shown to be particularly responsive to the appearance of sudden events in the visual field even when such events are irrelevant for the task at hand (Theeuwes, Kramer, Hahn & Irwin, 1998; Theeuwes, Kramer, Hahn, Irwin & Zelinsky, 1999), and this phenomenon has been termed 'attentional capture'. Sudden abrupt onsets have been shown to capture both attention (e.g., Yantis & Jonides, 1984) and eye movements (e.g. Theeuwes *et al.*, 1998, 1999). However, there has recently been some suggestion that attentional capture is not the only process that is capable of activating the exogenous attentional orienting system. For example, Kean and Lambert (2003) have shown that useful information in the periphery can be extracted to guide saccadic behaviour. However, exactly what type of and how much information can be extracted from the periphery is not yet fully understood.

Although voluntary selection describes the process whereby orienting is controlled by the aims or expectations of the observer, the endogenous eye movements accompanying this type of orienting are frequently produced with highly automated routines (Findlay & Walker, 1999), even for more complex tasks such as reading. Orienting to new events in the visual field, especially those that are unexpected and appear in the periphery of vision will often produce saccades which have a reflexive quality, and these saccades are said to be involuntary, that is, they are controlled by properties of the visual stimulus rather than the goals of the observer and as such they are described as being exogenous. Thus, visual selection of information can be achieved by overtly or covertly attending to items in the visual array, and this attentional orienting can be achieved by voluntary control, or may be influenced by involuntary responses to newly presented parafoveal or peripheral information even though this information may be irrelevant to the task at hand (Theeuwes *et al.*,1998, 1999).

Godijn and Theeuwes (2003) provide an overview of the relationship between attention and saccades for exogenous (involuntary) and endogenous (voluntary) orienting. They conclude from the body of literature examining the relationship between the saccade generating system and the visual attentional system, that attention precedes the execution of endogenous saccades (apart from those in detection tasks, which it is argued demand a different type of attentional allocation, 'preparatory attentional allocation' which is slower than selective attention), but that the evidence for attention preceding exogenous saccades is inconclusive since, they suggest, many of the studies looking at this have had some instructional component which by default necessitates the use of the voluntary orienting system.

They argue that there are only two experimental paradigms that permit the examination of exogenous attention and exogenous saccades. These are the-anti saccade paradigm (Hallet, 1978) and the oculomotor capture paradigm (Theeuwes *et al.*, 1998, 1999) which both result in a percentage of erroneous saccades, either to the target in the anti-saccade task (about 20%), or to an abrupt task irrelevant onset in the oculomotor capture task (about 30%) of the trials. These erroneous saccades are said to be exogenous, since they occur in spite of an instruction to make a voluntary saccade elsewhere. In the anti saccade paradigm participants are requested to make a saccade in the exact opposite direction to the target that they are presented with, whereas in the oculomotor capture paradigm participants have to saccade to a target set amidst distractors. The erroneous saccades produced in theses experiments are much faster than the correct first saccades produced in both paradigms. However, Godijn and Theeuwes (2003) suggest that it is unclear from the evidence from the anti-saccade task whether attention actually precedes the initiation of exogenous saccades in this task, and the suggestion from the oculomotor capture paradigm findings that onsets capture attention even when the eyes go directly to the target, is indirect. They conclude that, to date, no study has directly examined the allocation of attention in the oculomotor capture paradigm. Therefore, the question as to whether attention precedes exogenous saccades remains unanswered.

The work on attention and eye movements has provided evidence to show that there is a strong link between the two but at least one model of saccade programming makes little reference to the role of attention (Findlay & Walker, 1999). Instead the authors argue that ''a theory of saccade programming is necessarily a theory of attentional deployment'' pp 672. In this model the role of covert attention in particular is questioned in every day normal visual scanning, and the authors suggest that nothing is gained by using the terminology of attention "since the properties assigned to attention mimic closely those of the eye itself'' (Findlay & Walker, 1999 pp 673).

Whilst there are contrasting claims as to the role of covert attention in saccadic orienting, and, whether indeed, attentional allocation precedes all saccades, the fact remains that attention and eye movements are intimately linked. The important point to extract from this discussion is that attention has an influence upon the generation of eye movements, and as such, it may be a factor which impacts upon the outcome of the experiment in this thesis. Since the abrupt presentation of peripheral information has been shown to capture attention and eye movements it is possible that in a task which demands one stimulus to be ignored in favour of saccading to another, both the endogenous and the exogenous orienting systems will be activated and as such this may influence saccadic behaviour. However, although studies of the effects of remote distractors on low-level oculomotor behaviour have sometimes directed attention to the location of saccade targets, this has been shown to have no effect upon increases in saccade latency compared to when no attentional instruction has been given (Walker *et al.*, 1995). A full description of the Remote Distractor Effect (RDE) is given in the next section.

1.4: The Remote Distractor Effect

It is well established that bilateral presentation of a target and a distractor produces prolonged saccade latencies compared to the presentation of a single target (e.g. Levy-Schoen, 1969; Walker *et al.*, 1995; Walker *et al.*, 1997). Double target onsets have been shown to produce prolonged saccade latencies compared to single target onsets. Early work used two peripheral targets in mirror symmetrical positions and later work showed that an abrupt onset at fixation simultaneous with a target also produced increased saccade latencies (Ross & Ross, 1980).

The remote distractor effect (RDE) refers to an automatic influence on the time it takes to make a target elicited saccadic eye movement when a target and distractor are presented simultaneously, compared with when the target is presented in isolation. This was first reported by Levy-Schoen (1969) who demonstrated that presentation of a target, along with a simultaneous distractor at a remote location, resulted in an increase in saccadic onset latency (20-40ms) to the target, compared to when no distractor was presented with the target. Since then it has been shown that advance knowledge of the target location still produces the effect (Walker, Kentridge & Findlay 1995) and a detailed investigation of the RDE (Walker, Deubel, Schneider & Findlay, 1997) has demonstrated that the effect occurs with distractors presented at various non-target locations in the visual field, with the exception of a window of 20 degrees around the target axis. Distractors in neighbouring locations within a window of 20 degrees do not produce increased latencies, but affect saccade landing positions. In that case saccade amplitude but not latency was affected. Moreover, a systematic relationship has been shown to exist between the position (eccentricity) of a remote distractor and the magnitude of the RDE. Central distractors (foveal) produce the biggest increase in saccade latencies and this increase reduces in a systematic way as the distractor is moved into the periphery.

The work by Levy-Schoen and Blanc-Garin (1974) showed that presenting two targets simultaneously on opposite sides of the fixation point results in prolonged saccade latencies (30-40ms) compared to single target presentation, even when participants were instructed to saccade to either target. Walker, Kentridge and Findlay (1995) as part of a set of three experiments examining the effects of endogenous orienting of visual attention on saccade onset latencies, examined whether the possibility of the increase in saccade latencies observed in a bilateral target presentation task resulted from a conflict between the choice of two possible saccade directions. They argued that if it was the case that an extra decision process was required to select one target in preference to the other, then the removal of this decision process by pre-specifying which side of the display to attend to, and also to saccade to, should reduce the slowing of saccade latencies compared to when a choice has to be made as to which target to saccade to. They showed however that this was not the case and that the increase in latency produced by bilateral target presentation was an independent effect that was not modified by an instruction to attend to the side of the presentation display to which a saccade would be generated. It was concluded that the bilateral target effect appeared to be an automatic inhibitory effect between two potential saccade targets, since it was not affected by a voluntary decision to saccade to a pre-specified direction.

In 1997 Walker *et al.* conducted a series of experiments examining the consistent observation of an increase in saccade onset latency when distractor stimuli are presented simultaneously with saccade targets at various non target locations. Their first study looked at the effects of targets and distractors presented along the horizontal axis. In experiment 1a targets could appear at either 4 degrees or 8 degrees with distractors along same axis. In experiment 1b targets could appear at 0.5 degrees, 1 degree, 2 degrees or 4 degrees with distractors along same axis. Their main observation was an increase in saccade onset latencies when distractors appeared at fixation and in the contralateral non target hemifield at eccentricities of up to 10 degrees. Distractors presented along the ipsilateral target axis did not affect latencies, but a modification was observed in amplitude in this condition with saccades often landing at intermediate positions between the two stimuli (the global effect). The next two experiments examined the effects of presenting distractors at various 2D locations in both the target and non target hemifields. Experiment 2 presented targets at 4 degrees or at 8 degrees with distractors positioned at locations along 8 possible axis (17 positions). Experiment 3 looked at the effects of presenting targets 4 degrees or 8 degrees with distractors along 9 possible axis within 45 degrees in the ipsilateral hemifield only. Again the maximum increase in saccade onset latency was observed when distractors appeared at fixation. Also distractors appearing at locations on any of the eight principal axis in either hemifield, other than the horizontal target axis, also increased latency. Furthermore, there was a reciprocal relationship between saccade amplitude and saccade latency. Within about 20 degrees of the target axis itself, distractors affected saccade amplitude, but not latency. Contrasting with this, distractors presented outside this 'window' increased latency, but had no effect on amplitude.

The findings from these experiments revealed a systematic quantitative relationship between the increase in saccade latency and the ratio between target and distractor eccentricities. Specifically, the increase was largest with small values of the ratio and reached a peak with distractors at the fixation location. Moreover, the increase with foveal distractors fitted the same function as that observed for more eccentric distractor locations. This finding shows that inhibitory effects upon saccade onset latencies are not limited to centrally presented distractors, but operate over large areas of the visual field. The findings were interpreted with reference to neurophysiological data which postulate inhibitory processes operating in the rostral region of the superior colliculus and the results suggest that these inhibitory processes are not restricted to the central foveal region alone, but operate over wider regions of the visual field. As mentioned earlier, the superior colliculus is a brain centre known to be involved in the spatial mapping of locations and since there are two superior colliculi and activation in one inhibits activation in the other then the presentation of a target in each hemifield could produce inhibition in both colliculi. Thus intra collicular inhibition could account for the pattern of prolonged saccade latencies produced when two possible targets are presented simultaneously, one in each hemifield.

It has already been mentioned that activity in the build up cells in the SC is related reciprocally to activity in the fixation cells. If fixation cell activity operates at the level of brainstem omnipause cells (excites these while having inhibitory effects over other areas of the colliculus) this could explain why distractors presented in either hemifield have been shown to affect saccade onset latency, since omnipause neurons do not form a lateralised system. There is therefore no need for crossed collicular inhibition to have effects at fixation. Although it is known that stimulus onset and offset affects visual events at fixation, the systematic eccentricity effects of the RDE may be directly caused by the effects of the distractor operating over larger areas of the visual field on the fixation system. Walker *et al.*, (1997) are suggesting here is that a possible cause of the RDE might be directly related to the properties of the collicular fixation system, and they interpret their findings for central and peripheral distractors as evidence for an extended fixation zone in the programming of saccades. It is therefore suggested that the RDE results from activation of fixation cells not only in the 2 degree rostral pole region of the superior colliculus but also in other more caudal areas of the superior colliculus.

The very detailed studies of the effects of remote distractors have shown clearly that simultaneous presentation of a distractor and a target has a very systematic effect upon the latencies of saccades. The behavioural data from the RDE paradigm have been explained with reference to underlying neurophysiology. In the next section two models of saccade generation that provide accounts for the generation of increased latencies observed in the RDE studies are presented.

1.5: Models of Eye Movement Control

There are many models of saccade generation. An early model proposed by Becker and Jurgens (1979) was very influential, and was the first to propose a separate triggering process for the control of the generation of a saccade, and a computational process that determined the amplitude of a saccade. Two recent models of saccade generation will be described here in detail, and an explanation for the RDE findings will be given as it is provided for by each of these models. The main difference between the two is that the first (Findlay & Walker, 1999) advocates separate processing for the 'where' and the 'when' aspects of saccade generation, whereas the second model (Godijn & Theeuwes, 2002) posits that the 'where' and the 'when' processing occurs in the same saccade map.

Findlay and Walker (1999) in their target article present an information processing model for the control of saccadic eye movements. The framework for the model is described in functional terms but has been considerably influenced by work completed in the area of oculomotor neurophysiology. A wide range of physiological and psychological data are presented to support the model which has five levels and can provide an account for a variety of oculomotor phenomena including the 'global effect', the 'gap effect', the 'remote distractor effect' and express saccades. The two principles of 'parallel processing of saccade timing and metrics' and 'competitive inhibition through a winner takes all strategy' are the main base of the model. In addition the model bears some close parallels to established physiological processes occurring in the oculomotor system.

The model draws a distinction between the spatial 'where' and the temporal 'when' systems of eye movement control with saccades being generated as a result of competition between these two processing streams. These independent streams descend through the hierarchy of the five levels and progress in parallel until either the fixate system or the move system avails a response. It is suggested that the lower levels (1,2 & 3) operate automatically. Various centres in each pathway are interconnected via reciprocal inhibition and visual onsets have automatic access to the eye movement control system via the lower levels of the model. The higher levels of the model are under voluntary control for tasks such as reading and visual search and it is suggested that the generation of saccades for such tasks operates through spatial selection and search selection, which generally combine in an automatised way in contrast to levels 1, 2 & 3. 'When' to move the eyes is determined by high level cognitive processes related to processing of the foveal information. 'Where' to move the eyes depends on low-level visual analysis of peripheral stimuli, although this can be modulated by level 4 activity. In the 'where' pathway there is spatially distributed coding and the selection of the saccade target is accomplished via parallel processing and competitive inhibition in a two-dimensional salience map. The metrics of the saccade (direction and amplitude) are a direct result of the location of a peak in the salience map. The model in its current form offers no account of paired saccade programming.

The main focus of the model is that processes operate stereotypically. Although optimal sampling of the visual environment is achieved by voluntary eye movements which are used to orient the fovea to salient visual stimuli for detailed inspection and analyses, these voluntary eye movements are usually produced with highly automated routines, even for higher level cognitive tasks such as reading which is achieved through ordered scanning of the text. Eye movements to new events in the visual field, however, especially those with an abrupt onset, often have a reflexive like quality. This automatic access of visual onsets means that when saccades are made visual onsets cannot be totally ignored. This does not mean however that visual onsets will automatically result in saccadic orienting.

It is suggested that the first three levels of the model are automatic and hardwired and that processes in these levels operate in a stereotyped automatic fashion which is not modifiable by cognitive influences, other than through the descending pathways. Saccade release is determined by resolution of conflict between the 'fixate' centre in the 'when' pathway and the 'move' centre in the 'where' pathway. In the model these centres are located in level 2. Level 1 of the model is the immediate pre-motor stage where a motor command is executed. This motor command is influenced by level 2 activity and initiation of an eye movement occurs when the balance between activation in the pause cells and the burst cells in the brainstem crosses some critical level. This triggering of a saccade is achieved through reciprocal interaction between a gating mechanism in the 'when' pathway and a motor command in the 'where' pathway. In level 2 of the model there is a slower and more variable build up of activity in one centre, either the fixate centre in the 'when' pathway or the move centre in the 'where' pathway, with a corresponding decline in the other centre. This push pull interaction between the two centres is competitive and the time taken to resolve the conflict between the two is what is largely responsible for the exact point in time at which a saccade is generated. Level 3 of the model is where the effects of transient visual events are dealt with. Visual events at fixation, either offsets or onsets impact upon the activity in the fixate centre in level 2. Events at fixation therefore have automatic influences on the signal in the 'when' pathway, whereas events in the periphery have influences upon activity in the fixate centre in level 2 and also have automatic effects on the salience map in the 'where' pathway in level 2. Levels 4 & 5 of the model are intended to show how automated habits and effects of cognitive control can have influences in the 'when' and the 'where' pathways of the model. At various levels in the model there is parallel processing of command signals for the eye movement, and processes of conflict resolution that are achieved by competitive inhibition between centres in the different pathways. This process of conflict resolution is time consuming and accounts for the time taken to initiate a saccade, even for simple orienting responses.

Although much evidence is provided in the form of behavioural data to account for low level influences on oculomotor behaviour (e.g. express saccades, anti-saccades, the gap effect, the global effect) these will not be discussed further here, but an account of the RDE as given by the model will be presented. If two widely separated stimuli are presented simultaneously then saccades will land accurately on one of these but the latency of these saccades will be prolonged. Levy-Schoen (1969) queried what it was that governed the choice of the stimulus fixated in these circumstances. A main finding was that the strongest influencing bias was proximity of the stimulus to the fovea. A further study (Walker *et al.,* 1995) showed that the latency increase for bilateral presentation of two target stimuli occurred whether or not participants had prior knowledge of the saccade target location. However in contrast to other studies, increased saccade latencies were not found for bilateral target presentation in one study (Rafal, Smith, Krantz, Cohen & Brennan, 1990).

Although the early studies on double onset targets used exclusively two targets on the horizontal axis, often at equal eccentricities a more detailed examination of the prolonged latency effect looked at the effects of distractor stimuli in various positions in the visual field (Walker *et al.,* 1997). The findings from this set of detailed studies revealed that the latency increases for remote distractors were not restricted to distractors on the opposite axis, nor were they restricted to distractors at the same eccentricity as the target. In fact, the visual onset of a distractor resulted in a latency increase, compared to when a single target was presented, at any location remote from the target, including distractors in the same visual field as the target. Moreover, a relationship was found between target and distractor, which showed that the latency increase was dependent upon the location of the remote distractor. The increase was greatest when distractors were positioned at central fixation and this reduced systematically as the distractor was positioned further into the periphery. Findlay and Walker's model of saccade generation postulates that when the distractor is positioned at the fixation point this results in a direct effect of activation in the fixate system. Therefore the results from the RDE study strongly implicate the non specific fixate system. If the effects depended on interactions within the salience map then the magnitude of the RDE would be expected to depend on the distance between the distractor and the target. They argue that the findings from the RDE studies show that activation in the fixate system extends to regions in the visual field from central vision up to about 10 degrees eccentricity. According to the model, therefore, remote distractors affect the 'when' process, whereas neighbouring distractors affect the 'where' process involved in the computation of saccades.

A Competitive Integration model of saccade generation, whereby the programming of endogenous and exogenous saccades occurred in the same saccade map, was put forward by Godijn and Theeuwes (2002). A set of three experiments performed by Godijn and Theeuwes (2002) provided evidence for the model. In the first experiment participants had to saccade to a target and on some trials an abrupt and task irrelevant onset distractor was presented at the same time as the target was defined. In the second experiment the target position was switched whilst the participant made the first saccade and in the third experiment this manipulation was repeated with a second target switch, which repositioned the target at its original starting position. All experiments employed the same stimuli, that of an around the clock display with possible target positions located at numbers 1, 3, 5, 7, 9, and 11. Participants were required to make an eye movement to the circle, which changed in colour from red to grey (600ms after the onset of the display). On some trials an abrupt onset occurred (red circle in an empty space in the display) simultaneous to the change in colour of one of the circles from red to grey (the target). Several eye movement parameters were recorded and analysed in detail, and the various manipulations of switching the target (Experiment 2) from one location to another once the first eye movement was initiated to the abrupt onset, and switching the target from one location to another and then back again to its original position (Experiment 3) once the second eye movement was initiated following fixation on the abrupt onset, were carried out to test whether voluntary and involuntary eye movements and the spatial and temporal aspects of these two types of eye movements were programmed together in the same system prior to the execution of a saccade. The results from all three experiments were not consistent with an independent horse race model of saccade generation which postulates that the programming of endogenous and exogenous saccades are processed in separate systems. The results from these three experiments (details of which are given below) instead support the competitive integration model which assumes that control signals for exogenous and endogenous saccades converge on a common saccade map.

Therefore in this set of experiments the authors provide evidence to support a model of eye movement generation in which voluntary and involuntary eye movements are programmed in the same 'saccade map' and the resulting eye movement in a situation where the stimulus evokes the possible execution of the two types of eye movement in any one given trial, will be determined by the ability to inhibit activity at one spatial location in favour of moving the eye to the other spatial location. A consistent pattern has emerged from these studies which suggests that not only eye movement latencies but also eye movement end points, amplitudes and saccade trajectories can all be predicted and generalised to other visual paradigms which adopt the use of abrupt onsets.

Namely, in cases where the eye moves to an abrupt onset instead of the target, latencies will be shorter than when the eye moves directly to the target. Fixation durations for the first eye movement to an abrupt onset will be shorter than those directly to the target. Undershoot to the abrupt onset will occur and in cases where the abrupt onset is close to the target amplitudes will be less than if there is a greater distance between target and abrupt onset and landing position of saccades will often be between target and abrupt onset (global effect). Trajectories of first saccades to the target will deviate away from the abrupt onset distractor. In relation to other models of saccade generation Godijn and Theeuwes argue that both the spatial and temporal information needed to make a saccade are available to the system concurrently. This is unlike Findlay and Walker's model in which the information available for the 'when' system and the 'where' system are not integrated in the same 'saccade map'.

The authors discuss in detail how the findings from these experiments which use a modified version of the oculomotor capture paradigm support their model of 'competitive integration' rather than an 'independent horse race model'. The competitive integration model assumes that the control signals for voluntary and involuntary eye movements come together on a shared saccade map. There is a retinotopic representation whereby the information for both types of saccades is integrated. Activation in this map is inhibited for distant locations but spreads to close locations (neighbouring). There is lateral inhibition when two distant locations are activated, but when two near locations are activated the resulting combined activation often results in a peak somewhere between the two locations. The point is that the competitive integration model for exogenous and endogenous saccades (Godijn & Theeuwes 2002) can also account for many oculomotor effects which have been consistently observed in eye movement laboratories and in addition can provide an explanation for the outcome when paired saccades are programmed whereas at present the Findlay & Walker (1999) model can not.

Both models advocate competitive integration but unlike the model of Findlay and Walker which assumes separate pathways for the temporal and spatial programming of saccades, Godijn and Theeuwes' competitive integration model of saccade generation does not have separate fixate and move centres. Instead it assumes that the temporal and the spatial aspects of saccades are integrated in the same saccade map. Furthermore, their model can account for the programming of paired saccades and their explanation of the RDE differs from Findlay and Walkers' which advocates that the systematic decline in the magnitude of the RDE for central distractors compared to peripheral distractors is a result of direct effects upon the fixation centre of the saccade generation system.

Three experiments were conducted which provided evidence for a competitive integration model whereby exogenous and endogenous saccades were shown to be programmed in the same saccade map. The authors argued that the RDE paradigm elicits both types of saccade since there is an abrupt distractor onset with the saccade target. In that case saccades directed to the distractor are considered to be exogenous whereas saccades directed to the target are considered to be endogenous. Their experiments manipulated the appearance of abrupt onsets with targets in a visual search paradigm and the findings clearly showed that reduced saccade onset latencies are produced when saccades go to the abrupt onset prior to the signalled saccade target. They claimed that this finding is incompatible with Findlay and Walkers model of saccade generation, whereby it is claimed that the RDE findings provide evidence for an extended fixation zone from central stimulation out into the periphery. Godijn and Theeuwes model, unlike Findlay and Walkers model, does not have separate fixation and move centres associated with the temporal 'when' and the spatial 'where' programming of saccades. In their model information for the temporal and spatial aspects of eye movement generation are coded in the same saccade map and the resulting saccade will go to the target as long as the programmed exogenous saccade can be suppressed before it has been initiated. This means that in the case of a task which demands a saccade to a pre-specified target and where a simultaneous irrelevant remote distractor is presented with the target, activation will occur in the saccade map for the exogenously elicited saccade first (their findings clearly demonstrate faster saccades for abrupt task irrelevant distractors) followed by activation in the saccade map for the endogenous saccade to the target. The activation for the exogenous saccade must be inhibited in order to make a saccade to the target. If it is not, then a fast erroneous saccade will be made to the abrupt onset, followed very quickly by a saccade to the target. If activation is inhibited then a correct saccade will be made to the target but the latency of the saccade to the target will be longer than latencies for erroneous saccades to the abrupt onset, and compared to latencies of correct first saccades to targets when no abrupt onset is presented with the target.

Thus, in the model of Godijn and Theeuwes (2002) the competition for saccade programming results from activation at different locations in the saccade map. Although the model is similar to Findlay and Walker's model in that it assumes competitive integration of information, it is different in that it does not separate the temporal and spatial aspects of eye movement control. It can explain the increase in saccade latencies for the early double onset target studies whereby both target and distractor are widely separated. However when targets and distractors are presented close together, because of the mutual excitation in the saccade map the threshold should be reached quicker than where no distractor is presented, the model would predict a reduction here for saccade latencies compared to a no distractor condition, but that is not the case. What happens here is that saccade amplitudes but not latencies are affected and the resultant saccade often lands between the target and distractor (global effect)? This was what was found in Walker *et al* (1997) detailed study of the effects of remote distractors.

Two models of saccade generation have been discussed. Whilst there are similarities between the two, they differ in that one (Findlay & Walker, 1999) advocates separate pathways for the 'when' and the 'where' aspects of eye movement control. Whereas the other (Godijn & Theeuwes, 2002) postulates that both the 'when' and the 'where' aspects of eye movements are programmed in the same saccade map. Thus although there is some debate as to whether these two aspects of eye movement programming are separable it has been recognised that decisions of 'where' and 'when' to move the point of fixation are key aspects of eye movement control and an understanding of the relationship between the two is crucial to understand fully the cognitive processes that eye movements reflect (Liversedge & Findlay, 2000).

The background information presented in this introduction has not yet focussed on aspects of cognitive processing, and how higher-level cognitive factors may impact upon low-level oculomotor behaviour. One example of higher-level cognitive influences on eye movement behaviour comes from the wealth of data in the reading literature, (for a review see Rayner, 1998), which shows that linguistic variables influence both landing position and fixation durations during text reading. Word length, orthography, phonological and lexical variables have all been investigated and all have effects upon fixation durations in reading. The next section of the introduction discusses why it might be interesting to look at the effects of linguistic distractors on eye movement onset latencies to simple targets.

1.6: The relationship between the visual processing system and the language processing system

In addition to work on low-level oculomotor effects on saccade generation there are many studies that provide evidence for the usefulness of detailed eye movement measurements as an indication of underlying cognitive processing (Liversedge & Findlay, 2000). It is therefore interesting to investigate whether any higher-level cognitive factors may impact upon lower-level oculomotor effects that are generally assumed to be reflexive in nature. Furthermore, since the visual processing system provides the information upon which the language processing system operates, then it is interesting to investigate whether language processes can influence the eye movement control system in a task where no processing of linguistic information is required for its successful completion. Specifically, if irrelevant linguistic distractor information is presented with a non-linguistic target, would the linguistic stimulus influence participants' ability to ignore this information and saccade to a non-linguistic target to a greater extent than for a comparable non-linguistic distractor. Furthermore, would the linguistic status of qualitatively different letter strings modulate the magnitude of any distracting influence?

It is generally accepted that the human brain is comprised of a number of functionally and anatomically specialised systems that are responsible for processing qualitatively different and uniquely structured stimuli (Fodor, 1982; see also Coltheart, 1999). Fodor termed these specialised systems 'modules' and attributed a number of defining characteristics to them. He suggested that modules are domain specific, mandatory and reflexive. He also argued that modules are informationally encapsulated, in that they have restricted access to stored knowledge. It seems possible, if not reasonable, therefore, to attribute the prerequisite characteristics of a modular system that Fodor identified to both the visual system and the language processing system. During written language comprehension, it is generally accepted that there are a number of processes that must occur in order that a reader may form a representation of the meaning of a sentence. One (simplistic) view of this process stipulates that the first stage of comprehension is word identification during which each letter string that forms a word unit is identified within the mental lexicon. Upon identification of a word, its semantic meaning and syntactic category information become available. Subsequent to word identification, syntactic parsing may occur. During parsing the structural relations between the constituents of a sentence are computed. Finally, the individual word meanings along with the structure of the sentence allow the reader to form a shallow semantic representation of sentential meaning after which inferential work and referential processing may occur to permit the formation of a full discourse representation. According to this point of view, the first process involved in written language comprehension is word identification and this process should be initiated in a reflexive and mandatory manner whenever we perceive a visually presented letter string (Fodor, 1983; see also MacLeod, 1991; Neely, 1991). This suggestion meets with most people's intuitions. For example, whenever we visually perceive the letter string C-A-T, it seems impossible to perceive the string as anything other than the word CAT. We do not seem to be able to automatically process the string as the three separate, individual, constituent letters C, A, and T.

There is a substantial body of evidence in favour of automatic lexical identification. This research is primarily centred on the Stroop Effect (Stroop, 1935). In one of Stroop's experiments participants were presented with two lists of colour words (e.g. *RED*, *BLUE*, etc). In one list the words were printed in an ink colour that was congruous with their colour name (e.g. *RED* printed in red ink), and in the second list the words were printed in ink that was incongruous with their colour name (e.g. *RED* printed in blue ink). Participants were simply required to name the colour in which the word was printed. Colour naming times were longer for the words printed in incongruous colours than for the words printed in congruous colours. This finding is generally accepted to be a very resilient demonstration of the automaticity of lexical processing. Despite only being required to name the colour of the letter string, the participants are unable to prevent themselves from identifying the word. Because the word is a colour name, this produces interference when it is incongruous with the colour in which the letter string is presented. Hence, the automatic identification of the word disrupts the colour naming process in the incongruous condition but not in the congruous condition.

Most models of word identification either explicitly, or implicitly assume automaticity of processing. For example, according to the Search model (Forster, 1979), readers initially form a representation of the perceived letter string before initiating a search of a series of bins within which are stored representations corresponding to all the words stored in the mental lexicon. When there is a match between the perceived stimulus and a stored representation, word identification is said to have occurred. Alternatively, if no match is found, then word identification does not occur indicating that a nonword has been perceived. Thus, whenever a letter string is perceived, word identification is assumed to proceed automatically and only when there is no representation corresponding to the perceived stimulus, can a decision be made that the perceived letter string is a nonword.

In contrast to search models, models of direct access such as the Logogen model (Morton, 1969; 1979), Interactive Activation (IA) model (McLelland & Rummelhart, 1981) and the Multiple Read Out (MRO) model, (Grainger & Jacobs, 1996), stipulate that the visual characteristics of the perceived stimulus feed directly into the word identification system. Activation based models, such as the IA model and the MRO model operate via activation flowing between levels of representation and competition occurring between entries within a level. According to the IA model, features of the perceived letter string activate corresponding feature representations at the feature level that, in turn, feed activation forward to the next level of representation, the letter level. Letters that have features consistent with the activated features in turn become activated and feed activation forward to the next level of the system, the word level. Activated entries within a level mutually inhibit other entries within the level. Through this system of activation between levels and competition within a level, a single candidate entry at the word level that corresponds to the perceived stimulus is selected. If no candidate is activated to a substantially greater degree than other competitors, then the system assumes that the perceived letter string is a nonword and that there is no representation corresponding to it within the mental lexicon.

The point of the preceding discussion is to illustrate that according to almost all models of written word identification, including those discussed here, word identification procedures are assumed to be initiated automatically whenever a letter string is perceived. Furthermore, the most common way an individual is able to know that a nonword has been perceived is when the word identification system fails to uniquely identify a lexical entry corresponding to the perceived letter string. In other words, word identification procedures must be initiated and fail in order for a reader to decide that a nonword has been perceived. To this extent, models of word identification assume that initiation of lexical identification procedures is reflexive and mandatory occurring automatically whenever a letter string is perceived whatever the nature of that letter string.

It follows that the orthographic status of a letter string should not affect whether word identification procedures are initiated. Whenever a letter string is perceived, lexical identification processes should proceed normally, no matter whether the letter string is a word (e.g. SHOE), an orthographically legal nonword (e.g. LANT), or alternatively an orthographically illegal nonword (e.g. FRGW). Clearly, factors such as the orthographic legality of a letter string will influence the speed with which it may be identified or rejected as a nonword. Such differences in speed of word identification or rejection as a nonword will occur as a direct consequence of the mechanics of the word identification process. However, it remains that identification procedures should be initiated automatically and proceed normally no matter what the orthographic status of the string. The idea that lexical identification procedures are always initiated automatically upon perception of a letter string has though been challenged by a recent set of studies reported by Stolz and Besner (Stolz & Besner, 1999; Besner & Stolz, 1999). It is important to note that although the findings from the Stolz and Besner studies show that the automatic processing of letter strings can be overridden, the default is to automatically process the letter strings. Therefore the findings in no way weaken the case for using words to examine whether higher-order factors can modulate oculomotor control.

1.7: Basis for Experimental work in this thesis

In order to determine therefore, whether there are systematic differences upon the magnitude of the RDE for different types of linguistic strings it will be necessary to use a variety of qualitatively different linguistic strings as stimuli. Linguistic strings can be categorized in a very structured way. For the purposes of the experiments in this thesis it is useful to categorise letter strings within a linguistic hierarchy, each level of which contains strings that are qualitatively different from the others. The simplest linguistic string that we can have is a uniform repeated letter string (e.g. AAAA) and strings of this type would be represented within the most linguistically simple level of the hierarchy. Although such a string is formed from constituent letters, it is both visually very simple and minimally linguistically complex. Orthographically illegal nonwords (e.g. TQDF) form the next level of the hierarchy. These strings are comprised of different letters and are therefore more complex than uniform strings, but are still linguistically very simple. At the next level orthographically legal nonwords are represented (e.g. LANT). Such strings are more complex in that they are orthographically legal and therefore form good potential candidate words (i.e. they could have a corresponding lexical entry). Note that it is merely arbitrary that such strings are not words and therefore do not have any semantic meaning Finally, the most complex level of linguistic string in the hierarchy for these experiments is that of real words which are obviously orthographically legal letter strings that have corresponding lexical entries and therefore semantic meaning (e.g. FORK). Therefore words are a good candidate visual stimulus to use to investigate whether higher-level cognitive effects can influence low level oculomotor control.

In summary, an important question must be; to what extent can cognitive processes such as lexical identification impose influence on oculomotor behaviour? One suitable paradigm for investigating this question could be The Remote Distractor (RDE) paradigm. In the RDE there must be some processing of the peripheral distractor which affects the 'when' system of saccade production. It is interesting therefore to query whether the magnitude of the RDE would be affected by using linguistic text strings as distractors. One would expect to get a difference in performance, which would be directly related to the eccentricity of the distractors relative to target position. A larger effect would be expected for centrally presented versus peripherally presented distractors. However, what may be more interesting would be an observed difference for the type of linguistic string at both central and peripheral locations. It may offer an answer to the question as to whether there are any systematic effects of peripheral linguistic information on the language processing mechanism, which impact directly upon the oculomotor system. A finding such as this would imply that higher level linguistic processing was occurring for both presentation locations, and this would argue against current models of saccade generation in reading which suggest that the 'when' decision of eye movement control is determined purely by the level of difficulty experienced at foveal inspection. Additionally, it would contrast with the saccade generation model of Findlay and Walker, which also advocates that the governing factor for 'when' to move the eye is a result of central stimulation variables.

It was reasoned that, if it were found that saccadic onset latencies could be modulated by different types of linguistic distractors or by manipulating the complexity of distractors in other systematic ways, then this would provide evidence that the RDE could be a useful tool for the investigation of processes underlying task performance. Any systematic differences between the different types of distractor on the magnitude of the RDE would demonstrate that the RDE was sensitive to higher-level cognitive factors and in turn would provide support for the investigation of higher-level cognitive or attentional influences by using this low-level oculomotor paradigm.

The first experiment therefore examined the assumption that visual word recognition is automatic and occurs whenever a letter string is perceived (Stroop, 1935). This was achieved by employing a non-lexical task and testing whether qualitatively different types of linguistic distractor strings systematically modulated the magnitude of the RDE. In line with the findings from lexical access studies linguistic distractors were manipulated with relation to the orthographic status of the distractor strings. Distractor strings were presented centrally or peripherally (8 degrees to the right or left of the centre of the display). Four types of four character length distractor strings were used (words, orthographically legal nonwords, orthographically illegal nonwords, uniform letter string) with an additional visual non-lexical control distractor string (uniform shape string i.e. four boxes). A further baseline condition displayed the target without a distractor. The participant's task was to make an eye movement to the target (a cross) and ignore the distracting stimuli. Saccade onset latency to the target was compared across the five conditions for all participants. This reasoning formed the logic for the first experiment.

The findings from the first experiment showed that there were similar increases in saccade latency for all linguistic string distractors, compared to single trial targets, and central distractors produced longer saccade latencies compared to peripheral distractors. The exception of this finding occurred for a non-linguistic shape string, which had the effect of producing shorter saccade latencies, compared to the linguistic distractors, at central presentation of the distractors. No differences were observed between central and peripheral presentation of the non-linguistic distractor. This unexpected finding was investigated further in Experiment 2 where it was found that constancy of the distractor (changing or repeating distractors) affected saccade onset latencies whereby constant (repeated) distractors produced shorter saccade latencies compared to changing distractors. Furthermore, no differences between central and peripheral distractors were observed when the distractors were constant (repeated). The next two experiments investigated this unexpected eccentricity effect further, and it was found that constant central distractors produced prolonged saccade latencies, compared to constant peripheral distractors, but only when the target was presented to a pre-specified unilateral side of the visual display monitor. The final experiment examined again the effects of linguistic distractors, and amongst many interesting findings for this experiment it was shown that linguistic distractors produced longer saccade latencies, compared to non-linguistic distractors, and that there were differential effects upon saccade onset latencies and RDE magnitudes for two types of linguistic distractor, but only when these were presented at a parafoveal location.

Chapter 2

Does the Linguistic Status of a Text String Systematically Modulate the RDE?

2.1: Experiment 1

Experiment 1 examined the effect of different types of linguistic distractor strings on eye movement response latencies to simple targets. One reason for choosing to address this issue was to test the general assumption that visual word recognition is automatic and occurs whenever a letter string is viewed. As detailed in the introduction, the most familiar demonstration of this is the classic Stroop effect (Stroop, 1935; see also Macleod, 1991 for a review). In the classic colour naming experiment of Stroop it was found that participants took longer to identify the colour of a stimulus if that stimulus was a written colour word which was incongruent with the actual colour of that word, for example, the written word 'red' presented in green font. Following these findings, which have been well replicated, comes the assumption that the processing of linguistic strings is 'automatic' and hence may well influence in some way the ability to perform non-lexical tasks. Clearly any influences of linguistic material on a non-lexical task would be an indication of cognitive processing of that material. The investigation of saccadic onset latencies formed a suitable way of testing the generality of this claim. Eye movement measures such as fixation durations and onset latencies have shown themselves to be sensitive to a number of physical and perceptual variables, and visual scanning patterns in studies on reading and in the visual search paradigm have revealed much about higher-level cognitive processes that affect the production of voluntary saccades (Liversedge & Findlay, 2000).

Since the oculomotor system is the system that provides the visual information to the language processing system for linguistic processing, any impact of automatic linguistic processing upon the saccade generation system should be revealed. Thus this first experiment investigated whether presentation of irrelevant linguistic information impacted upon the eye movement system for a task that required no processing of this linguistic information for successful completion. The Remote Distractor Effect (RDE) paradigm was chosen as suitable to investigate this question. In this paradigm, which was described in detail in the general introduction, participants are asked to make an eye movement to a simple target whilst ignoring anything else that might be presented simultaneous with the target. The first demonstration of an increase in saccade latencies on trials where two possible targets were presented, compared to trials where a single target was presented, was shown by Levy-Schoen (1969). The effect occurs for both central and peripheral distractors, and apparently shows a smooth transition with central distractors producing a greater effect than peripheral distractors (Walker *et al.*, 1997), and furthermore the RDE occurs both when unilateral and bilateral saccades are elicited (Walker *et al.*, 1995). This type of task has been used to investigate in detail the effects of remote distractors presented at various locations in the visual field, on eye movement latencies to targets presented at the same time as these distractors. The resulting Remote Distractor Effect (RDE) is a robust finding in vision research whereby an increase in response latencies (mean 20 - 40ms) is observed when simultaneous presentation of bilateral target and distractor stimuli occur and the task requirement is simply to 'look at the target', compared to when a simple target is presented on its own (Walker *et al.,* 1997). What has not been investigated to date is the effect upon the magnitude of the RDE for more complex distractors, such as those with any linguistic content. Manipulation of distractor complexity using linguistic distractors allowed the investigation of the questions set out to be addressed in this first experiment. Namely, could the automatic nature of visual word recognition impact upon one aspect of the oculomotor control system (saccade onset latencies), and, as the linguistic status of a string increased towards the level of a word, would this have a greater effect upon saccade onset latencies. Finally, would the presentation of irrelevant linguistic information impact upon the eye movement system in a way that systematically differed from other types of distractors that had no linguistic content?

Two variables were be manipulated in Experiment 1. The first was the Eccentricity of the distractor. It has been demonstrated by Walker *et al.*, (1997) that a central presentation of a distractor produces the biggest RDE, with a systematic decline in saccade onset latencies for distractors positioned out to the periphery. For the current experiment two levels of distractor eccentricity were chosen; central presentation, and peripheral presentation at an eccentricity of 8 degrees. The selection of these two eccentricities was adopted to optimise the chances for producing clear effects for the different types of distractor in the experiment, at each of the eccentricities. The biggest effects of remote distractors have been found for central presentation (Walker et al., 1997), and effects of orthographic status have been shown for lexical decision tasks that have presented material at fixation (e.g. Coltheart, Davelaar, Jonasson and Besner, 1977). Therefore an effect of remote distractors would be expected for central presentation of a distractor, and also any differential effects for the different types of linguistic distractors would also be expected at this presentation location. The peripheral presentation location of 8 degrees has been shown to produce a Remote Distractor Effect which is smaller in magnitude compared to that shown for distractors presented at central fixation, and also the presentation of the different types of distractors at this peripheral location would be expected to produce the same effects for all types of distractor, since visual acuity declines into the periphery this should result in a visual degradation of the distractors such that it will be difficult to discriminate between them at a visual level. The peripheral eccentricity should therefore exclude any lexical processing of the material. However there must be some processing of the peripheral distractors in the RDE paradigm, since increases in saccade onset latencies are observed for peripheral distractor presentation conditions compared to single target conditions (e.g. Walker *et al.,* 1995, 1997). If this processing is purely visual then all types of distractor should produce the same effects at this eccentricity, however if any linguistic processing is done at the peripheral distractor location, then this could also produce differences between the different types of distractors on the generation of saccades. It is however unlikely that this will be the case since it has been shown that, at least during the reading of text, only low level visual information is available to the language processing system outside the parafovea (see Rayner & Pollatsek, 1989). The selection of these two eccentricities therefore enabled some predictions to be made as to the outcome for the different types of distractor used. What was anticipated was that there would be qualitatively different effects for the linguistic variables at the different distractor eccentricities. Specifically, the two variables of distractor type and distractor eccentricity should show an interactive effect. The target location was kept constant at 8 degrees eccentricity to avoid any possible confounds which may have resulted from an asymmetric relationship between peripheral targets and distractors. Levy-Schoen (1969) found prolonged saccade latencies of up to 40ms when a distractor was presented in the contralateral hemifield, simultaneously with, and in the mirror symmetric position to, the target. A control condition in which only a target is presented was also used to provide the baseline data for a comparison to be made between this condition and the central and peripheral distractor eccentricity conditions. Again in this condition the target was presented at an eccentricity of 8 degrees. Both targets and distractors were displayed on both the right and left of the display since it has been shown that a Remote Distractor Effect occurs in situations where the target location is both pre-specified and when it is not (Walker et al., 1995).

The second variable to be manipulated in Experiment 1 was the linguistic status of the distractor strings. The five different levels of distractor type were: words, orthographically legal non-words, orthographically illegal non-words, uniform letter strings and a non-linguistic uniform shape string. Each distractor was made up of four letters or four symbols. The reason for selecting these five types of distractor was that theoretical predictions could be made for each type of distractor according to its linguistic status. How like a word each distractor is should influence the effect the distractor has upon saccade latencies in the RDE paradigm. Well established findings from the literature have shown that the more like a word a letter string is, the more difficult it is to reject this string in a lexical decision task (e.g. Forster & Chambers, 1973). The selection of, and the predictions for, the particular distractors in this experiment were justified as follows. Since words are automatically processed (Stroop, 1935) these distractors should produce the greatest magnitude upon the RDE, since the time taken to discontinue processing should be greatest for words.

Following this, the longer it takes for the lexical processor to compute that a letter string is not a word, the greater the distracting influence of that letter string in the RDE paradigm, see section in the introduction on mandatoriness of processing. This should be followed by orthographically legal non-words since these letter strings require an exhaustive search through the lexicon before they can be rejected as a non-word (e.g. Coltheart *et al.,* 1977). Orthographically illegal non-words should have had less of an effect than words and the orthographically legal letter strings because they violate the orthographic regulations of the English language and hence should therefore have been quickly rejected as non-words. Uniform letter strings have linguistic status and also break the rules of orthography, but in addition to this they also provide strong visual cues as to their non-word status. The final distractor type in this experiment was a uniform shape string (four squares) that had no linguistic content. Any differences observed between the latter two types of distractor can only be attributed to the effects of abstract linguistic information associated with the representation of a letter, compared with an arbitrary shape.

The measurement of eye movement onset latencies in the RDE task allowed an investigation of how the visual processing system and the language processing system interacted for a non-lexical task. An assumption for Experiment 1 was that lexical identification procedures would be initiated automatically for all types of linguistic distractor strings at central presentation. This was not anticipated to be the case for peripherally viewed distractors, since distractors at this eccentricity would not automatically induce lexical processing because they would be too far in the periphery for any discrimination to be made between them at a lexical level (Rayner, Well & Pollatsek, 1980). Thus it is suggested that the nature of the linguistic processing will be obligatory for centrally presented distractors but not for peripherally presented distractors. The completion of lexical processing on a distractor string should affect the RDE by 'releasing' the eye so that it is free to move to the target. Furthermore, systematic differences on the RDE would be predicted for the different types of linguistic string distractors at central presentation. To be clear, it is not being suggested that the greater the amount of processing, the greater the RDE will be, rather, it is being suggested that the linguistic distractors will not be able to be ignored in the same way as the non-linguistic distractor since they will automatically initiate lexical identification procedures. Differences between the different types of linguistic distractors should result from differences in the time it takes to discontinue processing of a particular type of linguistic string prior to moving the eye to the target.

2.2: Predictions

1. For the no distractor condition eye movement latencies should be shorter than for any condition where a target and a distractor are presented simultaneously. This is the standard finding from the RDE studies.

2. Since a systematic decrease in the magnitude of the RDE occurs as the distractor is moved from the central fixation position into the periphery (Walker *et al.*, 1997) it was predicted that for all types of distractor, the eye movement latencies to the target would be greater for central presentation of the distractor than for peripheral presentation of the distractor. There should therefore be a main effect of Eccentricity in this experiment.

3. It was predicted that there would be a main effect of distractor type, regardless of eccentricity. Linguistic distractors were expected to produce longer saccade onset latencies compared to the non-linguistic uniform shape string distractors.

4. Linguistic distractors should have a greater effect upon eye movement latencies than non-linguistic distractors at central presentation of the distractors. This prediction was based on the assumption that the presentation of linguistic distractors would initiate both visual and linguistic processing whereas non-linguistic distractors would only initiate visual processing. As the classic Stroop (1935) findings show, visual word recognition is automatic and occurs whenever a letter string is viewed. Therefore the time taken to process this information will result in an increase of the magnitude of the RDE which will be greater than that observed for the non-linguistic distractors. What is being predicted here is that all types of linguistic string will be treated differently from the non-linguistic uniform shape string. The non-linguistic strings only have visual content and so there will be no abstract linguistic representation associated with these distractors, but all the types of linguistic strings will have at least some linguistic representation associated with them over and above that associated with the uniform shape string. At peripheral presentation of the distractors it was anticipated that there would be no difference between the linguistic and the non-linguistic distractors, since at this eccentricity the visual degradation of the stimuli will be such that it will not be possible to discriminate between the two types of distractor (linguistic and non-linguistic), and furthermore, it is likely that the only processing initiated at the peripheral eccentricity would be visual processing.

5. It was also predicted that there would be different effects for the different types of linguistic strings at central presentation of the distractors, although in principle the uniform shape string distractors and the uniform letter strings could have a similar effect. This is because the uniform nature of the stimulus makes it easy to reject each of these distractors as non-words whereas the visual nature of the other three linguistic distractors is such that there is the possibility that all three of these linguistic strings could be words. The work on parafoveal preview (see Rayner & Pollatsek, 1989) indicates that word shape is extracted prior to direct fixation. Thus there is the possibility that the uniform shape strings and the uniform letter strings may produce equivalent saccade onset latencies, which would be markedly different from the other types of linguistic distractors.

2.3: Method

2.3.1: Participants

22 members of the University of Durham community participated in the experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were paid to participate and all were naïve in relation to the purpose of the experiment.

2.3.2: Eye movement recording

Eye movements were monitored using a Fourward Technologies Dual Purkinje Generation 5.5 eye tracker with spatial resolution of 10 min of arc. Viewing was binocular, but only the movements of the right eye were monitored. Viewing distance was 67 cm.

2.3.3: Materials

Stimulus files were prepared using a software graphics program (Macdraw) and saved as PICT files. The target was a cross (+) drawn in 4-point plain pen, size 0.8cm. Four qualitatively different types of linguistic distractor strings were created using the same software package. Both target and distractors were black in colour and the background for each display was white. All characters for the linguistic distractor strings were created in upper case using Helvetica font size 32 point, overall length of string was approximately 3.8cm subtending 3.3° of visual angle. One character subtended .8 degrees of visual angle. Distractor text strings were of four types: Words, Legal non-words strings, Illegal non-words strings, or Uniform letter strings.(examples are given below, and see Appendix A for full list of stimuli used) In addition to the linguistic distractors ,a non-linguistic distractor string made up of four uniform shapes (squares) and called a Uniform shape string was also created. All distractor strings were four letters or four symbols. Fifty two four letter words were selected on the basis of high frequency (*e.g.* LOST). Legal non-words strings were orthographically regular, that is, they were pronounceable (*e.g.* LUPT) and shared two letters in common with the word strings corresponding to the same letter positions. Illegal non-words strings were orthographically irregular, that is, unpronounceable (*e.g.* LGNT) and shared two letters in common with the word strings, identical to the legal non-words. The position of the shared letters was varied (see Appendix A for a full list of the linguistic distractor strings). Uniform letter strings were also orthographically irregular and comprised sequences of identical letters (*e.g.* **AAAA**). The non-linguistic distractor was a uniform shape string made up of a sequence of four boxes (□□□□) and these were similar in size to the letter strings.

Visual stimulus types were matched for visual similarity and comparisons of visual similarity were made for each set of word, legal non-word and illegal non-word stimuli. For example, LOST was compared to the matched legal non-word LUPT. LUPT was compared to the matched orthographically illegal non-word LGNT, and LOST was also compared to LGNT. Letter by letter comparisons were made using a confusion matrix (Van der Heijden, Malhas and Van den Roovaart,1984) between each condition for each set of stimuli. These comparisons were analysed using paired samples t-tests and the results were as follows: Word/legal comparison vs. Word/illegal comparison ($t_{102} = -.687$, $p>.49$), Word/legal comparison vs. Legal/illegal comparison ($t_{102} = -.624$, $p>.53$), Word/illegal comparison vs. legal/illegal comparison ($t_{102} = -.082$, $p>.93$). No significant differences were observed between the visual similarity of the letters between the levels of the string variables. A total of 26 strings were created for each type of linguistic distractor. For the uniform letter string distractors the letter I was replaced with a uniform string of A's and a uniform string of B's as the letter I was much smaller than the other letters which made up the uniform linguistic string distractors.

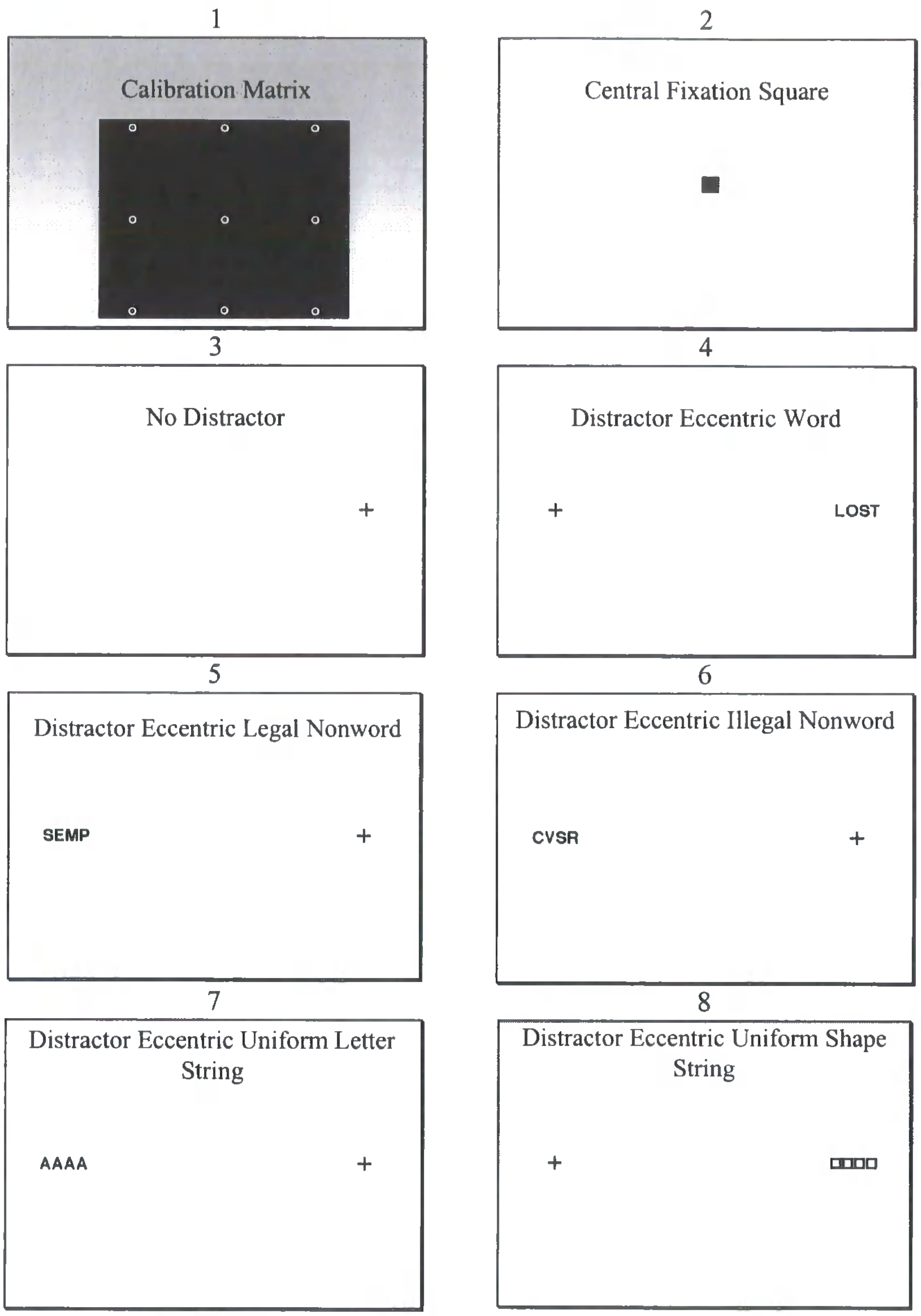
Displays consisted of presentation of these distractor strings at either central or peripheral location with an accompanying target either on the left or right of the display at an eccentricity of 8 degrees for centrally presented distractors, or in the opposite hemifield at an eccentricity of 8 degrees for peripherally presented distractors. The 'uniform shape string' distractor was repeated 26 times for the non-linguistic condition in the experiment. Distractors were therefore either at the centre of the display or at an eccentric location 8 degrees to the left or right of the midline of the display. Targets were positioned at an eccentricity of 8 degrees either on the left or the right of the display.

2.3.4: Design

Two files of trial blocks were created, A and B which each contained 5 blocks of 104 randomly ordered trials. File and block were counterbalanced across participants. Centrally presented items (distractors) were the same in both files . For peripherally presented items (distractors), if an item in file A was positioned on the right of the display, then in file B it was positioned on the left of the display. The design of the experiment was within subjects with two independent variables, Eccentricity (central or peripheral distractor presentation), and Distractor Type (word, orthographically legal non-word, orthographically illegal non-word, uniform letter string, uniform shape string). There was also a single target control condition in which no distractor was present. In this condition the target always appeared at the left or the right of the midline at an eccentricity of 8 degrees. The main dependent variable was eye movement onset latency although error rates were also recorded and analysed.

2.3.5: Procedure

The experiment was run on a Macintosh Quadra 700 computer with a Macintosh 21-inch screen operating at 76 Hz. In house software displayed a central fixation target for a fixed period of 1 second (0.6 deg black square on a white background) designed to ensure participant's fixated the centre of the screen prior to the start of each trial. This was followed by the stimulus display, which initiated eye-movement recording (5 ms sampling) for 1 second, followed by a blank screen for 1 second. The program used a command to modify the colour lookup table to allow display of any PICTformat file within a single video frame. Each display contained a target cross, either on its own or with a distractor (All participants were tested individually. Preceding each block of trials participants performed a calibration procedure consisting of nine points in a square grid, each of which had to be fixated sequentially. The results of the calibration procedure were checked online prior to running the experimental trials. A practice block (20 trials) was completed prior to recording, followed by the 5 experimental blocks with breaks between each block. The task was to,' Look at the cross', and ignore any other stimuli appearing in the displays. A fixed level of screen brightness and contrast were used was used for all experiments. Figure 2 shows the sequence of presentation and also examples of the Distractor Types at the different Distractor Eccentricities.


1
Calibration Matrix
2
Central Fixation Square
3
No Distractor
+
4
Distractor Eccentric Word
+
LOST
5
Distractor Eccentric Legal Nonword
SEMP
+
6
Distractor Eccentric Illegal Nonword
CVSR
+
7
Distractor Eccentric Uniform Letter String
AAAA
+
8
Distractor Eccentric Uniform Shape String
+

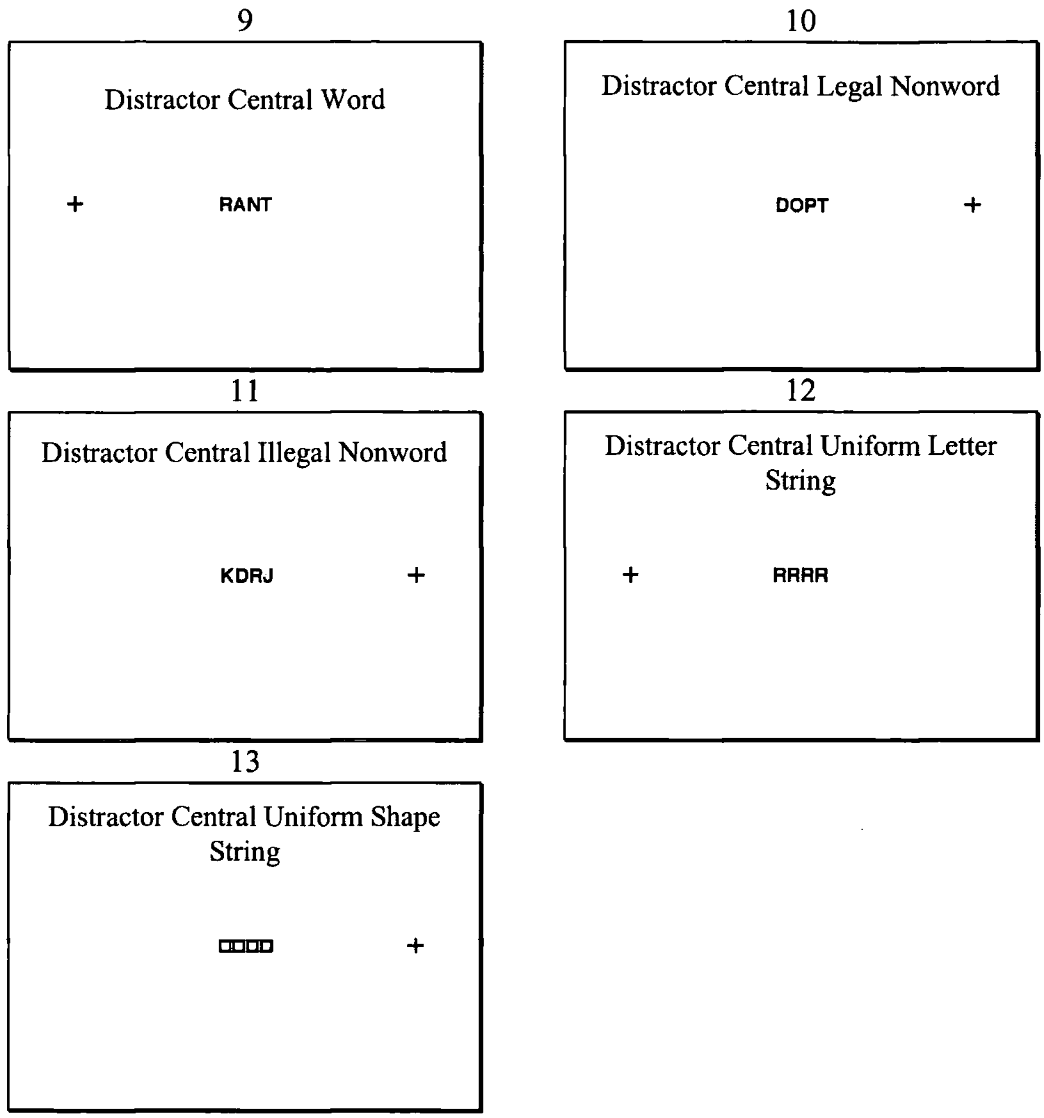


Figure 2: *Slides showing the sequence of presentation and examples of the different Distractor Types at the different Distractor Eccentricities.*

2.4: Results

For these data and data for all subsequent experiments a semi-automated procedure was used to analyse the eye movement data. Eye movement onset latency was measured as time elapsing from the presentation of a trial stimulus, to the initiation of a saccade. The first saccade was detected using a velocity criterion of 30°/sec and each record was inspected individually to ensure that the software had detected saccade onset latencies appropriately. In subsequent data analysis, any trials in which tracker loss occurred were excluded, as were saccades outside the range of 100 ms - 500 ms. This criterion was chosen on the basis that saccade onset latencies were classed as anticipatory eye movements if they were less than 100ms, and those greater than 500ms were regarded as not being stimulus driven (Wenban-Smith & Findlay, 1991).

Data excluded from analyses therefore included Tracker Loss trials and trials where correct saccades to target were initiated either before 100ms or after 500ms (6%). Directional errors were also excluded from the final analysis of eye movement onset latencies. The total percentage of errors was 23%. Table (1) shows the mean percentage of errors made for each condition. In all cases where a directional error was made, a corrective second saccade to the actual target was also made during the trial presentation. Errors were made only for the condition where a peripheral distractor was presented, and so the calculation of error rates did not include the trials where either central distractors were presented, or those trials where no distractor was presented with the target. Two participants were excluded completely on the basis of making greater than 25% errors.

Table 1: The mean percentage of errors made for each type of distractor at the peripheral distractor location.

Type of Distractor

Words	Orthographically legal strings	Orthographically illegal strings	Uniform letter strings	Uniform shape string
22%	26%	26%	23%	22%

Thus, for the error data a 1(Eccentricity) by 5 (Distractor Type) analysis of variance was carried out on the mean error rates treating participants as random variables. Analysis of the error data revealed that there were no significant differences between the different Distractor Types (F<1). All types of distractor in this experiment produced equivalent error rates.

Main analyses were conducted on the latencies of correct first saccades to the target Table 2 shows the mean eye movement latencies and the standard deviations for each condition. Standard deviations were computed on a between participants basis for this and all further experiments.

Table 2: The mean onset latencies and standard deviations (in parentheses) for each type of distractor at each distractor presentation location (ms).

Type of Distractor

	Words	Orthographically legal strings	Orthographically illegal strings	Uniform letter strings	Uniform shape string
Central distractor	233.07 (36.69)	235.16 (38.35)	234.86 (40.07)	235.92 (40.66)	225.25 (36.13)
Peripheral distractor	216.86 (31.58)	219.87 (33.89)	223.63 (34.94)	219.73 (32.37)	220.65 (32.16)

There was a highly reliable Remote Distractor Effect (10 paired samples tested whether each type of distractor at each distractor eccentricity differed from the no distractor condition. All t tests revealed significant effects: All t's > 10, all p's < .0001, with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present (No distractor mean saccade onset latency = 180.12ms).

The results are consistent with the prediction that all distractors would produce longer eye movement latencies compared to the control condition where no distractor was presented with the target. This supports the first prediction of shorter saccade onset latencies for the no distractor condition compared to the distractor present conditions.

A repeated measures ANOVA was conducted on the means for the correct eye movement latencies with Eccentricity (central and peripheral) and Distractor Type (word, legal non-word, illegal non-word, uniform letter string and uniform shape string) as within subject variables. The mean saccade onset latencies for each of the five distractor types at each of the two eccentricities are given in Figure 3 along with the mean saccade onset latency for the no distractor condition. There was a main effect of Eccentricity ($F\,(1,19) = 3.93, p <.01$) with centrally presented distractors (mean = 232.9ms), producing longer saccade onset latencies than distractors presented at the peripheral (mean = 220.2ms) location. This supports the prediction of central distractors having a greater effect upon the magnitude of the Remote Distractor Effect than peripheral distractors. The magnitude of the RDE for central distractors is 53ms and the magnitude of the RDE for peripheral distractors is 40 ms. This magnitude is greater than that observed in Walker *et al.*'s study and this will be discussed in more detail later.

A main effect was also found for Distractor Type ($F\,(4,76) = 17.07, p <.001$), which indicated that there were different effects upon saccade onset latencies between the different types of distractors. Since it was predicted that the non-linguistic distractors would produce shorter saccade onset latencies than the linguistic distractors paired samples t-tests were computed to see if this was the case. The results provided support for this prediction for the non-linguistic uniform shape string distractor (mean = 223.0ms) compared to the uniform letter string (mean = 227.8ms), $t\ (1,39) = -2.2, p < .05$), the orthographically illegal non word (mean = 229.2ms), $t\ (1,39) = -4.2, p < .001$), and the orthographically legal non word (mean = 227.5ms), $t\ (1,39) = -2.7, p < .01$),There was no difference between the non-linguistic distractors and the word distractors (mean = 225.0ms), $t < 1, p > .1$). The prediction that the non-linguistic distractors would produce shorter saccade latencies compared to the linguistic distractors is upheld for all the linguistic distractors, apart from the comparison for the uniform shape strings and the words.

An interaction was also obtained for Distractor type and Eccentricity ($F\ (4,76) = 4.15$, $p < .005$).

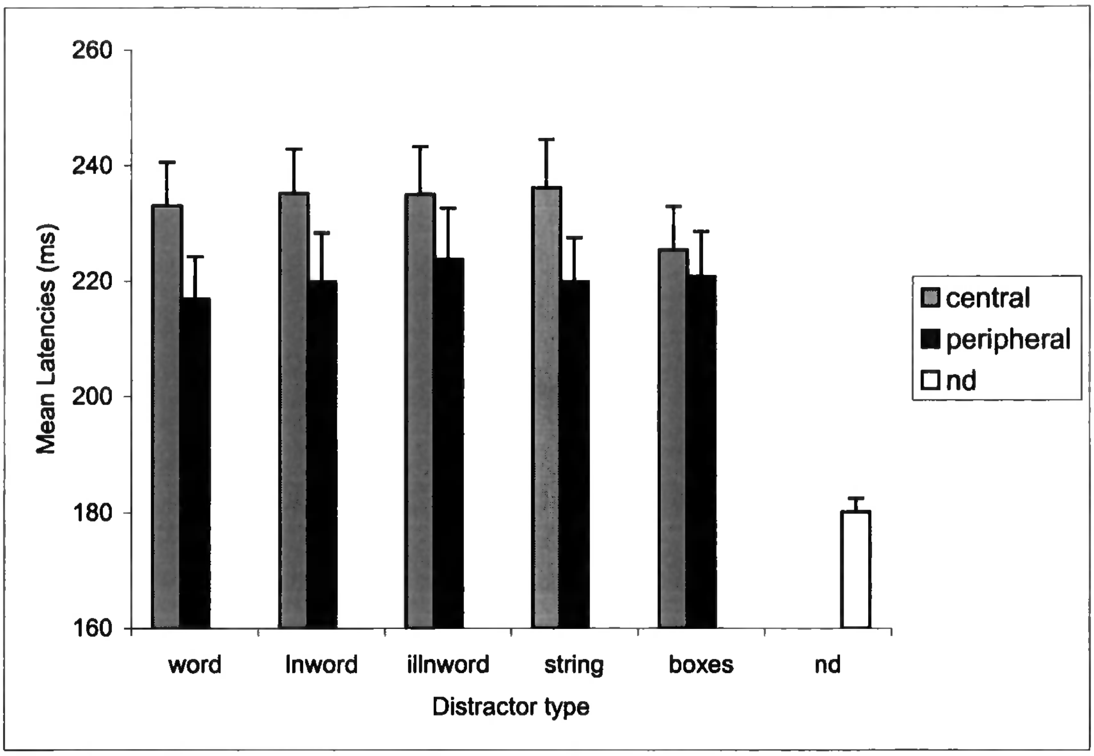


Figure 3: *The mean saccade onset latencies for each of the five distractor types plotted for each of the two distractor eccentricities, with, additionally, the mean for the no distractor condition. Error bars denote 1 standard error from the mean.*

It is clear from Figure 3 that the magnitude of the difference between the effects for the non-linguistic uniform shape distractors is smaller than that for the linguistic string distractors. In order to formally test for differences between the different types of distractor paired samples t-tests were carried out for each type of distractor for each eccentricity. This analysis revealed that there were significant differences between central and peripheral presentation for all types of linguistic string distractors (all t's > 3.7; p's $\leq .001$).

There was however no significant difference between central and peripheral presentation of the non-linguistic distractor strings ($t\,(1,19) = 1.3, p > .1$). The second prediction of a difference between central and peripheral presentation of the distractors for each type of distractor was upheld for linguistic string distractors but somewhat surprisingly not for the non-linguistic string distractor.

The fourth prediction was that linguistic distractors would have a greater effect upon saccade onset latencies than non-linguistic distractors at central but not peripheral eccentricities. This prediction was upheld for central presentation of a distractor. All types of linguistic distractor strings were significantly greater than non-linguistic distractor strings (all t's > 3.7; p's < .001). The prediction was also upheld for the peripheral presentation of the distractor. No differences were obtained for the non-linguistic uniform shape string compared to the linguistic distractors (all t's < -1.5; p's ≥ .05). Thus the prediction that non-linguistic distractors would produce shorter saccade onset latencies, compared to the linguistic distractors, at central but not at peripheral presentation was fully upheld.

The fifth prediction hypothesised that there would be a difference in the magnitude of the RDE for the different types of linguistic distractors at central presentation but not at peripheral presentation. This prediction was not upheld. No significant differences were found between the different linguistic distractor types for central presentation of the distractors (all t's < 1.1; p's ≥ .1). However at the peripheral presentation a difference between the orthographically illegal distractor string and all the other types of distractor strings was obtained (all t's > 2; p's ≤ .05). This result was not expected, since it was anticipated that any differences that did occur between the different types of linguistic string would manifest themselves at foveal distractor presentation locations rather than eccentric presentation locations. Accordingly, because it was not predicted that an effect of orthographic status of the linguistic strings would be observed at the peripheral presentation of the distractors, it was decided to compute a one way ANOVA on the peripheral data only. This analysis revealed that there were no significant differences between the different types of distractor at peripheral locations (F <1). It would therefore be premature to conclude that the results from the t-tests for the comparisons between the orthographically illegal distractors and the other distractors in Experiment 1 were reliable.

2.5: Discussion

The first prediction of a Remote Distractor Effect was upheld. The difference between the mean eye movement latencies for the no distractor condition compared to the mean eye movement latency for the distractor condition for central presentation was 53ms, and for peripheral presentation of the distractors it was 40ms. This is a bigger RDE difference than was observed in Walker *et al.'s* (1997) original experiments. The Walker *et al.*, (1997) figures were approximately 40ms for central distractors and 15ms for the same eccentricity peripheral ones. The biggest discrepancy in the current experiment is therefore for the peripheral distractors (25ms difference between the RDE magnitude in Experiment 1 compared to the RDE magnitude in Walker *et al.'s* 1997 study), compared to a discrepancy of 13ms for the central distractors. One possible reason for this difference could be attributed to the difference in size between the distractors and the target. Both the central and the peripheral distractors were more visually salient than the target that they were presented with and hence the larger physical size of the distractor may have produced more of an inhibitory effect on saccade onset latencies. Differences in the magnitude of the RDE, corresponding to differences in the size of remote distractors, were observed by Weber and Fischer (1994). They examined the effects of distractors on the generation of short latency express saccades. It was found that larger distractors had more of an inhibitory effect on the production of express saccades (35.4% express saccades generated) compared to smaller distractors (68.1% express saccades generated) which had less of an effect than distractors that were of equal size to the target (43.1% express saccades generated).

The distractor to target size difference in the current experiment could also go some way to account for the quite large numbers of errors made by some participants in this experiment since the peripheral distractors were more visually salient than the simple target. It should be noted however, see Table 1, that in most trials participants were able to ignore the distractor and make an eye movement to the target. No participants made100% errors although two participants (excluded from the analyses) made more than 25% errors. A comparable number of errors was also found (Weber and Fischer, 1994) in a study where the target consisted of a single vertical bar and the distractor was made up of three bars arranged in a vertical row. In this case it was argued that the erroneous saccades were produced as a result of the randomisation of the presentation location of the target and the distractor (each could appear at either the left or the right in any given trial), and that these saccades were reflexive in nature, rather than voluntary.

Accordingly, although the size discrepancy between the distractors and the target may have had some effect on the number of errors made for the peripheral distractor presentation and could also offer an account for the overall increase in the magnitude of the RDE, it cannot account for the remainder of the observations from Experiment1. If it was only the size difference between the distractors and the target that was having an effect upon saccade onset latencies then the observed differences between the different distractor types in this experiment would not have been obtained.

It is important to note also that in the current experiment it was necessary to visually discriminate the target from the distractor. In Walker *et al's*.,(1995) experiment this was not the case, although a competing target and distractor were presented, they were visually equivalent and participants were free to saccade to either one of them. Additionally, in Walker *et al.*'s 1997 studies, although the target and distractor were of similar size, they differed from each other in that the target was an 'x' and the distractor was an 'o'. However in that set of experiments it was not necessary to discriminate between target and distractor, since the location of the target was pre-specified and kept constant throughout a block of trials. It was however necessary to discriminate between the target and the distractor in one of the experiments in the Weber and Fischer (1994) study, and this had the effect of increasing saccadic reaction times by 30ms compared to a condition whereby the target and distractor were presented to a pre-specified location which was kept constant throughout a block of trials. Therefore the additional discrimination process in the current experiment could also be a factor in the observed increase in the RDE magnitude compared to Walker *et al.*'s (1997) finding.

The second prediction was that all types of distractor would produce longer saccade onset latencies for central presentation of the distractor compared to peripheral presentation of the distractor. This was expected since this is what has been observed in the remote distractor study of Walker *et al.*,(1997). This prediction was upheld but the findings were qualified by and interaction between Eccentricity and Distractor Type which showed that the effect was true for linguistic distractors but not for the non-linguistic distractor. There were significant differences for all of the linguistic distractors between central and peripheral eccentricities with central presentation having a greater effect upon saccade onset latencies than peripheral presentation. However there was no difference between central and peripheral presentation of the Uniform shape string distractor. This finding for the non-linguistic distractor contradicts the findings from earlier RDE experiments that show a systematic decrease in the magnitude of the RDE from central presentation of distractors to peripheral presentation of distractors Walker *et al.,* (1997). The reason for this finding is unclear at present, but it could be that discontinuation of processing for the non-linguistic distractors at central presentation was faster than for the linguistic distractors, whereas at peripheral presentation discontinuation of processing of the non-linguistic distractor took the same time as the linguistic distractors. This would have resulted in the observed smaller difference between central and peripheral saccade onset latencies for the uniform shape string.

The third prediction that linguistic distractors would produce longer saccade onset latencies compared to the non-linguistic distractor was also upheld, thus showing that overall the linguistic distractors impacted to a greater degree upon the saccade generation system compared to the non-linguistic distractors. This was what was anticipated and the finding provides further support for the automaticity of processing for linguistic material (Stroop, 1935).

The fourth prediction that linguistic distractors would have a greater effect upon eye movement latencies than non-linguistic distractors at central presentation but not at peripheral presentation was supported. There was no difference with peripheral presentation between linguistic distractor strings and uniform shape strings, but there was a significant difference between centrally presented uniform shape strings and all types of centrally presented linguistic distractors. It was easier to ignore uniform shape strings than all types of linguistic strings at central but not peripheral presentation. This suggests that there could be a lexically based effect operating at central presentation, which results in the production of longer saccade onset latencies for linguistic distractors compared to non-linguistic distractors.

The fifth prediction of a difference between the different types of linguistic distractors at central but not peripheral locations was not upheld. From the findings on the reported lexical decision task studies it was anticipated that there would be an effect of orthographic status on performance (e.g. Coltheart, *et al.*, 1977) and see detailed discussion in the introduction on this. The results however, showed no clear effects for the different types of linguistic string distractors at central presentation of the distractors. Conversely, for peripheral presentation of the linguistic distractors, the orthographically illegal non-words produced significantly longer saccade onset latencies than the other distractors. However, recall that this finding was not predicted, and furthermore it was not supported by a one way ANOVA on the peripheral data. Therefore any claim as to the reliability of the observed differences between orthographically illegal distractors and all other types of distractor presented at the peripheral location should be viewed with caution.

There are several possible reasons as to why the prediction of a difference in the magnitude of the RDE between the different types of linguistic strings at central presentation was not borne out. Firstly, it is possible that the RDE paradigm may be sensitive only to gross effects of different characteristics of distractor type, but it may not be suitable for investigating subtle effects within a category of distractor type. This might explain why the non-linguistic distractors produced shorter saccade latencies than all types of linguistic distractor at central presentation of the distractor.

Secondly, the linguistic distractors used at the central presentation eccentricity may have resulted in a ceiling effect. What is meant here by this term is that at central presentation all linguistic distractors initiated lexical processing and the ability to discontinue the processing of each type of distractor at this location was equivalent for each type of linguistic distractor. No effect upon saccade latencies would therefore have been observed at this distractor location, since the ability to discontinue the automatic processing initiated for each of the linguistic strings at this eccentricity occurred in parallel with the initiation of a saccade, thus inhibiting the appearance of any temporal differences in processing. What is crucial here is that, as stated in the introduction to Experiment 1, it is it is not simply the extent of processing which is important but also the speed with which the processing terminates (discontinues). Specifically, while lexical processing is initiated for all of the different types of linguistic string, and lexical identification procedures are discontinued at different points within the identification procedure, the automaticity with which the identification procedures proceed is such that none of the lexical processes associated with processing the linguistic distractors impacted upon the oculomotor processes associated with saccade onset. To be clear, it is so 'easy' to process linguistic strings of any kind at central locations that this doesn't interfere with the processes associated with controlling the eye.

In summary, this experiment investigated whether the linguistic status of a distractor would systematically affect the magnitude of the RDE. Four types of linguistic distractor string and one non-linguistic distractor string were presented at either central or peripheral locations. Participants were required to ignore the distractor and saccade to a target (a cross) presented peripherally. Distractors presented both in the centre of the display and at the periphery of the display resulted in increased saccade onset latencies compared to the condition where no distractor was presented with a target. The analyses of the data for the distractor present conditions showed a main effect of Eccentricity on eye movement onset latencies, a main effect of Distractor Type on eye movement latencies, and a significant interaction between these two. However no differences were found between the different types of linguistic distractor strings at central presentation, and an unexpected (but possibly unreliable) effect of orthographically illegal non-words was found at peripheral presentation. For the RDE paradigm linguistic variables (at central presentation) had a greater effect upon saccade onset latencies, compared to non-linguistic distractors, but they do not appear to affect in any systematic way how the saccadic computation system decides when to move the eye.

An unpredicted finding from this experiment was that of no difference between central and peripheral presentation for the non-linguistic uniform shape string distractor. This is important as it is contrary to the previous findings (Walker *et al.*, 1997) which showed a greater effect upon the magnitude of the RDE for central distractors compared to peripheral distractors. The finding cannot be accounted for by the size difference between the distractor and the target since all linguistic distractors (which were the same size as the non-linguistic distractor) resulted in the predicted increase in saccade onset latencies at central compared to peripheral distractor presentation. Moreover the data clearly showed that the effect was a result of an ability to ignore the central non-linguistic distractor more efficiently than the central linguistic distractors. At peripheral presentation there was no difference between the non-linguistic distractor and the linguistic distractors. Since the linguistic distractors at central presentation initiate both linguistic and visual processing, whereas the non-linguistic distractors initiate only visual processing, it could be argued that the decrease in saccade onset latencies for the non-linguistic distractors at this location is a reflection of only a single processor impacting upon the saccade computation and saccade initiation timing. For the linguistic distractors both visual and linguistic processing is initiated. The time taken to discontinue processing of the linguistic information at central stimulation could be what is producing the difference between central linguistic distractors and central non-linguistic distractors.

However, this still would not explain why the expected difference between central presentation and peripheral presentation of the non-linguistic distractor was not found. The non-linguistic distractor was introduced in Experiment 1 as a control condition for the linguistic distractors. It was not anticipated that this distractor would produce such an unexpected finding with respect to predictions based on Walker *et al.'s* (1997) RDE findings. Since it has come about however, and since it is not clear what could be causing the effect, then the finding merits further investigation.

It was also suggested in the introduction to Experiment 1 that any differences observed between the uniform letter strings and the uniform shape string distractors could only be attributed to the effects of abstract linguistic information associated with the representation of a letter, compared with an arbitrary shape. However, the validity of this claim must be questioned, since although there were clear differences between these two types of distractor, and indeed, between the uniform shape strings and all types of linguistic distractor, there was also another difference between the distractors which could in principle account for the discrepancy between the saccade onset latencies for the linguistic versus the non-linguistic strings in Experiment 1.

A further important factor here therefore, is that the uniform shape string condition in Experiment 1 repeated the same distractor string throughout the experiment, whereas each type of linguistic distractor had a total of 26 different strings, including the uniform letter distractor strings. Therefore, all the linguistic distractor strings, for each type of linguistic distractor, comprised a set of changing distractors. In contrast to this the non-linguistic distractor comprised a set of constant (the same uniform shape string repeated throughout the trials) distractors. The next experiment will explore whether this discrepancy between the nature of the distractor types (changing versus constant) can account for the equivalent saccade onset latencies that were produced for central and peripheral presentation for the non-linguistic distractors in Experiment 1. Specifically, Experiment 2 will test two alternative hypotheses for the findings in Experiment 1. The first hypothesis is that the differences in response latencies between the linguistic and the non-linguistic distractors resulted from the effects of linguistic processing. The second hypothesis is that the differences in response latencies between the linguistic and the non-linguistic distractors resulted from processing changing distractors compared to repeated (constant) distractors. These two possibilities were examined in the next experiment. Additionally, the design of the next experiment permitted a further investigation of why there was no difference in saccade onset latencies between the central and the peripheral distractors for the non-linguistic distractor in Experiment 1.

Chapter 3

Two Alternative Hypotheses for the Linguistic versus Non-linguistic Distractor Differences in Experiment 1

3.1: Experiment 2

This second experiment was designed to address whether the observed decrease in saccade onset latencies for centrally presented non-linguistic distractors in Experiment 1, compared to all types of linguistic distractors, resulted from linguistic processing effects, or whether it resulted from repeatedly presenting the same non-linguistic distractor, as opposed to presenting changing linguistic distractors. Recall that in the introduction to Experiment 1 it was suggested that any differences observed between the uniform linguistic string (e.g. **AAAA**) and the uniform non-linguistic string (i.e. □□□□) could only be attributed to the effects of abstract linguistic information associated with the representation of a letter, compared with an arbitrary shape. However, close inspection of the experimental stimuli in Experiment 1 revealed that there were not one, but two, main differences between the uniform non-linguistic distractors and the uniform linguistic string distractors. First, the uniform non-linguistic distractors differed from the other distractors employed in Experiment 1 in that they had no linguistic status. Thus it is possible that the differences in saccade onset latencies between the two types of distractor, linguistic versus non-linguistic, for central distractor presentation, could have been a result of the linguistic versus the non-linguistic status of the distractors. Secondly, the uniform non-linguistic distractor was a constant distractor throughout the experiment. That is to say, there was only one uniform non-linguistic distractor which was presented repeatedly during the experiment, whereas there were 26 different linguistic distractors for each of the four different types of linguistic distractor string. The particular linguistic string, therefore, was changing across the experimental trials, whereas the non-linguistic string was constant throughout the trials. Thus, in addition to a difference in linguistic status of the distractors there was also a difference in the constancy of the distractors. It is important therefore to determine whether the observed difference in performance in Experiment 1 occurred as a result of the linguistic status of the distractors, or as a result of the changing nature of the distractors. This second experiment therefore investigated the effect of constant distractors versus changing distractors for linguistic versus non-linguistic distractors presented at central and peripheral locations.

Furthermore, in Experiment 1, there was no difference between saccade onset latencies for the central and peripheral presentation of the non-linguistic distractor. This was inconsistent with the documented findings from Walker *et al.*'s (1997) studies of the RDE. In their experiments various manipulations between target and distractor presentation locations revealed a systematic effect upon saccade onset latencies. For the purposes of the experiments in this thesis one of the primary effects of importance from the RDE studies is that centrally presented distractors should produce the biggest magnitude upon the RDE with a declining influence as the distractor is presented further into the periphery. In Experiment 1 this was found for the linguistic distractors, but for the non-linguistic distractors there was no difference in saccade onset latencies between central and peripheral distractor presentation. Therefore in Experiment 2, in addition to examining the two alternative hypotheses of linguistic versus non-linguists distractors, and constant versus changing distractors, for the observed reduction of the saccade onset latencies in Experiment 1 at central presentation, Experiment 2 also allowed a further examination of the equivalent saccade latencies that were shown in Experiment 1 for the non-linguistic distractors. This was achieved by orthogonally manipulating linguistic versus non-linguistic distractors and constant versus changing distractors.

There is some evidence in the visual search literature that shows that items that are repeated during the course of the experiment do not attract attention to the same degree as novel items (Johnston, Hawley,& Farnham, 1993; Johnston, Hawley Plewe, Elliot & De Witt, 1990). In these experiments the repeated items became 'familiar' during the course of the experiment. In relation to the current experiments therefore, in Experiment 1, the repeated item presented at the central location (the non-linguistic distractor) could have become familiar to the participants during the course of its repeated presentation. A possible result of this was that at this location, the ability to discontinue processing of the repeated item was quicker in comparison to the changing linguistic distractors that were presented at this location.

In order therefore, to determine whether the differences in saccade onset latencies between the linguistic and the non-linguistic distractors was a consequence of any lexical property of the distractors, or a consequence of the repetition of one type of distractor, Experiment 2 employed some of the stimuli from Experiment 1 and manipulated three variables. Both the uniform non-linguistic string and the uniform letter strings from Experiment 1 were used in Experiment 2. However, rather than having only one uniform non-linguistic string, a new set of uniform non-linguistic strings was created comprising 26 different uniform shape strings. What is meant here is that although the shape strings were uniform (i.e. four of the same shape in each string), they were different in that 26 different uniform shape strings were created (e.g. ◊◊◊◊, ƊƊƊƊ) which were of a similar size to the uniform letter strings. These will be referred to as uniform shape strings. The two types of distractor were therefore made up of either uniform letter strings (e.g. **AAAA, BBBB** etc.) or uniform shape strings. Additionally, in each set of changing distractors there was one repeated distractor, which was from the alternative distractor set. To be clear, the uniform shape string distractor set had 25 changing uniform shape strings plus one repeated (25 repetitions) uniform letter string, chosen randomly from the full set of 26 uniform letter strings. The uniform letter string distractor set had 25 changing uniform letter strings plus one repeated (25 repetitions) uniform shape string, chosen randomly from the full set of 26 uniform shape strings. Thus each set of changing distractors had one constant distractor from the alternative category embedded in each set. This manipulation enabled the investigation of whether the constancy of the distractor, or the linguistic status of the distractor, was the main factor for producing the differences in saccade onset latencies between the linguistic and the non-linguistic distractors at central presentation in Experiment 1. The design of the experiment also afforded the opportunity to investigate the unexpected finding of no difference between central and peripheral presentation for the non-linguistic distractors in Experiment 1.

The independent variables in Experiment 2 were therefore; Eccentricity of the distractor string (central or peripheral), Constancy of the distractor string (changing distractor or constant distractor) and Distractor Type (uniform letter string or uniform shape string). On the basis of the findings from Experiment 1 the following predictions were made.

3.2: Predictions

1. For the no-distractor condition it was anticipated that eye movement latencies would be shorter than for any condition where a target and a distractor were presented simultaneously. This is the standard finding from the RDE studies.

2. Since saccade onset latencies were longer for central than peripheral distractors in Experiment 1, a similar main effect was predicted in the current experiment.

3. It was also anticipated that if the effects of distractor type in Experiment 1 were a consequence of the linguistic status of the distractors rather than their constancy status, then a larger distractor effect should occur for uniform letter string distractors than for uniform shape string distractors. Conversely, if the effects in Experiment 1 were due to the changing nature of the distractor strings, then we should obtain a main effect of constancy with longer saccade onset latencies for changing than for constant distractors.

4. Note however, that the main effects predicted in the current experiment should be qualified by specific patterns of interaction associated with different theoretical possibilities. Recall that in Experiment 1 there was no difference between saccade onset latencies for central and eccentric uniform shape string distractors, but there was such an effect for uniform letter string distractors. Consequently, in the current experiment it is possible that the effect of eccentricity may be modulated by

constancy, in which case we may observe a greater difference between changing central and peripheral distractor strings than for constant central and peripheral distractor strings.

5. Alternatively, the eccentricity effects observed in Experiment 1 may have been due to the linguistic status of the distractor string. If this was the case, then an interaction between distractor type and eccentricity might be expected, such that there is a larger difference in saccade onset latencies between central and peripheral letter string distractors than there is for central and peripheral shape string distractors.

6. The design of the current experiment also provides a valuable opportunity to examine the influence of changing and constant linguistic and non-linguistic distractor strings regardless of eccentricity. It is quite possible that any influence of a changing distractor string relative to a constant distractor string may be modulated by the linguistic status of that string. For example, it may be, that because there is an abstract level of representation associated with letter strings that simply does not exist for strings of shapes, then perhaps changing strings of letters may have a greater intrinsic distracting influence on the oculomotor control system than constant letter strings, whereas changing shape strings may have no more of an influence on saccade onset latencies than constant shape strings. The current design permits the opportunity to explore such a possibility. If changing distractor strings cause longer saccade onset latencies than constant distractor strings, and if this effect is modulated by the linguistic status of the distractor string, then we might expect that the difference between changing and constant shape strings will be less than the difference between changing and constant letter strings.

6. Finally, the results from Experiment 1 are in line with the possibility that for a distractor string to have a differential influence on the magnitude of the remote distractor effect at central and peripheral locations, then it may have to be simultaneously both changing and linguistic. That is to say, it is possible that the current experiment may show an interactive influence of both constancy and distractor type on the basic eccentricity effect that occurred in Experiment 1. If this is the case, then longer saccade onset latencies should occur for central than for peripheral distractors when the distractor is a changing string of letters than when it is either a constant string of letters, or a constant or changing string of shapes. These predictions were tested in the following experiment.

3.3: Method

3.3.1Participants

16 members of the University of Durham community participated in the experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were paid to participate and all were naive in relation to the purpose of the experiment.

3.3.2: Eye movement recording

Eye movements were monitored using a Fourward Technologies Dual Purkinje Generation 5.5 eye tracker with spatial resolution of 10 min of arc. Viewing was binocular, but only the movements of the right eye were monitored. The stimulus files were displayed on a Phillips 21B582BH 21inch monitor at a viewing distance of 67cm. The monitor had a P22 phosphor with a decay rate to zero of less than 2 milliseconds. The monitor and the eyetracker were both interfaced with a Phillips Pentium III PC that controlled the experiment. The eye position was sampled every 5 milliseconds.

3.3.3: Materials

Stimulus files were prepared using an in house software program and saved as bitmap files. The target was a cross drawn in 4 point plain pen, size 0.8cm. Both target and distractors were black in colour and the background for each display was white. As in Experiment 1 all characters for the linguistic distractor strings were presented in upper case. They were created using Microsoft Sans Serif font size 24 point, overall length approximately 3.8cm, subtending 3.3° of visual angle. All distractor strings were four uniform letters or four uniform symbols. The uniform shape strings were comprised of either four shapes or four symbols of a similar size to the letter strings and each of these distractors had no linguistic content. See Appendix B for a full list of the materials. Distractors were either at the centre of the display, or at an eccentric location 8 degrees to the right or left of the midline of the display. The target appeared at an eccentric location 8 degrees to the right or left of the midline of the display.

3.3.4: Design

The design was within subjects with three independent variables; Constancy (2 levels; changing distractor or constant distractor), Eccentricity (2 levels; central distractor or peripheral distractor) and Distractor type (2 levels; uniform letter string or uniform shape string). The dependent variables were eye movement onset latencies and directional errors. Each display contained a target cross (+) which could appear by itself or simultaneous with a distractor. In condition A distractors comprised 25 different uniform letter strings and 1 constant shape string (uniform shape string from Experiment 1). In condition B distractors were 25 different uniform shape strings and 1 constant letter string (**HHHH**) which was randomly selected from the set of uniform letter strings used in Experiment. 1 Order of block (condition A or condition B) was counterbalanced across participants.

3.3.5: Procedure

Participants performed a calibration procedure in which they had to sequentially fixate nine dots in a square array. This was followed by two experimental blocks of trials (400 trials in each block). Each trial was presented for one second and the task was to ignore anything else that might appear on the display and 'Look at the cross'. Breaks were taken on request of individual participants. The sequence of presentation, as in Experiment 1 was maintained. This was, central fixation cross (duration 1s), followed by trial (duration 1s), followed by a blank screen, (duration 1s).

3.4: Results

Data excluded from analyses included trials in which tracker loss occurred and trials where saccades were outside the range of 100ms - 500ms. In total the percentage of trials rejected on this basis was 8%. Directional errors were also excluded from the main analysis of eye movement onset latency. The total percentage of errors was 17%. Table (3) shows detail of the percentage of errors made for each condition. As was the case in Experiment 1 in all cases where a directional error was made, a corrective saccade to the actual target was also made during the trial presentation. In the present study, participants were only able to make an error when the distractor appeared at an eccentric location since when it appeared centrally, the participant was fixating this position anyway. Thus, for the error data a 2(Constancy) by 2(Distractor Type) analysis of variance was carried out on the mean error rates treating participants as random variables.

Table 3: The mean percentage of errors made for each type of distractor at the peripheral distractor location for changing and constant distractors.

Type of Distractor

Changing		Constant	
Uniform letter strings	Uniform shape strings	Uniform letter strings	Uniform shape strings
19%	15%	19%	14%

Analysis of the error data revealed that there was a significant main effect of distractor type ($F\,(1, 15) = 8.25, p < .05$), with participants making more errors when the distractor was a linguistic string (mean = 19%) than when it was a shape string (mean = 14.5%). There was no significant effect of constancy, and no interaction between the two, (F's < 1). This shows that participants made more errors to the letter string distractors, compared to the shape string distractors, and this was independent of whether the distractors were changing or constant.

There was a highly reliable Remote Distractor Effect (8 paired samples t-tests compared whether each type of distractor at each distractor eccentricity differed from the no distractor condition. All t tests revealed significant effects: All (t's > 9, all p's

< .0001), with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present (No distractor mean saccade onset latency = 170.53ms). The results are consistent with the prediction that all distractors would produce longer eye movement latencies compared to the control condition where no distractor was presented with the target. This supports the first prediction of a difference for the distractor absent condition compared to the distractor present conditions. Additionally, the magnitude of the RDE for central distractors (41.7ms) was in line with that obtained for Walker *et al.'s* findings, whereas the magnitude of the RDE for peripheral distractors (37.0ms) was greater than that obtained in Walker *et al.'s* 1997 study. Recall that the magnitude of the RDE for the mirror symmetrical peripheral distractors in their investigation was in the order of 15ms.

Main analyses were conducted on the latencies of correct first saccades to the target Table 4 shows the mean eye movement latencies and the standard deviations for each condition. For the saccade onset latencies (correct responses) data were available for all conditions. Consequently, a 2(Eccentricity) by 2(Constancy) by 2(Distractor Type) ANOVA was carried out on the mean saccade onset latencies treating participants as random variables.

Table 4: The mean onset latencies and standard deviations (in parentheses) for each type of distractor at each distractor presentation location for changing and constant distractors.

Distractor Type

	Changing		Constant	
	Uniform letter strings	Uniform shape strings	Uniform letter strings	Uniform shape strings
Central distractor	223.17 (41.81)	207.35 (35.17)	207.10 (35.63)	211.44 (38.48.)
Peripheral distractor	214.50 (36.86)	200.74 (34.11)	203.19 (33.81)	211.80 (39.15)

There was a main effect of constancy (F (1,15) = 8.05, $p < .05$) with saccade onsets being longest when distractors were changing (mean = 211.4ms) than when they were constant (mean = 208.4ms). It was anticipated that if the effects in Experiment 1 were due to the changing nature of the distractor strings, then a main effect of constancy would be obtained with longer saccade onset latencies for changing than for constant distractors. This prediction was supported in the current experiment. Repeated presentation of the same distractor produced saccade onset latencies that were decreased in comparison to the presentation of changing distractors.

There was a main effect of eccentricity (F (1,15) = 4.59, $p < .05$), with saccade onset latencies being significantly longer when distractors were presented centrally (mean =

212.3ms) compared to when they were presented peripherally (mean = 207.6ms). This supports the second prediction of central distractors producing longer saccade onset latencies than peripheral distractors , and this is in line with the typical findings from Walker *et al.'s,* 1997 RDE investigation.

There was also a reliable effect of distractor type (F (1,15) = 10.17, p <.01). Saccade onset latencies were longer for the uniform letter string distractors (mean = 212.0ms) than for the uniform shape string distractors (mean = 207.8ms). It was anticipated that if the findings in Experiment 1 were a consequence of the linguistic status of the distractors rather than their changing status, then a larger distractor effect should occur for letter string distractors than for uniform shape string distractors. This prediction was supported by the findings in this experiment.

Thus the main effects found in the current experiment show that all variables have an influence upon saccade onset latencies. Central distractors produced longer saccade onset latencies than peripheral distractors. Changing distractors produced longer saccade onset latencies than constant distractors and the uniform letter strings produced longer saccade latencies than the uniform shape strings. These main effects were qualified by interactive effects.

There was a reliable interaction for Constancy and Eccentricity (F (1,15) = 5.4, p < .05). Figure 4 shows the mean saccade onset latencies for changing and constant distractors for each of the distractor eccentricities. Recall that in Experiment 1 there was no difference between saccade onset latencies for central and eccentric uniform shape string distractors, but there was such an effect for uniform letter string distractors. Consequently, in the current experiment it was anticipated that the effect of eccentricity could be modulated by constancy, in which case a greater difference between changing central and peripheral distractor strings would be obtained compared to the difference between constant central and peripheral distractor strings. For the Constancy and Eccentricity interaction means comparisons (paired sample t-tests) for changing distractors showed that central distractors (mean = 215.3ms) produced longer saccade onset latencies compared to the peripheral (mean = 207.6ms) distractors (t (1,31) = 3.71, $p < .001$). However, for constant distractors, there was no reliable difference between central (mean = 209.3ms) and peripheral distractor (mean = 207.5ms) strings (t <1). Thus, the results indicate that when the distractors were changing they produced a greater effect at central compared to peripheral locations. When the distractors were constant there was no difference in saccade onset latencies between central and peripheral distractor presentation. This supports the finding in Experiment 1 of no difference between central and peripheral distractors for the repeated (constant) shape string, but it contradicts what would be predicted from the Walker *et al.* 1997 study.

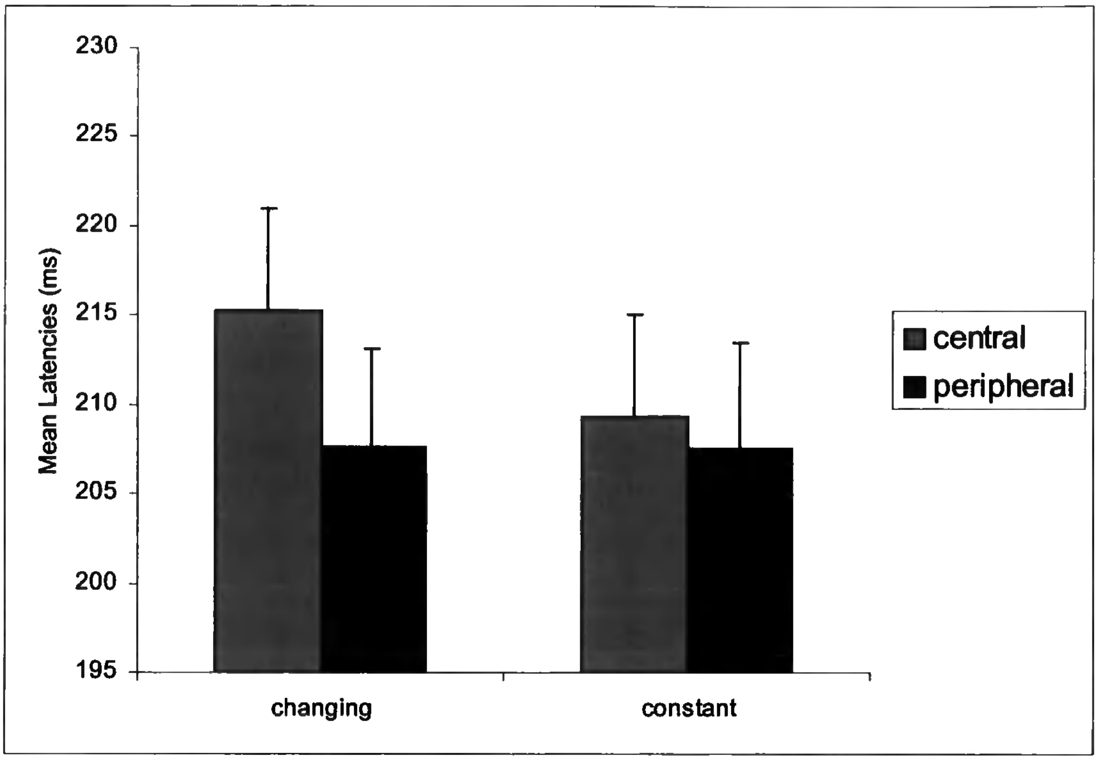


Figure 4: *The mean saccade onset latencies for changing and constant distractors for each of the distractor eccentricities. Error bars denote 1 standard error from the mean.*

There was an interaction between Constancy and Distractor Type ($F\,(1,15) = 5.3, p < .05$). Figure 5 shows the mean saccade onset latencies for uniform letter string distractors and uniform shape string distractors for the changing and constant distractor conditions. For the Constancy and Distractor Type interaction, means comparisons (paired sample t-tests) showed that longer saccade onset latencies were produced for the uniform letter strings when these were changing (mean = 218.8ms) compared to when this distractor type was constant (mean = 205.1ms), ($t\,(1,31) = 3.47, p < .001$). However, the comparison for the uniform shape strings revealed that longer saccade onset latencies were produced for the constant strings (mean = 204.0ms) compared to changing strings (mean = 211.6ms), ($t\,(1,32) = -2.31, p < .05$).

Thus the finding for the uniform shape strings actually goes in the opposite direction to what was predicted. Note that although this effect was much weaker than for the uniform letter string distractors, it was still an unexpected finding, and possible reasons for the finding will be given in the discussion to this experiment.

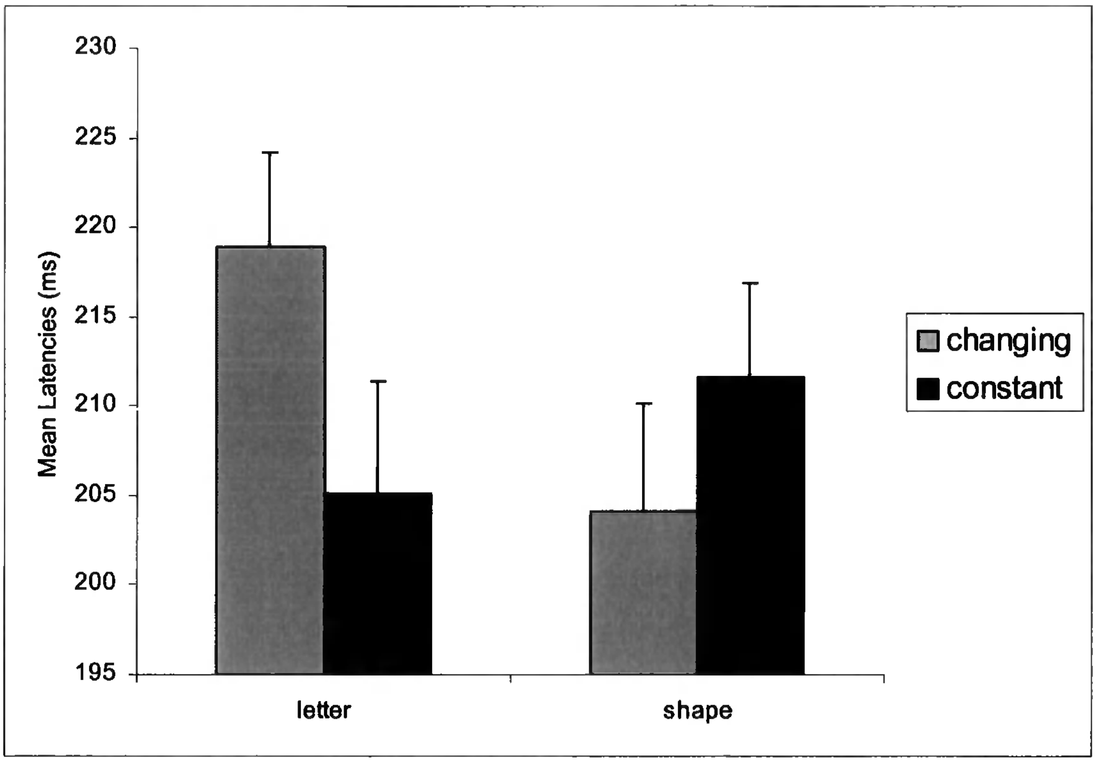


Figure 5: *The mean saccade onset latencies for uniform letter string distractors and uniform shape string distractors for the changing and constant distractor conditions. Error bars denote 1 standard error from the mean.*

There was also a marginal interaction between Eccentricity and Distractor Type (F $(1,15) = 4.0, p = .06$). Figure 6 shows the mean saccade onset latencies for uniform letter string distractors and uniform shape string distractors for each of the distractor eccentricities. Even though this was not quite significant, analyses were conducted to explore it since it had been predicted that if the eccentricity effects observed in Experiment 1 resulted from the linguistic status of the distractor string then an interaction between Distractor Type and Eccentricity would be obtained, such that a larger difference in saccade onset latencies would be found between central and peripheral uniform letter string distractors compared to central and peripheral uniform shape string distractors. Means comparisons (paired sample t-tests) showed that longer saccade onset latencies were produced for the uniform letter strings at central presentation (mean = 215.1ms) compared to peripheral (mean = 208.8ms) presentation (t (1.31) = 3.26, $p < .01$). However, the comparison for the uniform shape strings revealed that there was no reliable difference between central (mean = 209.4ms) and peripheral distractor (mean = 206.3ms) presentation (t (1.32) = 1.26, $p > .1$). The pattern meets with the predictions but one of the differences was not reliable. This will also be explored in detail in the discussion.

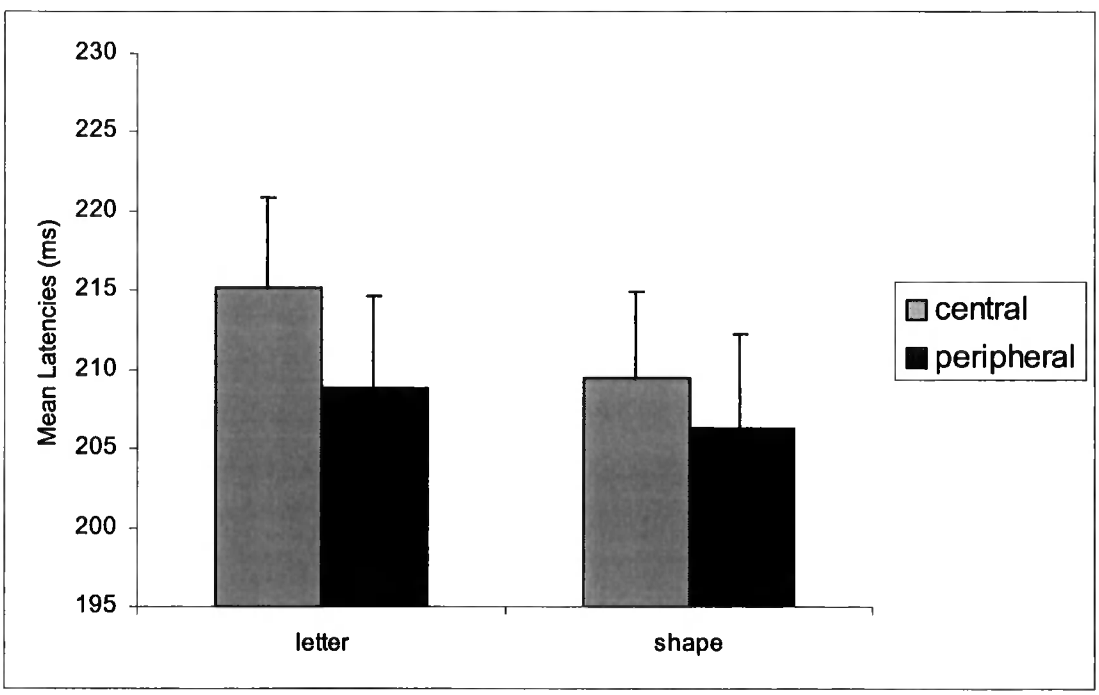


Figure 6: *The mean saccade onset latencies for uniform letter string distractors and uniform shape string distractors for each of the two distractor eccentricities. Error bars denote 1 standard error from the mean.*

3.5: Discussion

On the basis of the findings from Experiment 1, a number of predictions were made for the current experiment. Some of these predictions were upheld, whilst others were not, and some unexpected findings occurred. A Remote Distractor Effect was found for both central and peripheral presentation of a distractor compared to the distractor absent condition. For central presentation of the distractors the magnitude of the RDE was comparable with that found for central distractors in Walker *et al.'s* (1997) study, whereas the finding for the peripheral distractors was much greater than the finding for the peripheral distractors in Walker *et al.'s* (1997) study, but was consistent with the finding for this distractor location from Experiment 1. Peripheral distractors in these experiments are producing longer saccade latencies than would have been predicted. This finding contradicts, in some way, the explanation offered by Findlay and Walker (1999) to account for the RDE effects. Recall from the introduction that the RDE is explained with reference to neurophysiological data. It was suggested by Findlay and Walker (1999) that the very systematic effects, of the biggest increase in saccade onset latencies for centrally presented distractors, with a linear decline in this effect as the distractor is moved into the periphery, results from activity in the central fixation zone of the Superior Colliculus. Findlay and walker (1999) suggested that activity in this fixation zone could have affects at up to 10 degrees into the periphery, and that this is why a decline in disruption to the saccade onset system declines with distractor eccentricity. Clearly these findings do not support that claim.

A possible reason for the difference in RDE magnitudes for peripheral distractors in the current Experiments, and those in Walker *et* al.'s (1997) investigation was given in the discussion of Experiment 1. Here, it was suggested that the discrepancy could be attributed to the difference in size between the distractors and the target. Recall, that, differences in the magnitude of the RDE, corresponding to differences in the size of remote distractors, were observed by Weber and Fischer (1994) who found that larger distractors had more of an inhibitory effect on the production of express saccades compared to smaller distractors, which had less of an effect than distractors that were of equal size to the target. Additionally, in the case of the centrally presented distractors participants do not have to discriminate between the distractor and the target, whereas in the case of peripherally presented distractors, there is a necessity to discriminate between the two prior to moving the eye to the target. The time taken to complete the discrimination process could also offer some explanation as to why there is such an increase in the RDE in the current experiments for peripheral distractors, compared to that shown in Walker *et al.'s* 1997 study.

In addition to the findings for the baseline comparison between the distractor present and the distractor absent conditions, three main effects were observed in Experiment 2. These showed that changing distractors produced longer saccade onset latencies than constant distractors, central distractors produced longer saccade onset latencies than peripheral distractors, and uniform letter string distractors produced longer saccade onset latencies than uniform shape string distractors. Overall the findings suggest that the differences between the linguistic and the non-linguistic distractors, obtained in Experiment 1were not entirely due to either the linguistic status of the distractor, or to the repetition of the uniform shape string distractor. Each of these variables, along with distractor eccentricity, had some impact on the saccade onset latencies in the current Experiment. This means that it is not just distractors per se which will have an influence on oculomotor behaviour, but rather, any systematic effects upon saccade latencies may be dependent upon the nature of the particular distractors presented.

An interaction between Constancy and Eccentricity revealed that when the remote distractors were changing, then the predicted RDE of a difference in performance for central versus peripheral presentation was upheld. This was found for both uniform letter string distractors and for uniform shape string distractors. It was not necessary for the distractor therefore to be both 'changing' and to have linguistic characteristics. This explanation can account for the findings in Experiment 1 where differences upon the magnitude of the RDE were found between central and peripheral presentation of the distractors for all linguistic string distractors, but no differences were found for the non-linguistic repeated uniform shape string distractors. The results from the current Experiment suggest that the lack of a distractor Eccentricity effect for the uniform shape strings, compared to the uniform linguistic strings (and indeed all types of linguistic distractors employed in the first experiment) that occurred in Experiment 1, was a consequence of changing versus constant distractor strings rather than linguistic versus non-linguistic distractor strings.

This interesting finding since implies that any distractor which is repeated during the experimental trials, at least at central presentation, achieves the status of either predictability or familiarity during the course of the experiment. As a result of this, such distractors have less of a distracting influence on the slowing of saccades to the target compared to changing distractors.

Furthermore, it appears that the constant distractors can be ignored as easily at central presentation as they are at peripheral presentation, since no differences are observed between the central and the peripheral distractor eccentricities for constant distractors. It does not matter whether the nature of the distractor is linguistic or non-linguistic. Unpredictability of the distractor, however, as in the case of the changing distractors results in the predicted RDE observation from Walker *et al.'s*, 1997 studies, of a greater effect upon eye movement latencies to the target when the distractor is positioned at central fixation compared to when it is positioned at a peripheral location.

The design of Experiment 2 provided an opportunity to examine the influence of changing and constant linguistic and non-linguistic distractor strings regardless of eccentricity. It was thought that an influence of a changing distractor string relative to a constant distractor string could be modulated by the linguistic status of that string. Since there is an abstract level of representation associated with letter strings, that simply does not exist for strings of shapes, it was predicted that changing strings of letters would have a greater distracting influence on the saccade generation control system than a constantly repeated letter strings, whereas changing shape strings may have no more of an influence on saccade onset latencies than constant shape string. For both Experiments 1 and 2 it has now been shown that changing distractor strings result in longer saccade onset latencies compared to constantly repeated distractor strings. Recall that in the introduction to this Experiment evidence from the visual search literature was introduced to show that items that are repeated during the course of the experiment do not attract attention to the same degree as novel items (Johnston *et al.*, 1990, 1993). In relation to the current experiments therefore, in Experiment 1, the repeated item presented at the central location (the non-linguistic distractor) could have become familiar to the participants during the course of its repeated presentation. A possible explanation of this was that at this location, the ability to discontinue processing of the repeated item was quicker in comparison to the changing linguistic distractors that were presented at this location. This explanation seems to be a valid one given that the results from Experiment 2 show the same effects for both types of distractor.

Moreover this effect was modulated by the linguistic status of the distractor string. The difference between changing and constant shape strings was smaller than the difference between changing and constant letter strings, but it was reliable, and furthermore it showed that saccade onset latencies were longer for the constant uniform shape strings compared to the changing uniform shape strings. One tentative, at this stage, explanation for this finding is that the increase in latencies for the constant uniform shape strings could be a consequence of this distractor type being presented amidst a set of changing uniform letter strings. It is possible that there was some carry over effect from processing the changing uniform letter strings, which manifested in an increase in saccade onset latencies for the constant distractor in that set of distractors. More discussion of this possibility will be given in the general discussion to this thesis, and a more detailed examination of carry over effects will be conducted as part of the final experiment in this thesis. The possibility of possible carry over effects is also given for a further unpredicted finding detailed below.

A further unanticipated finding was revealed by a marginal interaction between Eccentricity and Distractor Type. The predicted difference between central and peripheral presentation of the distractors occurred for the uniform letter strings, but no reliable difference was found for the uniform shape strings. This supports the prediction that there would be a bigger difference between central and peripheral linguistic distractors, compared to central and peripheral non-linguistic distractors and provides some support for a linguistic effect over and above any constancy effects. However it was not expected that there would be no reliable differences between the central and the peripheral non-linguistic distractors. This would seem to argue against the conclusion, that the findings from Experiment 1, for the non-linguistic distractor, resulted from the constant status of that distractor, rather than its non-linguistic status. However, in this interaction the mean saccade onset latencies for the uniform shape strings is in the predicted direction and it could be that the explanation given for the increase in saccade latencies for the constant compared to the changing uniform shape strings in the interaction between Constancy and Distractor Type also applies to the finding in the interaction between Eccentricity and Distractor Type. Namely, that the constant uniform shape string distractors are longer than the constant uniform letter string distractors because they were presented in the set of changing uniform letter string distractors. This, it has been suggested in the previous pages, resulted in prolonged saccade onset latencies for the constant uniform shape string distractors in this experiment, and this effect was a possible consequence of a carry over effects from the type of changing distractor set within which they were embedded. What this means is that, since increases in the time taken to discontinue processing for the changing linguistic distractors, was greater than for the changing non-linguistic distractors, then this had the effect of also increasing the time taken to discontinue processing of the constant non-linguistic uniform shape string that was presented randomly within the set of changing linguistic strings.

It was also anticipated from the findings in Experiment 1 that in order for a distractor string to have a differential influence on the magnitude of the RDE at central and peripheral locations, it would have to be simultaneously both changing and linguistic. However no three-way interaction between Constancy, Eccentricity and Distractor Type was obtained. Longer saccade onset latencies did not occur for central than for peripheral distractors when the distractor was a changing string of letters compared to when it was either a constant string of letters, or a constant or changing string of shapes. Therefore the findings for Constancy and Eccentricity are independent of the findings for Constancy and Distractor Type, and the findings for Eccentricity and Distractor Type. This means that these three lines of enquiry can be investigated separately in future Experiments.

What can be concluded from Experiment 2 is that the magnitude of the RDE can be modulated by the nature of the distractors. The second experiment was designed to test two alternative hypotheses. Specifically, was the observed decrease in saccade onset latencies for centrally presented non-linguistic distractors in Experiment 1, compared to all types of linguistic distractors, a result of linguistic processing effects or, was it a result of repeatedly presenting the same non-linguistic distractor, as opposed to presenting changing linguistic distractors. In essence, the overall findings from Experiment 2 show that both linguistic and constancy variables have an effect on the timing of saccades. Shorter latency saccades will be produced when the distractors are repeated (constant) compared to when they are not repeated (changing).

This modulation also affects the timing of saccade onset latencies for distractors presented at central fixation and peripheral location. Changing distractors produce longer saccades for central versus peripheral distractor presentation. Constant distractors produce equivalent eye movement onset latencies for each distractor eccentricity. This was what was also shown in Experiment 1(for the non-linguistic distractor which was repeated throughout the trials) and is problematic for Walker *et al.'s* (1997) findings where it would be predicted that there would be differences between the effects of central and peripheral distractors on the magnitude of the RDE. The next two experiments will address this discrepancy.

Letter string distractors produce longer saccade onset latencies compared to shape string distractors. This modulation also affects the timing of saccade onset latencies for changing and constant distractors. Changing distractors produce longer saccade onset latencies compared to constant distractors, for the uniform letter strings. The finding for the uniform shape strings however showed the opposite effect. This finding though is probably not a result of constant uniform shape strings producing longer saccade onset latencies than changing uniform shape strings, since an overall effect of longer saccade onset latencies was observed for the uniform letter string distractors. It is more likely to result from an influence of the longer saccade latencies produced for the changing uniform letter strings elevating those produced for the constant uniform shape strings because they were presented together. This hypothesis of a carry over effect will be investigated further in a later experiment.

Finally, central distractors produce longer saccade latencies than peripheral distractors, and again this modulation was shown to affect the timing of saccade onset latencies for the different distractor types. There was a greater difference between central and peripheral uniform letter strings compared to central and peripheral uniform shape strings which showed no reliable difference between the distractor eccentricities. The lack of an effect for the uniform shape string distractors for this comparison is again likely to result from increased saccade onset latencies for the constant uniform shape strings, as a consequence of carry over effects from presenting these amidst a set of changing uniform letter strings.

The above findings, and the possible explanations for these findings are important and will be examined in more detail in the following experiments. The next two Experiments will concentrate on the finding that constant distractors do not produce a difference between saccade onset latencies for central and peripheral presentation of distractors. This finding does not follow what would be predicted from Walker *et al.'s* (1997) studies of the RDE. The distractor used in their experiments was constant (repeated) and they found robust systematic differences for eye movement onset latencies. The greatest increase in saccade latency was consistently observed for remote distractors presented centrally, and a systematic decline in the magnitude of this effect was found when the distractor was moved out into the periphery. The findings from Experiments 1 & 2 have shown that greater saccade onset latencies are produced for central distractor presentation compared to peripheral distractor presentation, but only when the distractors were changing. When a distractor was constant (repeated) then there was no difference between the two distractor locations upon the magnitude of the RDE. The next two experiments will address this finding and an attempt will be made to replicate the findings from Walker *et al.'s* (1997) study using constant distractors only.

Chapter 4

The Effects of Predictable Distractors at Unpredictable and Predictable Target Locations

4.1.1: Experiment 3

One of the most surprising findings from Experiments 1 and 2 was the fact that the eccentricity of the distractors did not appear to modulate the RDE in the expected manner when the distractors were constant (repeated). Specifically, the finding of no difference between centrally and peripherally presented distractors on eye movement onset latencies did not fit with Walker *et al.'s* (1997) RDE findings.

The next two experiments were therefore conducted as a further investigation as to why central and peripheral constant distractors produced equivalent eye movement latencies in Experiments 1 & 2. The prediction on the basis of Walker *et al.'s* (1997) RDE investigation was that there should be a greater difference in the magnitude of the RDE for central versus peripheral distractors. In their experiments the target was an 'X' and the distractor was a similar size 'O' which was kept constant throughout. Their finding was that central distractors produced a RDE in the order of 40ms and peripheral distractors produced a RDE in the order of 15ms (when the distractor and the target were presented in mirror symmetrical positions on the horizontal axis). In the experiments reported here for the two Experiments conducted so far, the target was a '+' and the distractors were made up of four letter strings or four shape strings. In principle, therefore, the difference in size between the target and the distractors could have been one factor that contributed to the lack of difference between saccade onset latencies for central versus peripheral distractor presentation locations for the constant distractors. However the size difference between distractor and target could not really account for the finding of no difference between central and peripheral constant distractors, since the expected difference was found for changing (not repeated) distractors. There must therefore have been some other reason for this discrepancy, and as the findings from Experiment 2 show, one likely cause of the finding of no difference between the central and peripheral distractors could have been due to the repeated nature of the distractor. In Experiments 1 and 2 longer latency saccades were produced for central versus peripheral distractors for changing distractors, but not for constant (repeated) distractors. This finding was obtained for both uniform linguistic strings and uniform shape strings. It therefore appeared to be the case that it was something about presenting a repeated distractor that modulated any eccentricity effects upon the RDE.

However, so far in these experiments the constant distractors have been presented amidst a set of changing distractors in a somewhat complex design. It could be that it was this manipulation, which clearly resulted in a decrease upon saccade onset latencies for the central constant distractors compared to the central changing distractors, that resulted in no differences between the saccade onset latencies for central versus peripheral constant distractors. It is interesting therefore to investigate what happens when constant distractors are presented without any changing distractors. If there were no changing distractors, and the predicted RDE from Walker *et al.'s* (1997) was found for the central and the peripheral distractors, then the changing distractors would necessarily be a possible causative factor for the findings from Experiments 1 and 2. In Experiment 3, therefore, only constant

(□□□□) distractors were presented. These were presented at the same distractor eccentricities used in Experiments 1 and 2. The target could appear either on the left or the right of the display, with or without a distractor. Peripherally presented distractors had a target at an equal eccentricity (8 degrees) in the opposite hemifield. Centrally presented distractors had an accompanying target which appeared either to the left or to the right of the distractor at an eccentricity of 8 degrees.

4.1.2: Predictions

1. Following from the findings from the first two experiments it was predicted that there would be a Remote Distractor Effect for both central and peripheral distractors compared to a condition where no distractor was presented with the target.

2. It was also anticipated that there would be a difference in the magnitude of the RDE for peripheral distractors which would be greater than that shown for peripheral distractors in Walker *et al.'s* (1997) investigation. This was consistently shown for the peripheral distractor eccentricities for Experiments 1 and 2.

3. Additionally, it was anticipated that, following the findings from Experiments 1 and 2, if it was the case that equivalent saccade onset latencies were produced for centrally and peripherally presented distractors for the constant distractors in these experiments because they were presented amidst a set of changing distractors, then removal of the changing distractors should now result in greater saccade onset latencies for central, compared to peripheral distractors in Experiment 3. This is a feasible assumption to make, since the differences between the two types of distractor

(constant versus changing) were only ever observed at the central distractor location. No differences were observed between them at the peripheral distractor location.

Alternatively, if the presentation of changing and constant distractors together in the same trial block was not the main factor which resulted in no differences between saccade onset latencies for central and peripheral presentation of the distractors, then no differences between saccade onset latencies for the distractor eccentricities would be expected for the constant distractors in Experiment 3.

4.1.3: Method

4.1.3.1: Participants

7 members of the University of Durham community participated in the experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were all naïve in relation to the purpose of the experiment.

4.1.3.2: Materials

The same uniform shape string distractor from Experiment 2 (□□□□) was used as the constant distractor for this experiment. The target cross was also the same that employed in the previous experiments. As in Experiments 1 and 2 the target could appear at either the left or the right of the display, at an eccentricity of 8 degrees, and the distractor was presented at either central fixation or at an eccentricity of 8 degrees (symmetrically opposite to the target).

4.1.3.3: Design

This was an independent subjects design. The independent variables were distractor present/absent, and distractor eccentricity. The dependent variables were saccade onset latencies and directional errors. Each participant completed one block of 480 trials in which the target could appear either on the right or the left of the screen, without a distractor (160 trials), with a central distractor (160 trials), or with a peripheral distractor positioned mirror symmetrically at 8 degrees eccentricity in the opposite hemifield to the target (160 trials). Random presentation of the trials occurred for all participants.

4.1.3.4: Procedure

Eye movement recording, sampling, calibration procedure and sequence of presentation for each trial was the same as in the previous experiment, as was the task. Participants were instructed to move their eyes to the target cross, which could appear either on the left or the right of the display, and ignore any other stimuli that might appear simultaneously with the target.

4.1.4: Results

Any trials in which tracker loss occurred were excluded from the main analyses, as were saccades outside the range of 100 ms - 500 ms. In total the percentage of trials rejected on this basis was 8%. Directional errors were also excluded from the final analysis of eye movement onset latency. The total percentage of errors was 22%. It should be noted that errors were only made when a peripheral distractor was presented, and that in all cases where a directional error was made, a corrective saccade to the actual target was also made during the trial presentation. Main analyses were conducted on the latencies of correct first saccades to the target Table 5 shows the mean eye movement latencies and the standard deviations for each condition.

Table 5: The mean onset latencies and standard deviations (in parentheses) for each distractor presentation location.

Type of Distractor		
Central distractor	Peripheral distractor	No distractor
250.97 (42.51)	262.49 (42.55)	226.89 (44.25)

There was a highly reliable Remote Distractor Effect (2 paired samples t-tests tested whether the uniform shape string at each distractor eccentricity differed from the no distractor condition). Both t-tests revealed significant effects. For central presentation of the distractor versus the no distractor condition (t (1,6) = 5.88, p <.001) and for peripheral presentation of the distractor versus the no distractor condition (t (1,6) = 7.48, p <.001), with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present. The results are consistent with the prediction that distractors would produce longer eye movement latencies compared to the control condition where no distractor was presented with the target. This supported the first prediction of a difference for the no distractor condition compared to the distractor present conditions.

The second prediction stated that there would be a greater RDE magnitude for the peripheral distractors in this experiment compared to that shown for the peripheral distractors in Walker *et al.*, (1997) would occur for the comparison of the magnitude of the RDE between the peripheral distractor presentation and the no distractor condition. Recall that in Walker *et al.*'s (1997) study the magnitude of the RDE was on average 15ms for mirror symmetrical target and distractor locations. This prediction was supported here, the difference between the peripheral distractor and the no distractor condition was 35.6ms and the difference between the central distractor and the no distractor condition was 24.1ms. The central distractors in this experiment are producing a smaller magnitude of the RDE compared to Walker *et al.*'s (1997) study and the peripheral distractors are producing a greater RDE magnitude compared to Walker *et al.*'s (1997) study.

Comparisons of the latencies of correct responses for the distractor eccentricities were also analysed using a paired samples t test. This revealed a significant effect for central presentation of distractor versus peripheral presentation of distractor (t (1, 6) = -3.08, p <.05) with central distractors producing shorter saccade onset latencies compared to the peripheral distractors. The prediction for this comparison was that there would be no difference between central and peripheral saccade onset latencies in this experiment. Therefore the prediction was not upheld, and furthermore, the results contradict the findings of Walker *et al.*, (1997) in that the effect is in the opposite direction to what would have been predicted from their study.

4.1.5: Discussion

The findings from this experiment are in direct contradiction to what would be predicted from Walker *et al.*'s (1997) RDE studies. In their experiments there was a clear and systematic difference between central and peripheral presentation of distractors upon the magnitude of the RDE, with central distractors producing longer saccade onset latencies than peripheral distractors. The findings from Experiment 3 show the opposite effect, with peripheral distractors producing longer saccade onset latencies than central distractors. The question of why there are such differences between the findings for Experiments 1, 2 and 3, and Walker *et al.*'s (1997) findings needs to be addressed. The distractor in Walker *et al.*'s (1997) experiments was 'constant' and was of a similar size to the target. However the difference in size between the target and distractor in these experiments cannot account for the findings observed. There are clear differences on eye movement onset latency between presentation of central and peripheral distractors (in the predicted direction) when these distractors are changing, but not when they are constant, irrespective of distractor to target size ratio. The task in both Walker *et al.*'s (1997) investigation, and the experiments reported here, was the same; participants are presented with a target either on its own or with a distractor and they simply had to ignore the distractor and make an eye movement to the target.

One further difference between the Experiments reported here, and those of Walker *et al.*, (1997), which could be explored to see if it could account for the discrepancy between the findings is that in Walker *et al.*'s (1997) studies, the target was always in a pre-specified unidirectional position. That is, participants were told the location of the target beforehand. They were informed that the target would always be on the 'right', or, on the 'left' of the display prior to each block of trials. In the experiments reported here the target could appear on the 'right' or the 'left' during each block of trials. Clearly, in the case of changing distractors this made no difference, and the predicted modulation of the RDE was upheld for central versus peripheral distractors. However, when the target appeared either to the left or right of the display, and the distractors were constant, then the expected finding for an increase in saccade onset latency to central distractors compared to peripheral distractors, was absent.

In the general introduction to this thesis it was reported that an earlier study by Walker *et al.*, (1995) which looked at differences in saccade onset latencies to single and double targets, found an increase in saccade latencies for the double target condition compared to the single target condition. However, no differential effects were observed between the increase in saccade latencies shown in the bilaterally presented double target condition, and a condition whereby participants were instructed to attend to the side of the display at which the target would appear. It was not therefore expected in the set of Experiments conducted here, that bilateral presentation of the target and distractors would produce any different effects to those observed by Walker *et al.*, (1997).

Presenting the target on a pre-specified side of the display removes any decision component as to the location of the target, and also means that there is no discrimination to be made between target and distractor. In Walker, Kentridge & Findlay *et al*, (1995), although there was bilateral presentation, no discrimination had to be made between the target and the distractor, since both were identical, but a decision had to be made as to which one of the two identical potential targets to saccade to. It appears therefore that the decision component associated with bi lateral presentation of the target might also modulate the RDE. Experiment 3 stripped out the changing and the linguistic components from Experiments 1 & 2 and employed a simple non-linguistic distractor. At central presentation of the distractor participants simply had to move their eyes to an area of peripheral stimulation. When participants were presented with a peripheral distractor a decision had to be made between two potential saccade targets. That is, participants had to work out what was at each location, decide which one was the target and then move their eyes to this target. The extra time taken to make this decision could explain why it took longer to saccade to a target with a peripheral distractor compared to a target with a central distractor. The finding is also similar to findings in the visual search literature which show that participants can employ a strategy whereby covert scanning of the display to locate the target results in a speed accuracy trade. If it is the case that peripheral distractors are behaving like competitive targets then we might expect the observation of an increase in saccade onset latencies for correct responses to the target for these distractors. One way to reduce this competitive effect would be to remove the decision component of the task. If a decision making component has a modulating effect upon the magnitude of the RDE then the removal of this should produce shorter saccade onset latencies for the peripheral distractors.

In the current experiment, and in the previous two experiments (Experiments 1 & 2), the anticipated finding of central distractors producing longer saccade onset latencies compared to peripheral distractors was not obtained when the distractors were constant. Furthermore in Experiment 3 peripheral distractors produced longer saccade onset latencies than central ones. These findings do not support those of

Walker *et al.*, (1997). Therefore to test whether it is the additional task requirement of a choice of two possible locations for the appearance of a target that is producing the effect that is inconsistent with Walker *et al.,* (1997), the next experiment adopted the unilateral design from the study of Walker *et al.,* (1997) such that targets were presented to a single pre-specified unilateral location only.

4.2.1: Experiment 4

This experiment was designed to investigate whether the expected prediction of a difference upon the magnitude of the RDE for central versus peripheral distractors would be obtained when the target can only appear at one pre-specified unidirectional location throughout each block of trials. From the experiments reported so far (Experiments 1, 2 & 3), the findings show that if the distractor is unpredictable (changing) and the target could appear at either the right or the left of the display (bilateral target presentation), then the findings from Walker *et al's* (1997) studies are supported, as was the case in Experiments 1 and 2 for the changing distractors. That is, saccade onset latencies were longer for central presentation of the distractor, compared to peripheral presentation of the distractor. This was not found when the distractors were predictable (constant). In Walker et al's studies the distractors were predictable but the task demand did not have the additional component of switching target location from left to right during blocks of trials. Since the findings from the three previous experiments appear to be consistent, and since the findings from Walker *et al.'s* (1997) studies appeared to be robust (occurred in 3 separate experiments), it is important to try to replicate the findings from Walker et al's studies using the stimuli employed in these experiments.

4.2.2: Predictions

1. Following from the findings from the previous three experiments it is anticipated that there will be a Remote Distractor Effect for both central and peripheral distractors compared to a condition where no distractor is presented with the target.

2. Furthermore, it is expected that the magnitude of the RDE for peripheral distractors compared to Walker *et al.'s* (1997) findings, will now show a smaller discrepancy. That is to say, in the Experiments reported so far there has been a consistent increase in the magnitude of the RDE for the peripheral distractors compared to that shown by Walker *et al.,* (1997). It is expected that by removing the decision component of the task, such that participants know in advance which side of the display the target will be presented in any given block of trials, this should have the effect of reducing the difference in the RDE magnitude for the peripheral distractors, compared to that shown for Experiments 1, 2 and 3.

3. It was also expected that there would now be a difference between saccade onset latencies for central and peripheral presentation of the distractors. Specifically, it was anticipated that the removal of the decision making component of the task would result in the predicted difference of centrally presented distractors having a greater disruptive effect upon saccade latencies compared to peripherally presented distractors. Since participants will not have to discriminate between target and distractor in the peripheral condition for this experiment, and nor will they have to make a decision as to where the saccade target is located, (since they were told in advance which side of the display it would appear at), then it was expected that the

slowing of saccade onset latencies observed for the peripheral distractors in the previous experiments, would not be shown in this experiment.

4.2.3: Method

4.2.3.1: Participants

8 members of the University of Durham community participated in the experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were paid to participate and all were naïve in relation to the purpose of the experiment.

4.2.3.2: Materials

The same materials from Experiment 3 were used for this experiment.

4.2.3.3: Procedure and design

These were the same as for Experiment 3 but in this experiment the target was always unidirectional and participants were instructed as to the location of the target prior to recording. The instruction identical to that given in the previous experiments 'Look at the cross' and ignore any other simultaneously presented stimuli. The presentation sequence, eye movement recording, and sampling, were also the same as for the previous experiments. One further manipulation was that the target for the no distractor condition could now appear at either 4 degrees or 8 degrees in the periphery. This manipulation was introduced to try to minimise the number of expected anticipatory saccades that might arise as a result of informing the participants as to the side of the display the target would appear (Wenban-Smith & Findlay, 1991). It also comes closer to the Walker *et al.* (1997) design. Each participant completed 320 trials randomised into four blocks. In total, for the distractor present condition, there were 80 peripheral distractor trials, and 80 central distractor trials. For the no distractor condition there were 80 trials where the target was located 4 degrees eccentric to central fixation and there were 80 trials where the target was located 8 degrees eccentric to central fixation.

4.2.4: Results

Any trials in which tracker loss occurred were excluded. In total the percentage of trials rejected on this basis was 10%. When participants are told which location the target will appear at, it is expected that some anticipatory saccades will be generated (Wenban-Smith & Findlay, 1991) What this means is that participants will move their eyes toward the target prior to it being presented. Anticipations in this experiment are classified as those saccades where the latency is less than 100ms and where the initial starting point for each trial is within one degree from the centre of the display. The total percentage of anticipatory eye movements (those saccades that started within 1 degree from the central fixation of the display at the initial start of the saccade) was 27%. These anticipatory saccades were also excluded from the main analyses. Also, since the main measurement from the Experiments in this thesis concerns distractor effects on saccade onset latency, no amplitude analyses have been conducted. It should though be noted that the distribution of amplitudes for Experiment 4 and Experiment 5 (unilateral presentation) would have been likely to show much more variability for the anticipatory eye movements to the target (Weber & Fischer, 1994). Table 6 shows the mean eye movement latencies and the standard deviations for each condition.

Table 6: The mean onset latencies and standard deviations (in parentheses) for each distractor presentation location.

Type of Distractor

Central distractor	Peripheral distractor	No distractor
223.94 (40.48)	205.32 (38.27)	192.29 (36.61)

There was a highly reliable Remote Distractor Effect (2 paired samples t-tests tested whether the uniform shape string at each distractor eccentricity differed from the no distractor condition. Both t-tests revealed significant effects. For central presentation of the distractor versus the no distractor condition (t (1,7) = 6.78, p <.001) and for peripheral presentation of the distractor versus the no distractor condition (t (1,6) = 5.79, p <.001), with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present. The results are consistent with the prediction that distractors would produce longer eye movement latencies compared to the control condition where no distractor was presented with the target. This supports the first prediction of a difference for the no distractor condition compared to the distractor present conditions.

The second prediction stated that the magnitude of the RDE, compared to Walker *et al.'s* (1997) findings, would now show a smaller discrepancy for the peripheral distractor presentation location compared to the discrepancy observed for this condition in the previous three experiments. Recall that in Walker *et al.'s* (1997) study this was 15ms for mirror symmetrical target and distractor locations. This prediction was supported here, the difference between the peripheral distractor and the no distractor condition was 13.0ms and the difference between the central distractor and the no distractor condition was 31.7ms. The distractors in this experiment, at both eccentricities, are producing a similar magnitude of the RDE as observed by Walker *et al.'s* (1997) study. Thus, when the target location was pre-specified, a similar pattern of saccade onset latencies was observed, for both distractor eccentricities, to that which would have been predicted from Walker *et al.'s* (1997) studies.

Comparisons of the correct responses for the two distractor eccentricities were also analysed using a paired samples t-test. This revealed a significant effect for central presentation of distractor versus peripheral presentation of distractor (t (1, 7) = 5.50, p <.001) with central distractors producing shorter saccade onset latencies compared to the peripheral distractors. This supports the final prediction for this experiment and also supports what would be expected for these distractor eccentricities from Walker *et al.'s* study. The findings from Experiment 4 follow those of Walker *et al.,* (1997). When participants no longer have to make a decision as to which side of the display the target will appear on, the prolonged saccade latencies that were observed for peripheral distractors in Experiments 1, 2 and3, are no longer evident.

Because such striking differences have been obtained for Experiments 3 and 4, it is interesting to compare the findings for the two Experiments. Figure 7 shows the means for the different distractor eccentricities for both experiments.

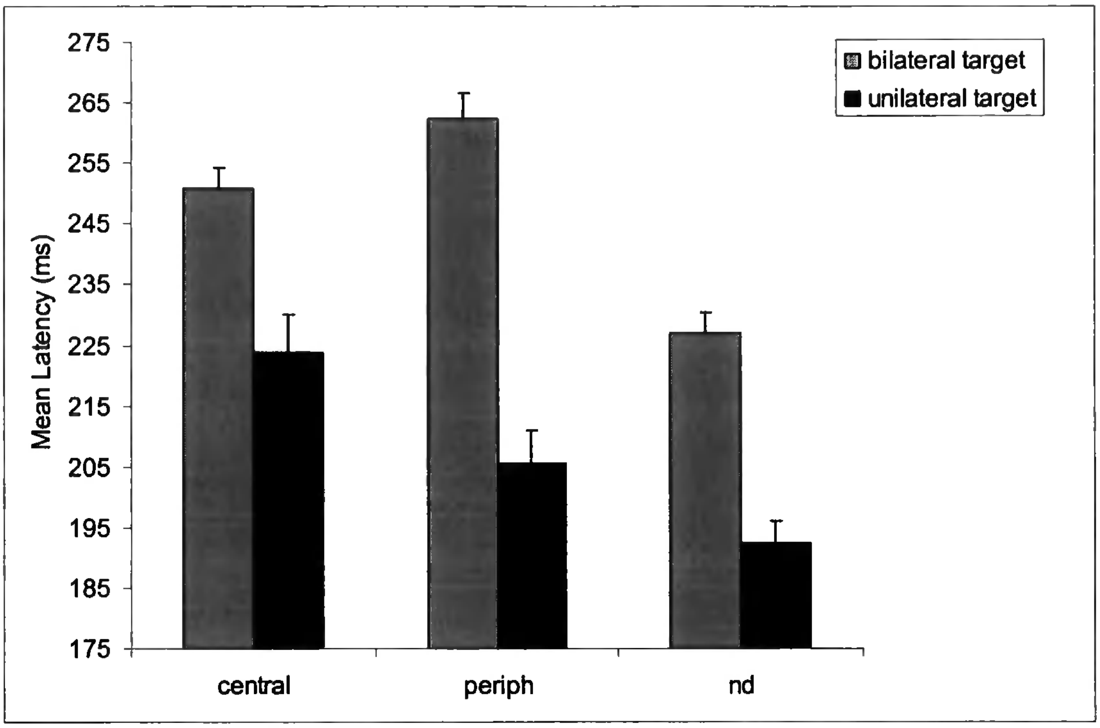


Figure 7: *The mean saccade onset latencies for each of the two distractor eccentricities and for the baseline no distractor condition for Experiment 3 (bilateral target) and Experiment 4 (unilateral target). Error bars denote 1 standard error from the mean.*

A repeated measures ANOVA was conducted on the correct eye movement latencies with Eccentricity (central and peripheral) as within subject variables and Experiment (Experiment 3 & Experiment 4) as between subject variables. A main effect was observed for the between subject variable Experiment (F (1, 13) = 9.6, $p < .01$) with Experiment 3 producing significantly longer saccade onset latencies (mean = 254.4ms) compared to Experiment 4 (mean = 214.0ms). There was no main effect for the within subjects variable of Eccentricity ($F > 1$), but there was a significant interaction between Eccentricity and Experiment (F (1, 13) = 36.5, $p < .001$). It is clear, from the Figure 7 that saccade onset latencies for the peripheral distractors are greatly reduced for Experiment 4 compared to Experiment 3. Furthermore the saccade latencies for the central distractors and for the no distractor condition were much higher for Experiment 3 compared to Experiment 4. Removing the decision component from the task has resulted in a speeding up of latencies for both distractor locations and for the no distractor condition. An independent samples *t*-test was conducted on the no distractor latencies and this revealed that the difference between the two Experiments ($t\ (1, 13) = -3.1, p < .01$) was significant. This seems an important finding as it implies that a more difficult task has knock on effects into the no distractor case and thus the Experimental difference may be said to be exerting a strategic effect (although not necessarily a conscious strategy). The biggest difference, as was expected occurred for the peripheral distractor. This supports the idea that the introduction of a decision component as to the location of the target results in prolonged saccade onset latencies for both central and peripheral distractors, with peripheral distractors.

4.2.5: Discussion

The data from Experiment 4 support the prediction of a greater effect upon the magnitude of the RDE for central versus peripheral distractors. All participants showed the same pattern of means for all conditions and the findings are consistent with Walker *et al.*'s (1997) RDE findings. Thus, in situations where the participant is informed as to the side of the display where the target will appear prior to each block of trials, the central and peripheral constant uniform shape string distractors do have a differential effect upon eye movement onset latency. Central presentation of the distractors results in a bigger effect upon the RDE than peripheral presentation of the distractors. This suggests that in bilateral target presentation (Experiment 3) the requirement of making a decision regarding which side of the display to make a saccade to results in a more disruptive effect for peripheral distractors compared to central distractors. A study by Weber and Fischer (1994) found that there was a reduction in the effects of peripheral distractors (30ms) if the targets were presented to a pre-specified display location, compared to when targets and peripheral distractors were presented randomly to the left or the right of the display (mirror symmetrically at 4 degrees eccentricity). No central distractors were used in their study, and similarly no central distractors were used in the Walker *et al.*, (1995) study. Therefore the consistently observed increase in RDE magnitude for peripheral distractors, compared to the RDE magnitude in Walker *et al.*'s (1997) investigation could be due to the differences between bilateral and unilateral presentation of the targets and distractors. Additionally, in the Walker *et al.*, (1995) study participants were free to saccade to one of two bilaterally presented targets (which were the same), so no discrimination needed to be made between the two, whereas in the Fischer and Weber (1994) study, in the bilateral presentation of target and distractor, participants had to discriminate between the two, since they differed from each other. The processes of deciding between one of two identical competing targets (Walker *et al.*, 1995), is different from the Experiments reported in this thesis, whereby participants had to discriminate between the target and the distractor.

Moreover, there appears to be a differential effect upon the magnitude of the RDE effect for the type of distractor presented in a bilateral target presentation task. If the distractor is changing throughout the trials (as for the letter string distractors in Experiment 1) then the expected difference between central versus peripheral presentation of the distractor will be observed, but if the distractor is constant then the peripheral distractor eccentricity causes greater disruption to the ability to saccade to a simple target. One reason which might explain why there was a bigger effect upon the magnitude of the Remote Distractor Effect for peripheral distractors compared to central distractors in Experiment 3 is that in this situation the extra time taken before moving the eye to the target resulted in part from the time taken to make the discrimination between the target and the distractor in order to decide to which location to make the eye movement.

There is also another possible reason as to why peripheral distractors had a greater influence in the bilateral target presentation task. That is, the difference between the physical size of the distractor and the physical size of the target (four characters compared to one) meant that the distractor was much more visually salient in the periphery than the target is (this assumes that visual salience in this instance equates to physical size). Since both target and distractor appeared simultaneously it is possible that attention was captured by the larger visual stimulation. Increases in distractor size have been shown to produce prolonged saccades (Weber & Fischer, 1994). In Experiment 3 therefore the finding of longer saccade onset latencies for peripheral distractors, compared to central distractors, could also, at least partly, be a result of the difference in size between target and distractor. However, this reasoning cannot explain why in Experiment 1 for all the linguistic string distractors, there was a stronger effect at central presentation than at peripheral presentation, for all types of linguistic string distractor. Neither can it explain why in Experiment 2 a difference was observed between central and peripheral distractors for the changing but not the constant distractors. This result was observed in spite of the fact that there is the same distractor to target size difference as in Experiments 1 and 3, and indeed in all the reported experiments. The bilateral presentation of the target in Experiments 1 and 2 meant that participants in those experiments also had to make the effort to discriminate between two possible target locations in the peripheral distractor trials.

Moreover, the latencies for the no distractor condition appear to be related to the latencies for the distractors with which they are presented. Note that the no distractor latencies are much higher for Experiment 3 compared to Experiment 4. This is interesting since it implies that there may be some carry over effect from the distractor conditions to the no distractor condition, which influences the programming and generation of saccade onset latencies. This finding will be explored in more detail in a later experiment.

In relation to Walker *et al.'s* (1997) experiments the findings from experiments 3 and 4 replicate only under unilateral target presentation conditions. In Experiment 4 where a replication of Walker *et al.,* (1997) was found for both distractor eccentricities compared to the no distractor condition, it is likely that the results for the central distractors and the peripheral distractors were influenced exclusively by those processes operating for their original RDE studies. That is foveally presented distractors had a greater influence than peripheral distractors because of the greater inhibitory effects upon the fixate/move centre of the eye movement system at central rather than peripheral presentation. Since there was no decision making component needed to discriminate the target from the distractor in the peripheral distractor presentation condition, then the effect of the peripheral distractor in Experiment 4 was influenced only by the same inhibitory effect for the central distractors, but in a reduced form. The explanation offered by Walker *et al.,* (1997) was based on an extended (collicular) fixation region. The results of Experiment 4 would be consistent with this account.

In experiment 3 where there is random bilateral presentation of the target location, the extra decision making component here resulted in an increase in eye movement onset latencies for the peripheral presentation of the targets. In experiment 3 therefore, the results were influenced by the extra time taken for the decision making process for the peripheral distractors. Additionally, although it has been suggested that the size differences between the targets and the distractors could also have contributed to the prolonged saccade onset latencies for the peripheral distractors in Experiments 1, 2 and 3, it is clear that this is not the case in Experiment 4 where the magnitude of the RDE for peripheral and central distractors was very similar to that shown for peripheral distractors in Walker *et al.,* (1997).

The results from Experiment 3 however, contradict Walker and Findlay's 1997 findings, and they are also incompatible with Findlay and Walker's (1999) model of saccade generation. Recall, from the introduction to this thesis that this model advocates that saccade onset latency is the result from competition between the level 2 fixate centre in the 'when' pathway, and the move centre in the 'where' pathway, which they argue in the case of the RDE results from central stimulation variables only. The findings from Experiment 3 are more in line with a model by Godijn and Theeuwes (2002) which, unlike Findlay and Walkers model, does not have separate fixation and move centres associated with the temporal 'when' and the spatial 'where' programming of saccades. In relation to the RDE, because information for the temporal and spatial aspects of eye movement generation are coded in the same saccade map Godijn and Theeuwes (2002) argue that both an exogenous saccade (toward the peripheral distractor) and an endogenous saccade (toward the target) are programmed in the same saccade map and the resulting RDE of an increase in saccade latency compared to single target conditions is a result of the time taken to suppress the initiation of an exogenous saccade in order to execute an endogenous saccade to the target. However, although the model can adequately explain directional errors to distractors in terms of exogenous capture, and it can offer an account for the early double target onset findings, it has problems explaining why amplitudes but not latencies are affected for close proximity double targets, and furthermore offers no predictions in the case of bilateral presentation of targets and distractors.

If the errors in Experiments 1, 2 and 3 resulted from exogenous or attentional capture by the peripheral distractors, and this seems a likely explanation then it could be suggested that in a bilateral target presentation task the peripheral distractor acts more like a competing target than a distractor. Thus, the effects in the bilateral presentation Experiments, unlike those obtained for Experiment 4 are not a result of inhibitory effects upon the move system from the extended fixation zone (as argued by Walker *et al.*, 1997), rather they may result from the time taken to inhibit the execution of an exogenous saccade in favour of executing an endogenous saccade to the target (Godijn & Theeuwes, 2002), but this would imply that all saccades made to the target were endogenous. This may not be the case, and indeed it has been shown that there is at least the possibility that on some trials exogenous fast saccades may be made to the target, where it looks like the distractor has had no inhibitory effect and on other trials slower saccades are made to the target, which may be said to be endogenous (Weber & Fischer, 1994).

A further possibility is that there are separate processes involved in the programming of exogenous and endogenous saccades, and that the reprogramming of an endogenous eye movement to the target after having programmed an exogenous eye movement to the distractor is what results in increased saccade latencies compared to the single target condition in the RDE paradigm. The work on saccadic inhibition outlined in the general introduction is relevant, should the assumption be made that both types of saccade are programmed in the RDE paradigm, and one must be inhibited in order to produce the other. Findings from the countermanding studies, (Colonius, Ozyurt & Arndt, 2001; Ozyurt, Colonius & Arndt, 2003),have suggested that voluntary inhibition of saccades results from competition between two processes.

More detailed discussion of this and of the model of Godijn & Theeuwes, 2002, and the model of Findlay and Walker (1999) in relation to the Experimental findings in this thesis will be reserved for the general discussion section. The important point here is that the findings from Experiments 3 and 4 using the simple constant distractor have shown that there are differences for unilateral pre-specified target conditions and bilateral randomly presented target conditions which at present cannot be fully accounted for by the models of eye movement generation and thus have implications for any model wishing to give an accurate description of distractor influences upon saccade onset latency.

In Experiments 1 and 2 a further difference between the conditions in those Experiments and in Experiments 3 and 4 was that there was additional design complexity in the earlier Experiments. That is, the distractors could be changing or they could be constant and this was shown to have some effect upon saccade onset latencies. Also, these changing and constant distractors differed in terms of which category they belonged to. Some had linguistic status whilst others did not. It is possible that these factors may be having modulating effects upon the magnitude of the RDE, which are either independent from each other or interactive with each other. Since it has been shown in Experiment 4 that the removal of the decision as to the side of the display the target would be presented at, results in a distractor eccentricity effect which would be predicted by Walker *et al.* (1997) for the constant distractors on their own, then it is important to determine whether the same findings from Experiment 4 will replicate if the constant distractors are embedded in a set of changing distractors in a unilateral target presentation task. Experiment 5 was therefore designed to see, firstly, if the constancy effect observed in Experiments 1 and 2 would replicate under unilateral presentation conditions. Secondly, following the findings from Experiment 4, the next experiment investigated whether unilateral target presentation produced the same eccentricity findings for constant and changing distractors, when constant distractors are set amidst changing distractors. Thirdly, Experiment 5 investigated whether there would be any differences for letter string distractors versus shape string distractors with unilateral target presentation, and finally, it provided an opportunity to assess whether any observed differences between the two types of distractor strings were dependent upon either constancy, or eccentricity.

Chapter 5

The Effects of Predictable and Unpredictable Distractors at Predictable Target Locations. Independent or Interactive?

5.1: Experiment 5

The conclusion from Experiments 3 and 4 was that if there was no decision to be made as to which side of the display the target appeared on, then the finding of prolonged saccades for central distractors compared to peripheral distractors should be observed. The results for a unilateral target presentation RDE condition (Experiment 4) replicated those of Walker *et al.*, (1997) in that similar magnitudes of the RDE were produced for central and peripheral distractors, in comparison to those that were produced for the central and peripheral distractors in Walker *et al.'s* (1997) study. If the task incorporated a decision component as to which side of the display to saccade to, then the opposite result for central and peripheral distractors was observed. Peripheral distractors produced prolonged saccades compared to central distractors. Experiments 3 and 4 have, together, shown that the RDE is modulated by the presence or absence of a decision component as part of the task. However this finding cannot explain why longer saccade onset latencies were produced for central versus peripheral distractors for the linguistic strings in Experiment 1, and nor can it explain why this saccade latency increase was also found for central versus peripheral distractors for the changing, but not the constant distractors in Experiment 2. There was a decision element in Experiments 1, 2 and 3, but the effects observed between the different Distractor Types, and between the different Distractor Eccentricities, for each of these Experiments was not always the same and was certainly different to those shown in Experiment 4. Therefore there must be something more than a decision element, as part of the task, which affects the production of saccade latencies in bilateral target presentation compared to those produced for unilateral target presentation.

One important difference between the conditions in Experiments 1 and 2 and those in Experiments 3 and 4 was that there was additional design complexity in the earlier Experiments. Distractors in Experiments 1 and 2 could be changing or they could be constant. Constant distractors did not show the same effects as changing distractors in these Experiments. Also, these changing and constant distractors differed in terms of whether they had any linguistic content. These factors were shown to have modulating effects upon the magnitude of the RDE, which interacted with each other. Since it has been shown in Experiment 4 that the removal of the decision as to the side of the display the target would be presented at, results in a distractor eccentricity effect which would be predicted by Walker *et al.* (1997) for the constant distractors on their own, then it is important to determine whether the complex design used in Experiment 2 would produce the same findings if target presentation was unilateral. This is important as it would imply that the differential distractor effects in Experiment 2 were not a result of bilateral target presentation effects.

Recall that in Experiments 1 and 2, where the target could appear either on the left of the display or on the right of the display, a difference between saccade onset latencies for central and peripheral distractor locations was observed for changing, but not for constant distractors. In these experiments (Experiments 1 & 2) central distractors produced longer saccade onset latencies compared to peripheral distractors when the distractors were changing, but when the distractors were constant, equivalent saccade onset latencies were produced for both distractor eccentricities. The opposite finding was obtained for Experiment 3, where again, the target could appear at either the left or right of the display, but this time only the constant uniform shape string distractor from the two previous experiments was presented. Peripheral distractors produced longer saccade onset latencies compared to central distractors. However, when the decision making component of the task was removed and participants were instructed as to which side of the display the target would appear on (Experiment 4), and the target appeared at that pre-specified side of the display consistently throughout a block of trials, a different pattern of eye movements was observed. The expected difference of a greater effect upon the magnitude of the RDE (Walker *et al.*, 1997) for centrally presented distractors compared to peripherally presented distractors, was now observed for the constant uniform shape string distractors.

Experiment 5 was therefore designed to see, firstly, if the constancy effect observed in Experiments 1 and 2 would replicate under unilateral presentation conditions. Secondly, following the findings from Experiment 4, the next experiment investigated whether unilateral target presentation produced the same eccentricity findings for constant and changing distractors, when constant distractors are set amidst changing distractors. Thirdly, Experiment 5 investigated whether there would be any differences for letter string distractors versus shape string distractors with unilateral target presentation, and whether any observed differences between the two types of distractor strings were dependent upon either constancy, or eccentricity, or both.

5.2: Predictions

1. For the no-distractor condition eye movement latencies will be shorter than for any condition where a target and a distractor are presented simultaneously. This is the standard finding from the RDE studies and this has been found consistently in the experiments reported so far.

2. Following from the findings of Experiment 4, there will be a bigger effect upon the magnitude of the RDE for central distractors versus peripheral distractors, for both constant and changing distractors. That is, the expected increases in latencies for central and peripheral distractors, compared to the no distractor condition should be of a similar order to those reported for these distractor eccentricities by Walker *et al.*, (1997). What is meant here is that the RDE magnitudes from Experiment 5 should be of a similar size as those obtained by Walker *et al.*, (1997). In the previous Experiments under bilateral target presentation conditions, this has not been the case, and bigger RDE magnitudes have been shown for the peripheral distractors, compared to the RDE magnitude for peripheral distractors in Walker *et al.*'s 1997 investigation. Unilateral target presentation in Experiment 5, was therefore expected to result in similar RDE magnitudes to those obtained by Walker *et al.*, (1997).

3. Following the findings from Experiments 1 and 2 it was anticipated that a main effect of constancy would be obtained, with longer saccade onset latencies for changing than for constant distractors. If the overall increase in saccade latencies for changing distractors compared to constant distractors observed in the earlier experiments is an independent effect, then the removal of the decision making component of the task should have no bearing upon this finding.

4. Since saccade onset latencies were longer for central than peripheral distractors in Experiments 1, 2 and 4, a similar main effect was predicted for the current experiment.

5. It was also anticipated that the effects of distractor type found in Experiments 1 and 2 would hold for Experiment 5, and a larger distractor effect should occur for letter string distractors than for uniform shape string distractors.

6. It was not anticipated that there would be any interactive effects in this experiment. The removal of the decision element (as to which side of the display the target will appear at) should result in the same constancy and eccentricity effects for both types of distractor. The results from Experiment 4 showed that the findings for the constant distractors in a unilateral presentation task were the same as would be predicted on the basis of *Walker et al.*'s (1997) findings. Therefore it was anticipated that the constant distractors would behave in the same way as the changing distractors in this experiment, and that the differences observed for the eccentricity variable manipulations in this experiment would be the same for both constant and changing distractors irrespective of whether these distractors are linguistic or non-linguistic. Consequently, in the current experiment it is anticipated that the effect of eccentricity will not be modulated by constancy, and we do not expect to observe a greater difference between changing central and peripheral distractor strings compared to constant central and peripheral distractor strings.

5.3: Method

5.3.1: Participants

16 members of the University of Durham community participated in the experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were paid to participate and all were naïve in relation to the purpose of the experiment.

5.3.2: Materials

The same materials as those used in Experiment 2 were used for this experiment. See Appendix B for a full list of materials.

5.3.3: Design

The design was within subjects with three independent variables; Constancy (2 levels; changing distractor or constant distractor), Eccentricity (2 levels; central distractor or peripheral distractor) and Distractor type (2 levels; uniform letter string or uniform shape string). The dependent variables were eye movement onset latencies and directional errors. Each display contained a target cross (+) which could appear by itself or simultaneous with a distractor. In Block A distractors comprised 25 different uniform letter strings and 1 constant shape string (uniform shape string from Experiment 1 (□□□□)) and the target always appeared on the right of the display. In Block B distractors were 25 different uniform shape strings and 1 constant letter string (**HHHH**) which was randomly selected from the set of uniform letter strings used in Experiment 1 and the target always appeared on the right of the screen. In block C the constant distractor was the uniform shape string (□□□□) and the changing distractor consisted of a set of 25 uniform letter strings, and the target appeared on the left. In block D the constant distractor consisted of one uniform letter string (**HHHH**) and the changing distractor consisted of a set of 25 uniform shape strings, and the target appeared on the left. Order of Block was counterbalanced across participants who were informed of the location of the target (right or left of the display) prior to recording each block of trials. Each participant completed two blocks of 200 trials. Four participants were presented with Block A followed by Block D. Four participants were presented with Block B followed by Block C. Four participants were presented with Block D followed by Block A and four participants were presented with Block C followed by Block B. As in Experiment 4, for the no distractor condition the target could appear at either 4 degrees or 8 degrees. This manipulation was introduced to try to minimise the number of expected anticipatory saccades that might arise as a result of informing the participants as to the side of the display the target would appear (Wenban-Smith & Findlay, 1991. See Appendix B for a full list of the materials. Distractors were either at the centre of the display, or at an eccentric location 8 degrees to the right or left of the midline of the display. The target appeared at an eccentric location 8 degrees to the right or left of the midline of the display when presented with a distractor, or at either 4 degrees or 8 degrees when presented on its own.

5.3.4: Procedure

Participants performed a calibration procedure in which they had to sequentially fixate nine dots in a square array. The results of the calibration procedure were checked online prior to running the experimental trials. Successful calibration recording was followed by presentation of two experimental blocks of trials (200 trials in each block). Breaks were taken on request of individual participants. Eye movement recording, sampling, calibration procedure and sequence of presentation for each trial was the same as in the previous Experiments, as was the task. Participants were instructed to move their eyes to the target cross, which could appear either on the left or the right of the display, and ignore any other stimuli that might appear simultaneously with the target. The sequence of presentation, was, central fixation cross (duration 1s), followed by trial (duration 1s), followed by a blank screen, (duration 1s). In this experiment the target was always unidirectional and participants were instructed as to the location of the target prior to recording.

5.4: Results

Any trials in which tracker loss occurred were excluded from the main analyses, as were saccades outside the range of 100ms - 500ms. In total the percentage of trials rejected on this basis was 13%. As in Experiment 4 there were no directional errors but all participants made some anticipatory saccades and these were also excluded from the main analysis of eye movement onset latency. The total percentage of anticipatory saccades (those saccades that were within 1 degree from the central fixation of the display at the initial start of the saccade) was 12%. Table 7 shows the mean eye movement latencies and the standard deviations for each Experimental condition.

Table 7: The mean onset latencies and standard deviations (in parentheses) for each type of distractor at each distractor presentation location.

Type of Distractor

	Changing		Constant	
	Uniform letter strings	Uniform shape strings	Uniform letter strings	Uniform shape strings
Central distractor	222.85 (43.61)	228.88 (39.46)	222.79 (41.14)	217.55 (40.01)
Peripheral distractor	203.69 (47.58)	207.72 (41.48)	199.46 (38.49)	203.33 (45.15)

There was a reliable Remote Distractor Effect (8 paired samples t-tests compared whether each type of distractor at each distractor eccentricity differed from the no distractor condition. All t tests revealed significant effects: All (t's > 2, all p's < .05), with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present (No distractor mean saccade onset latency = 189.63ms). The results are consistent with the prediction that all distractors would produce longer eye movement latencies compared to the control condition where no distractor was presented with the target. This supports the first prediction of a difference for the single target condition compared to the distractor present with target conditions. Additionally, the magnitude of the RDE for central distractors (33.4ms) was in line with that obtained for Walker *et al.'s* (1997) findings, as was the magnitude of the RDE for peripheral distractors (13.9 ms). Thus these results are similar to those obtained for Experiment 4 and further demonstrate that when the extra decision process of having to either discriminate between the target and the distractor, or, having to make a choice, between two potentially competing targets, is removed then the findings are similar to those of Walker *et al.,* (1997) for the different distractor eccentricities in this study.

A repeated measures ANOVA was conducted on the correct eye movement latencies with Constancy (changing and constant), Distractor Type (uniform letter string and uniform shape string) and Eccentricity (central and peripheral) as within subject variables. In line with prediction 3, a main effect was observed for Constancy (F (1,15) = 13.86, $p < .001$) with changing distractors producing longer saccade onset latencies (mean = 216ms) compared to constant (mean = 211ms) distractors. This result provides further support for what will, from here on in, be termed the 'constancy effect'. This constancy effect has now been observed in three Experiments, Experiments 1, 2 and also in Experiment 5.

There was also a highly reliable main effect for Eccentricity (F (1, 15) = 55.56, $p < .0001$) with central distractors (mean = 223ms) producing longer saccade onset latencies compared to peripheral (mean = 204ms). This supports the fourth prediction of central distractors producing prolonged saccade latencies compared to peripheral distractors and also supports the Walker *et al.,* (1997) findings.

It was also anticipated that the effects of Distractor Type found in Experiment 2 would hold for Experiment 5, and a larger distractor effect should occur for letter string distractors than for uniform shape string distractors. There was however no main effect for Distractor Type (F (1,15) = 2.37, $p > .1$) in this Experiment, which suggests that in a pre-specified unilateral target presentation task, both types of distractor, linguistic and non-linguistic, produced the same effects.

Furthermore, as predicted, there were no interactions between any of the variables, all F's < 1. In a unilateral target presentation task the modulation of the RDE for constant versus changing distractors is independent from the modulation of the RDE for central versus peripheral distractors.

5.5: Discussion

The first two predictions for Experiment 5 were upheld. As was the case for all previous experiments there was a difference between the no-distractor condition and all conditions where a distractor was presented. The effect of presenting a distractor produced prolonged saccade onset latencies compared to the single target condition. Additionally, when the task was a unilateral target presentation task there was a bigger effect upon the magnitude of the RDE for central versus peripheral distractors. This supports Walker *et al.*'s (1997) findings and provides support for Findlay and Walker's (1999) account of the RDE effects with reference to their framework for saccade generation. Specifically, in this type of task where the location of the target is pre-specified, at least in terms of which side of the display it will be presented to, then the resulting RDE for both central and peripheral distractors may be influenced only by the competitive inhibitory effects in the fixate/move centre of the eye movement control system. Both Experiments 4 and 5 have produced the expected (on the basis of Walker *et al.'s* 1997 studies) magnitude for the RDE at both the distractor eccentricities. It would seem reasonable therefore to conclude, at least tentatively, that in order to obtain a similar RDE effect to that shown by Walker *et al.*, (1997) it is necessary to remove the decision element of the task. However, although the removal of the decision element produces what would be expected for central and peripheral distractors in terms of RDE magnitudes, there must be additional factors responsible for the discrepancy between the findings reported here for bilateral target presentation, since Walker *et al.,* (1995) has also shown that there are no differences in the magnitude of the RDE for a condition where participants have to choose between two identical possible targets, and where participants are instructed to always go in one direction.

Recall that, in Experiments 1 & 2 where there was bilateral target presentation, the peripheral distractors produced the biggest discrepancy between the distractor versus the no distractor condition, compared to Walker *et al.*'s (1997) findings and this was given additional support in Experiment 3 where the peripheral distractors, again showed a bigger discrepancy than the central distractors, when compared to the no distractor condition, and furthermore in that experiment the peripheral distractors produced longer saccade onset latencies than the central distractors. This discrepancy between the size of the RDE for peripheral distractors in Experiments 1, 2 and 3 compared to the RDE shown by Walker *et al.,* (1997) disappears when a unilateral target presentation task is employed. This has now been shown in Experiments 4 and 5 and as such provides further evidence for differential effects upon the saccade generation system when prior knowledge of the target location is made available, and when no discrimination process is required to differentiate the target from the distractor. It is puzzling that the early study of Walker *et al.,* (1995) found no differences between RDE effects for bilateral and unilateral target presentation. Although no discrimination between target and distractor had to be made in that investigation for the bilateral target presentation, participants still had to decide which of the two possible targets to saccade to in the bilateral condition, whereas in the unilateral condition they were told in advance which of the two targets to saccade to. An increase in saccade latencies was observed for these conditions, compared to the single target condition, but there was no difference between the increase shown for saccade latencies for these two conditions. It appears therefore that the decision process (between the two possible targets) in that study had no effect, since the removal of a choice between two identical targets produced equivalent saccades to the condition where there was no choice between the two (when participants were told to always go to the target on the left or the right). There were no central distractors in Walker *et al's* (1995) study and so a comparison of the effects of central versus peripheral distractors could not be made for the bilateral and the unilateral target presentation conditions. In a unilateral target presentation task there is a systematic effect upon the magnitude of the RDE. Central distractors produce the biggest effect and there is a linear decline as the distractor is moved into the periphery. In a bilateral target presentation task this is not always the case, at least for the Experiments reported in this thesis.

In the Experiments reported here the target and the distractor differed from each other on a number of parameters. Although there was a decision element in selecting which side of the display to saccade to in the bilateral condition, it is unlikely that this was the cause of the observed differences between the bilateral target presentation since the removal of the decision element has been shown to have no effect in at least one investigation (Walker *et al.,* 1995). It is more likely that the critical difference was not the introduction of a where (is the target?) decision in the bilateral target presentation conditions, so much as the introduction of a perceptual discrimination to be made preceding this decision.

Experiment 5 looked at the effects of the same three variables manipulated in Experiment 2 (Distractor Eccentricity, Distractor Constancy and Distractor Type), but in Experiment 5 the target could only appear at a single pre-specified location (either always on the right of the midline of the display in a block of trials, or always on the left of the midline of the display in a block of trials). The results showed a main effect for eccentricity with central distractors having a greater effect upon saccade onset latencies than peripheral distractors, and this finding was obtained for both changing and constant distractors. A main effect of constancy was also found, with changing distractors having a greater effect than constant distractors overall. There was no main effect of distractor type and no interactions for any of the variables were obtained. The predicted increase in the magnitude of the Remote Distractor Effect for central versus peripheral distractors (from Walker *et al*'s., 1997 studies) was upheld, regardless of whether the distractor was changing or constant, or whether it was a uniform letter string or a uniform shape string.

In a unilateral target presentation therefore, it doesn't appear to matter whether the letter strings are constant or changing, differences will be obtained between central versus peripheral presentation conditions for both constant and changing distractors, with central presentation resulting in a greater increase in the magnitude of the RDE than peripheral presentation. Furthermore, no interactions between the three variables were observed for unilateral presentation of the distractor. To put it simply, distractors at central presentation have a bigger effect than at peripheral presentation, on eye movement latencies, and changing distractors have a bigger effect than constant distractors, and these effects are independent from each other in a unilateral presentation task. In a bilateral presentation task they are not.

Overall the results so far show that the magnitude of the RDE can be modulated by a number of variables. In particular, unpredictable distractors (changing) have a greater effect upon the magnitude of the RDE than predictable distractors (constant) in a bilateral target presentation task. Furthermore, in a bilateral target task differences in saccade latencies are also observed for the type of distractor. Letter string distractors have a greater effect than shape string distractors. Conversely, in a unilateral target presentation task, these differences are not observed, and in this situation constant distractors also show the expected difference of an increase in the magnitude of the RDE for central versus peripheral presentation. There is no interaction between constancy and eccentricity in a unilateral target presentation condition because the effects of both variables are independent from each other. Since the same stimuli were used for Experiments 2 and 5, the only factor that could have produced the differential effects between the two Experiments was that of bilateral versus unilateral target presentation.

It has been shown therefore, that under certain conditions it is possible to modulate the Remote Distractor Effect. Furthermore, under some circumstances one can produce an effect which is the opposite of what would be predicted from the original Remote Distractor Effect findings. In this case it may be feasible to assert that the role of the distractor acts more like a competitive target. When attention is already allocated to the side of the display at which the target will be presented, the presentation of the central distractors has an equally disruptive effect for each type of distractor, whether they are changing or constant and whether they are letter strings or shape strings. Additionally, and possibly also a result of pre-allocation of attention to one side of the display, there are no directional errors to the peripheral distractors in a unilateral target presentation condition, and so the oculomotor capture for the peripheral distractors in bilateral target presentation conditions is absent. Unilateral target presentation also has the effect of reducing the effects of the peripheral distractors upon the magnitude of the RDE. In a bilateral task the peripheral distractors produce a much greater RDE magnitude than would be predicted from Walker *et al.'s* (1997) study. In a unilateral presentation task the RDE magnitude for peripheral distractors is in line with the Walker *et al.*, (1997) finding.

Stripping out the discrimination element of the task in Experiment 5 has resulted in (a) a replication of the RDE magnitudes for central and peripheral distractors (predicted on the basis of Walker *et al.*, 1997), (b) equivalent saccade onset latencies for the different types of distractor (linguistic versus non-linguistic) and (c) a replication of the constancy effect observed in Experiments 1 and 2 (constant distractors produce decreased saccade onset latencies compared to changing distractors). Thus any further investigation of possible differential effects between different types of distractor at different eccentricities will, logically need to adopt a bilateral target presentation, since it is only under this condition that distractor type differences for constant and changing distractors are observed.

One consistent and apparent robust finding from the Experiments reported has shown that changing distractors have a greater disruptive effect than constant distractors on eye movement onset latencies. This finding has been obtained under both unilateral and bilateral target presentation tasks. The next experiment was designed to investigate whether the constancy effect would hold if the changing and the constant distractors were from the same category. It is possible that the constancy effects observed so far have resulted from the presentation of constant distractors from one category set amidst changing distractors from another category. To date if a changing distractor has been a letter string then the constant distractor has been a shape string and vice versa. This categorical difference between the constant and the changing distractors could be responsible for differences in saccade latencies for the constant and changing distractors in the bilateral presentation tasks. It is therefore interesting to see if the constancy effect will hold when constant and changing distractors from the same category are presented together.

Recall also, that an initial aim at the outset of these experiments was to see if linguistic variables had a modulating effect upon the magnitude of the RDE. It was anticipated that by adopting the RDE paradigm to investigate the effects on oculomotor behaviour for complex distractors, that differential effects for the different types of linguistic string distractors would be observed. The results from Experiment 1 suggested that there may be differences between linguistic and non-linguistic variables, but showed no differential effects for the different types of linguistic strings. The design of the next Experiment will permit a further investigation of whether there are any differential linguistic effects upon saccade latencies. Since the modulation of the RDE has shown itself to be sensitive to task demands and can be influenced by predictability of the distractor it seems reasonable to suggest that manipulation of the predictability of the type of linguistic string distractors could elicit subtle effects between the different types of string used.

In order to look at the constancy effect for within category changing and constant distractors it will be necessary to present the different types of linguistic and non-linguistic distractors in separate blocks. This therefore also allows further investigation of possible different effects between the different types of string, or at the very least, enables the conclusion to be made that there aren't any.

It was noted in the discussion of the findings from Experiment 1, that one reason for the lack of any differences between the different types of string could have been that at central presentation the findings for the linguistic distractors resulted from a ceiling effect (i.e. all types of string had the same effect). Although it was expected that any differences between the different types of linguistic distractors would be revealed at central presentation of these distractors, it is possible that at this eccentricity the time taken to discontinue processing the task irrelevant string, and move the eye to the target, was the same for all types of string. An additional distractor eccentricity will be introduced to test the ceiling hypothesis that was put forward to account for the lack of observed differences between the different types of linguistic distractors at central presentation in Experiment 1.

Unilateral target presentation does not permit the investigation of distractor type differences, since none are observed between linguistic and non-linguistic distractors in a unilateral target presentation. Therefore bilateral target presentation will be used for Experiment 6.

Chapter 6

The 'Constancy Effect' revisited. Will within category constant and changing distractors still produce it?

6.1: Experiment 6

A constancy effect, whereby changing distractors produce significantly longer saccade onset latencies, compared to constant distractors, has been consistently found throughout this set of Experiments. Moreover, any modulatory effects of distractor eccentricity on the RDE have themselves been influenced by whether distractors were changing or constant. Furthermore, the preceding Experiments have shown that the constancy effect can be influenced by task type (unilateral or bilateral presentation of the target) and by presentation type (constant distractor on its own or embedded in a set of changing distractors). What has not yet been investigated, however, is whether the constancy effect will hold for constant distractors which are embedded in a set of changing distractors where both constant and changing distractors fall within the same category. That is, to date the constancy effects from the Experiments reported have all resulted from either presenting a constant distractor on its own (Experiments 3 & 4) or a constant distractor embedded in a set of changing distractors which have belonged to a different category from the constant distractor (Experiments 1,2 & 5, shape strings versus linguistic strings). It is important, therefore, to investigate whether the constancy effect will be upheld if constant distractors are embedded with changing distractors of the same category and this will be explored in the next Experiment. This is to ensure that the differential Remote Distractor Effects found so far in these Experiments are not specific to cross category differences between the changing and the constant distractors.

The distractors in this next experiment will therefore be separated into discrete categories, and within each category, presentation of changing and constant distractors will occur. Any evidence of a constancy effect for this manipulation will provide additional support for the reported findings of a decrease in processing time for material that becomes familiar to participants during the course of the experiment.

The design of the next experiment will also afford an opportunity to further address one of the original aims of this thesis, which was to examine whether different types of linguistic string can modulate the Remote Distractor Effect. In Experiment 1 the prediction of a differential effect for the different types of linguistic distractors was not obtained. However it should be noted that in Experiment 1 all types of letter string were presented randomly together during the five blocks of trials. Although there was a systematic effect for all types of letter string distractor (between central and peripheral presentation of these), no differences were observed between the different types of letter string. In the introduction to Experiment 1 an explanation as to why differences might be expected for the different types of string was put forward, and in the discussion to Experiment 1 it was stated that one of the reasons for not obtaining any differential effects between the different types of letter string could have been caused by presenting all types of letter string together. The adoption of the design for this Experiment 6, which is similar to that of a blocked design, may increase the chances of observing any differences that may exist between the different types of linguistic string distractors.

Therefore in Experiment 6, for each block of trials, participants were presented with a constant category of linguistic string (chosen from some or all of those used in Experiment 1; words, legal non-words, illegal non-words and uniform letter strings), which contained changing items within that category and included the presentation of one constant item within that category. For example the word 'TALK' could be presented as the constant distractor at central and peripheral locations for the string category of words, with different words presented at central and peripheral locations for the changing distractors for the string category of words. In order to ensure that the number of conditions in Experiment 6 remained manageable, the different types of distractor were separated into the following categories; words, orthographically illegal strings and shape strings (e.g. **'TALK'**, **'PVTK'** '□◇○△'). This allowed an examination of whether the constancy effect would be upheld when the constant distractor was embedded in a set of changing distractors of the same category and also allowed an investigation of any differential effects for the linguistic variables under different conditions than those adopted for Experiment 1. The reason for choosing words and orthographically illegal non-words for this experiment was that these two types of linguistic string differ most from each other in terms of their linguistic status (i.e. how word like a string is). This choice therefore optimised the possibility of obtaining linguistic modulation of the RDE.

Also in this experiment, as in Experiment 1, a shape string distractor was employed but in Experiment 6 each shape string was made up of four different shapes (in the same way that each linguistic string was made up of four different letters). This was to ensure that all the (linguistic and shape) distractors were equal, at least in terms of their visual saliency. While the letter and shape distractors were each made up of four different sub units, it was still predicted that the shape strings would produce saccade onset latencies shorter than those produced by the linguistic distractors. This is because the letter strings are symbolic to a degree that the shape strings are not. Specifically, it was anticipated that while participants would automatically attempt to extract linguistic meaning from the letter strings, no such automatic linguistic processing would be possible for the shape strings. Thus, although an attempt was made to make all the distractor types equivalent in terms of their visual saliency, clearly, there still existed a qualitative difference between the shape strings and the letter strings. The inclusion of the shape strings in this Experiment 6 was designed therefore to act as a control to show any differential effects of non-linguistic versus linguistic distractors.

What is important to note here is that the relationship between the changing and constant distractors for Experiment 6 was different to that in the preceding experiments. In the previous experiments a constant letter string (e.g. **AAAA**) was embedded within changing shape strings, and a constant shape string (e.g. □□□□) was embedded within changing letter strings. In particular, in Experiments 2 and 5, the constant and changing stimuli differed with respect to both their category (shape versus letter string) and also their uniformity (four shapes or letters that were the same compared with four that were different). Thus, in the present experiment there were two important differences from the preceding experiments: Firstly, all distractors were made up four different shapes or letters; and secondly, changing and constant distractors were from the same category (e.g. words, orthographically illegal letter strings and shapes). It is important also to note that the visual complexity of the constant distractor was now increased relative to the changing distractors and therefore the difference between the constant and the changing distractors was less in Experiment 6 than in the previous Experiments. That is to say, previously the constant item **AAAA** was presented with changing uniform shape strings and vice versa, whereas in Experiment 6 a constant item in the word category was a word (e.g. **TALK**) as were all the changing items in the word category. The same applied to the other categories of distractor. The design of the Experiment was therefore similar to a blocked design, but differed in that each block also contained one repeated item. The adoption of this particular design would ensure that if a specific type of processing was activated by the presentation of the distractor, then it should remain active throughout the entirety of each block and participants would not have to alternate between any different types of processing that could have occurred for the different types of distractors presented within a block in the previous experiments. It was anticipated that again, this aspect of the design would maximise the possibility of producing differences in performance for the different types of distractor string.

A further manipulation in Experiment 6 was the introduction of an intermediate four degree peripheral distractor location. Although it is the case that at central presentation a distractor has the strongest effect in Walker *et al*'s (1997) studies, the findings from this set of experiments suggest that this may vary for qualitatively different types of distractor and this in turn is related to whether or not a decision component is included in the task. In particular it is possible that the distractor eccentricities in the preceding experiments, either central location, or a peripheral location at 8 degrees may have contributed to the finding of no differential effects being observed between the different types of linguistic strings (Experiment 1). It could be argued that at central presentation all the linguistic string distractors were having the same effect upon saccade onset latencies because at this location the mandatory nature of linguistic processing was such that there would be no detectable cost on the processes associated with computing a saccade that occur in parallel with the word identification processes. The word identification system is such a highly specialised and automatised system that at central eccentricities, it is a trivial task to process letter strings like 'talk' or 'ptvk' so that they may be identified as words or categorised as non-words. By contrast, it is also possible that the eccentric distractor location of 8 degrees in Experiment 1 resulted in the visual degradation of the distractors at this eccentricity to such an extent that the linguistic status of the letter strings was not discriminable and therefore all the different linguistic distractor types had the same influence on the oculomotor system. It is plausible, therefore, that the visual information supplied to the language processing system is so degraded that the word identification mechanism cannot discriminate between the different types of linguistic distractors at this peripheral location. Indeed it was predicted that this would be the case in Experiment 1. Recall that in Experiment 1 the saccade onset latencies at the peripheral distractor location were equivalent for all types of linguistic strings and the non-linguistic distractor.

The introduction of the intermediate four degree peripheral distractor location could produce results for the linguistic distractors, which would not be predicted from Walker *et al.*'s (1997) studies. Namely it was anticipated that a bigger effect of the distractor would occur at this intermediate location for Experiment 6, if as has been suggested in the introduction to this experiment, both floor effects (peripheral presentation) and ceiling effects (central presentation) were operating for the linguistic distractor strings in Experiment1. It was therefore predicted that the inclusion of an intermediate peripheral distractor location would provide an optimal condition whereby any subtle differences in processing for the different types of linguistic distractor would be revealed.

To summarise, in Experiment 6 a design that separated the different type of linguistic string distractors into the discrete categories of 'words', 'orthographically illegal strings', and 'shape strings' was be adopted. Each block of trials contained a constant distractor of the same category of that particular string of equivalent visual salience to determine whether the constancy effect of decreases saccade latencies for constant distractors compared to changing distractors would hold for constant items embedded within a set of changing items from the same category. Presentation of these was at central fixation, and 4 degrees or 8 degrees in the periphery. This manipulation was carried out to determine whether the intermediate eccentricity would produce differential effects for the linguistic distractors. Target presentation was bilateral, since the previous experiments (Experiments 1 & 2 compared with Experiment 5) showed that this manipulation resulted in differential effects for the different distractor types, whereas unilateral target presentation resulted in the same effects for both linguistic and non-linguistic distractors, and for constant and changing distractors.

Finally, since the previous experiments showed that only unilateral target presentation resulted in RDE magnitudes, which were similar to Walker *et al.'s,* (1997) findings then a replication of these was not expected in Experiment 6. The bilateral target presentation experiments in this set of experiments has clearly demonstrated that peripheral distractors act more like competing targets, and either induced directional errors (which are absent in unilateral target presentation conditions) or resulted in an RDE magnitude which was much bigger than that found for peripheral distractors in unilateral target presentation. Therefore, in Experiment 6 the predicted eccentricity effects (Walker *et al.,* 1997) were not expected to occur. What was expected was that there would be differences between the different types of distractor at the different distractor eccentricities, but not necessarily any overall differences for distractor eccentricity.

6.2: Predictions

As in all previous Experiments and in line with the original Walker et al. study, it was predicted that there would be a Remote Distractor Effect for all trials where a distractor was presented simultaneously with a target compared to single target presentation trials.

Also in line with the findings from the experiments reported so far it was predicted that there would be a main effect of Constancy, with changing distractors having a greater overall effect upon eye movement latencies than constant distractors. However, it was also predicted that the constancy effect for this experiment, that is, the difference between saccade onset latencies for changing versus constant distractors, would be weaker than in the previous experiments. The reasons for this prediction were that the relationship between the changing and constant distractors had been manipulated so that both constant and changing distractor now belonged to

the same category. It was anticipated that the constancy effect would be modulated by this manipulation since the difference between the changing and the constant distractors was now decreased on both a visual level and category status level.
A main effect of Distractor Type was predicted. The word distractors should produce the longest saccade onset latencies, followed by the orthographically illegal distractors, followed by the shape string distractors. The reasons for this prediction were put forward in detail in the introduction to this thesis and have been outlined in the introduction to this Experiment. Although no differences were observed between the different types of linguistic distractors in Experiment 1, in that experiment all types of linguistic string were presented together, and it was suggested that a consequence of this was the possible suppression of any differential processing effects between each type of string being revealed.

The findings from Experiments 1, 2 and 5 have shown that the eccentricity effect in a bilateral target presentation task hold for changing but not constant distractors, and furthermore, in a bilateral task where the distractors are all constant, the opposite effect was found, with peripheral distractors having a greater effect on saccade onset latencies than central distractors. It was therefore anticipated that any eccentricity effects observed in Experiment 6 would interact with the other variables manipulated in this experiment. In particular, it was predicted that Eccentricity could interact with both Constancy and Distractor Type.

For the Constancy and Eccentricity interaction the prediction was that there would be a difference between changing and constant distractors at central presentation of the distractors, but no, or a reduced difference between changing and constant distractors at either of the two peripheral distractor locations. This is what was found in the previous bilateral experiments (Experiments 1 & 2).

For the Eccentricity and Distractor Type interaction the prediction was that there would be longer saccade onset latencies for word distractors than orthographically illegal distractors at the peripheral 4 degree location, and equivalent saccade onset latencies when these distractors were presented at the central and the far peripheral (8 degree) distractor locations. On the basis of the finding from the bilateral task in Experiments 1 and 2 an overall prediction could be made that shape distractors would produce shorter saccade latencies than both types of linguistic distractor at all distractor locations.

Finally, a 3-way interaction was expected for Constancy, Eccentricity and Distractor Type. To be clear, it was predicted that onset latencies would be consistently shorter for shape string distractors compared to the linguistic distractors for both changing and constant distractors at all distractor locations. For the linguistic distractors there would be a difference between words and orthographically illegal distractors at the peripheral 4 degree presentation for both changing and constant distractors. No difference was predicted between the word distractors and the orthographically illegal distractors at the central distractor location and at the far peripheral distractor location, for both changing and constant distractors. These differences were predicted to occur regardless of whether the distractor is changing or constant.

6.3: Method

6.3.1: Participants

15 members of the University of Durham community participated in Experiment 6experiment. All of the participants were native English speakers with normal or corrected to normal vision. The participants were paid to take part and all were naive in relation to the purpose of the experiment.

6.3.2: Materials

Stimulus files were prepared using an in house software program and saved as bitmap files. The target was a cross (+) drawn in 4 point plain pen, size 0.8cm. Both target and distractors were black in colour and the background for each display was white. As in Experiment 1 all characters for the linguistic distractor strings were presented in upper case using Microsoft Sans Serif font size 24 point, overall length approximately 3.8cm, subtending 3.3° of visual angle. All distractor strings were four different letters or four different symbols. The symbol strings were comprised of either four shapes or four symbols of a similar size to the letter strings and had no linguistic content. The letter string distractors were either four letter high frequency words or four letter orthographically illegal letter strings. These letter string distractors were taken from the same set of letter string distractors used in Experiment 1. A total of 26 different distractor strings were created for each of the three different types of distractor string (word, illegal non-word and shape). One string from each type was selected randomly to appear as the constant distractor, leaving 25 distractor strings from each type to appear as the changing distractors. The constant distractor for the word distractor condition was (**JUMP**), the constant distractor for the orthographically illegal non-word condition was (**RFMP**), and the constant distractor for the shape condition was the following sequence of symbols (⬡♡□⌘). In total there were 25 changing and 25 constant distractors at each of the three eccentricities with the target positioned at left or right of the display at either 4 degrees eccentricity or 8 degrees eccentricity. In each block of trials there were therefore 400 trials for each condition where a distractor was presented simultaneously with a target and additionally to these there were 100 trials where a target was presented on its own without a distractor (25 times at Left and Right for the two eccentricities of 4 and 8 degrees). This made a total of three blocks of trials (one for each distractor type) each block comprising 500 trials. See appendix C for a full list of the materials used in Experiment 6.

6.3.3: Design

The design of the Experiment was within subjects with three independent variables; Constancy (2 levels; changing distractor or constant distractor), Eccentricity (3 levels; central distractor or peripheral distractor at 4 degrees or peripheral distractor at 8 degrees) and Distractor Type (3 levels; four letter word, four letter orthographically illegal non-word and four symbol shape string). The dependent variables were eye movement onset latencies and error rates. Each display contained a target cross (+) which could appear by itself or simultaneous with a distractor. In condition A distractors comprised 25 different words for the changing condition and 1 word repeated 25 times for the constant condition. In condition B the changing distractors were 25 different orthographically illegal non-words and the constant distractor was an orthographically illegal non-word repeated 25 times. In condition C changing distractors were made up of 25 different shape strings and the constant distractor was a shape string repeated 25 times. Distractors were either at the centre of the display or at an eccentric location either 4 or 8 degrees to the right or left of the midline of the display. The target appeared at an eccentric location either at 4 or 8 degrees to the right or left of the midline of the display. The distance between target and distractor for peripheral distractors was equal, that is, if a peripheral distractor was presented at 4 degrees from the centre of the display, then the target was also presented at 4 degrees from the centre of the display, on the opposite side to the distractor. Order of block was counterbalanced across participants. For each of the three distractor types, both changing (25 different distractors), and constant (the same distractor repeated 25 times), were presented randomly at central fixation with the target on either the left or the right of the midline, at either 4 degrees eccentricity or at 8 degrees eccentricity, and at both peripheral locations (4 degrees and 8 degrees) with the target on the contralateral side of the display at an equal eccentricity to the distractor from the centre of the display.

6.3.4: Procedure

Participants performed a calibration procedure in which they had to fixate nine dots in a square array. This was followed by three blocks of trials (500 trials in each block). Each trial was presented for one second and the task was to ignore any other stimuli on the display and 'Look at the cross' which appeared on all trials, either on its own or with a simultaneously presented distractor. Breaks were taken on request of individual participants and the sequence of trials for each block could be interrupted at any time to re-calibrate the participant. The sequence of presentation, as in all previous experiments was maintained i.e. central fixation cross (duration 1s), followed by trial (duration 1s), followed by a blank screen (duration 1s).

6.4: Results

6.4.1: Data Loss

Data excluded from analyses included Tracker Loss trials (5.3%) and trials where correct saccades to target were initiated either before 100ms or after 500ms (0.4%). Directional errors were also excluded from the final analysis of eye movement onset latency.

6.4.2: Errors

The total percentage of errors was 17.2%. Table 8 shows the mean percentage of errors made for each condition. It should be noted that as in the previous experiments in nearly all cases where a directional error was made, a corrective second saccade to the actual target was also made during the trial presentation.

Table 8: The mean percentage of errors for each type of distractor at each distractor presentation location.

Type of Distractor

	Changing		Constant	
	Peripheral 4 degree eccentricity	Peripheral 8 degree eccentricity	Peripheral 4 degree eccentricity	Peripheral 8 degree eccentricity
Illegal	17.1%	26.1%	18.7%	24.8%
Shape	16.0%	27.0%	21.1%	25.2%
Word	21.3%	33.5%	23.6%	29.2%

As in the previous bilateral target presentation experiments, participants were only able to make an error when the distractor appeared at an eccentric location since when it appeared centrally, the participant was already fixating this position. Although it is theoretically possible that in this situation participants could have made an anti-saccade to the opposite side of the display to the target, this did not happen.

Thus, for the error data a 2 (Constancy) by 2 (Eccentricity) by 3 (Distractor Type) ANOVA was carried out on the mean error rates treating participants as random variables. Analysis of the error data revealed that there was a significant main effect of Eccentricity (F (1, 14) = 19.74, p = .001), with participants making more errors when the distractor was at the 8 degree location (mean = 28%) than when it was at the 4 degree location (mean = 20%). There was no significant effect of Constancy (mean changing = 23%, mean constant = 24%), or Distractor Type (mean illegal = 22%, mean shape = 22% and mean word = 27%), and no interaction between any of the variables, (F*'s* < 2.1). Although the mean percentage of errors was higher for words compared to the other two Distractor Types, this difference was not significant as a main effect of Distractor Type was not obtained.

The main finding for the error analysis shows that more errors were made when the distractor was positioned at the far peripheral location of 8 degrees eccentricity. This finding shows that at this eccentricity participants found it more difficult to make a correct saccade to the target. This was reflected in a greater number of erroneous saccades being made to distractors at this eccentricity. This suggests that the competition between the distractor and the target is greatest when the peripheral distractor is at 8 degrees eccentricity compared to 4 degrees eccentricity, at least in terms of inducing erroneous saccade to the distractor. Directional errors are only found when the task is bilateral (see earlier experimental findings), and the number of errors made seems, at least from this Experiment 6 to be dependent upon how far into the periphery the distractor is. Distractors at 8 degrees eccentric locations have a greater effect upon the number of directional errors made than those at 4 degrees eccentric location.

6.4.3: Main Effects for Saccade Onset Latencies

For the analyses of the saccade onset latencies for correct responses to target stimuli data were available for all conditions. The mean saccade onset latencies and the standard deviations for each condition are shown in Table 9. A 2 (Constancy) by 3 (Eccentricity) by 3 (Distractor Type) ANOVA was performed on the mean saccade onset latencies for correct responses treating participants as random variables.

Table 9: Mean saccade onset latencies (with standard deviations in parentheses) for each Distractor Type, at each Eccentricity for Changing and Constant distractors.

Type of Distractor

	Changing			Constant		
	Central	Peripheral 4	Peripheral 8	Central	Peripheral 4	Peripheral 8
Illegal	207.01 (30.68)	208.37 (28.75)	204.58 (29.97)	205.86 (30.69)	207.87 (26.28	200.55 (26.03)
Shape	202.66 (29.55)	203.15 (28.37)	198.50 (26.75)	200.06 (27.56)	201.69 (24.97)	198.30 (27.13)
Word	209.26 (31.68)	213.53 (29.64)	206.01 (29.48)	205.38 (28.62)	213.10 (29.38)	208.17 (32.25)
Mean	206.31 (30.64)	208.35 (28.92	203.03 (28.73)	203.77 (28.96)	207.55 (26.88)	202.34 (28.47)

There was a highly reliable Remote Distractor Effect (18 paired samples tested whether changing and constant distractors at each eccentricity for each type of distractor differed from the no distractor condition. All t tests revealed significant

effects: All t's > 3.5, all p's < .005), with saccade onset latencies being longer for all conditions where a distractor was present compared with the condition where no distractor was present (No distractor mean saccade onset latency = 182ms).
There was a small but highly reliable main effect of Constancy ($F\,(1,14) = 9.10$, $p < .01$) with saccade onset latencies being longest when distractors were changing (mean = 205.9ms) than when they were constant (mean = 204.6ms). The prediction of a main effect of Constancy was therefore upheld. Furthermore, the prediction that in this the effect would be weaker in Experiment 6 compared to that shown in the previous bilateral presentation experiments incorporating changing and constant distractors, was also upheld (Experiment1 mean difference between changing and constant distractors = 4.4ms, Experiment 2 mean difference between changing and constant distractors = 3.1ms, Experiment 6 mean difference between changing and constant distractors =1.4ms).

No other main effects were obtained (F's < 2.4). Recall that a main effect for Distractor Type was predicted whereby it was anticipated that word distractors would produce the longest saccade onset latencies, followed by the orthographically illegal distractors, followed by the shape string distractors. This was not supported, and it is somewhat surprising since Figure 8, which depicts the Eccentricity and Distractor Type interaction shows a clear pattern of the shape strings producing shorter saccade latencies than the linguistic strings. It is possible that this result is a reflection of a minority of the participants not showing this pattern. The pattern for the Interactions suggests that the difference between the linguistic and the non-linguistic distractors is a reliable one.

6.4.4: Two-way Interactions

There was a reliable interaction between Eccentricity and Distractor Type (F (4,56) = 3.1, $p < .05$). The mean saccade onset latencies for each of the three distractor types at each of the three eccentricities are given in Figure 8. For the Eccentricity and Distractor Type interaction means comparisons were computed to compare differences between the three Distractor Types at each of the three distractor Eccentricities. For central presentation of a distractor there was no difference in saccade onset latencies between words (mean = 207.3ms) and orthographically illegal strings (mean = 206.4ms, F <1). There was however a difference between words and shape strings (t(1,14) = 27.4, $p < .001$), with saccade onsets for words being significantly greater than those for shape strings (mean = 201.4ms). Similarly, the orthographically illegal string also produced significantly longer saccade onset latencies than the shape string (t(1,14) = 19.8, $p < .001$). Thus at central presentation shape strings produced significantly shorter saccade onset latencies than word distractors and orthographically illegal distractors, which in turn both had the same effect. The findings at the central distractor location are therefore entirely in line with the predictions.

For the intermediate peripheral presentation of 4 degrees, there was a difference between saccade onset latencies for words (mean = 213.3ms) and orthographically illegal strings (mean = 208.1ms), (t(1,14) = 20.8, $p < .001$), with words producing significantly longer saccade onset latencies at this presentation location than orthographically illegal strings. There was also a difference between words and shape strings (t(1,14) = 91.5, $p < .001$), with words again producing significantly greater saccade onset latencies than the shape strings (mean = 202.4ms). Similarly, the orthographically illegal strings also produced significantly longer saccade onset latencies than the shape strings ($t(1,14) = 25, p < .001$). Thus when the distractors were presented at the intermediate peripheral location (4 degrees eccentricity), again the shape strings produced significantly shorter saccade onset latencies than both the word distractors and the orthographically illegal distractors. However at this location there was a difference also between the words and the orthographically illegal strings. The findings from the peripheral distractor location of 4 degrees eccentricity are therefore, again, in line with the predictions. Shape strings produced significantly shorter saccade onset latencies than both types of linguistic distractor, and, a difference was obtained between the two types of linguistic distractor with words producing longer saccade onset latencies than the orthographically illegal distractors.

For the far peripheral presentation of 8 degrees there was a difference between saccade onset latencies for words (mean = 207.1ms) and orthographically illegal strings (mean = 202.6ms), ($t(1,14) = 15.8, p < .001$), with words producing significantly longer saccade onset latencies at this presentation location than the orthographically illegal strings. This finding was not in line with the predictions. It was expected that there would be no difference between the two types of linguistic distractor at this eccentricity. No effects were obtained between the different types of linguistic distractors in Experiment 1, and none were predicted for that experiment or for Experiment 6, since at this eccentricity of 8 degrees it was thought that the visual degradation of the materials would be such that no discrimination between the two types of linguistic distractor would be made. However, since this two-way interaction between Eccentricity and Distractor Type has shown, even at this eccentricity linguistic distractors appear to have a more disruptive effect upon saccade latency production, compared to non-linguistic distractors.

There was a difference between saccade onset latencies for words and shape strings ($t(1,14) = 58.2, p < .001$), with words again producing significantly longer saccade onset latencies than shape strings (mean = 198.4ms). Similarly, the orthographically illegal strings also produced significantly longer saccade onset latencies than the shape strings ($t(1,14) = 13.4, p < .001$). Thus when distractors are presented at the far peripheral location at 8 degrees eccentricity, again the shape strings produced significantly shorter saccade onset latencies than both the word distractors and the orthographically illegal distractors. This finding is in line with the prediction for this distractor eccentricity. However, at this location there was also a difference between words and orthographically illegal strings, with words producing significantly longer saccade onset latencies than the orthographically illegal strings. This finding was not in line with the predictions, which stated that there would be no difference between the two types of linguistic distractor at this eccentricity.

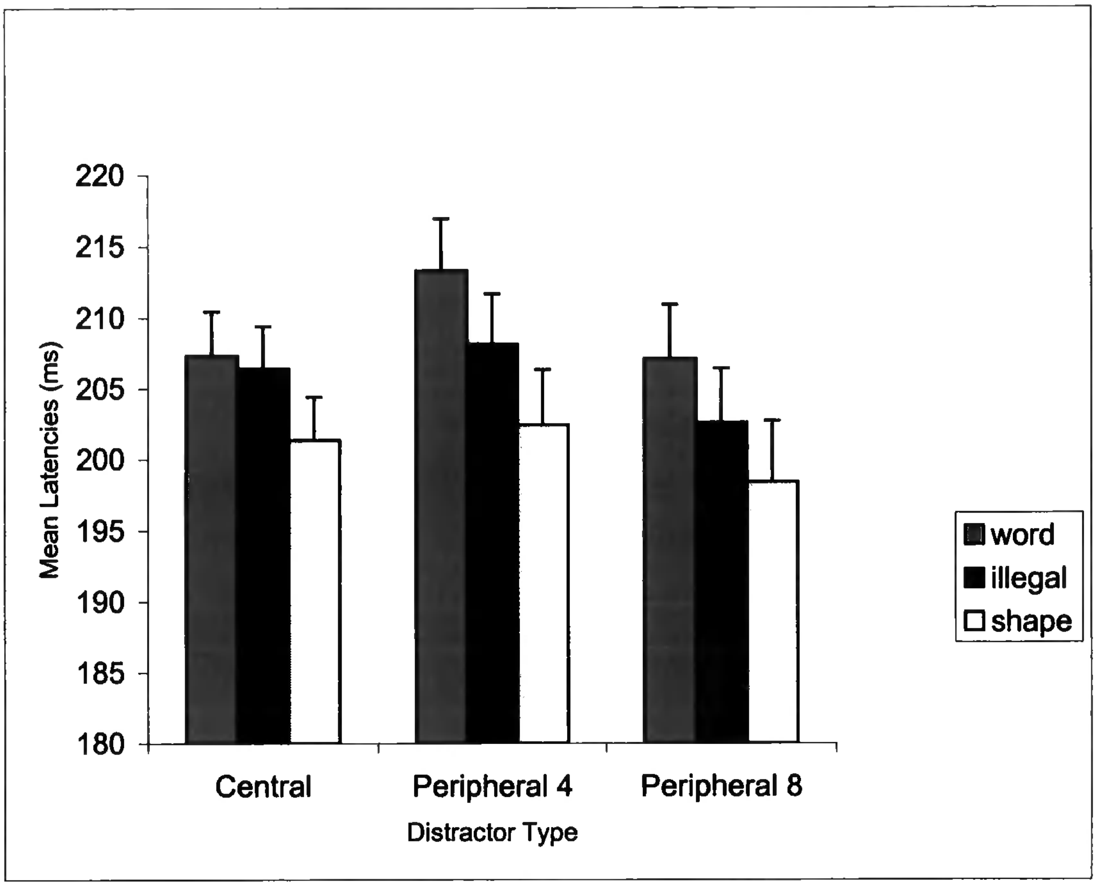


Figure 8: *The mean saccade onset latencies for each of the three DistractorTypes at each of the three Eccentricities in Experiment 6. Error bars denote one standard error from the mean.*

Briefly, to summarise, this two way interaction suggests that linguistic strings produced an overall greater effect upon eye movement onset latencies compared to the non-linguistic shape string distractors, at all of the distractor eccentricities. Furthermore, at central presentation both types of linguistic distractor have the same effect upon saccade onset latencies, but at both of the peripheral presentation locations, words produced longer eye movement latencies than the orthographically illegal distractors. Obtaining such a difference at the 8 degree distractor location was not predicted. Recall that in Experiment 1 there were no differences between the different types of string at both central and peripheral (8 degrees) locations.

However, recall also that in Experiment 1 all the linguistic distractors were changing in that there were no repeated linguistic distractors. By contrast, in Experiment 6, the linguistic distractors in each block of trials are made up of both changing strings (25 different items) and constant distractors (one item repeated 25 times). Clearly, this difference between experiments may have contributed to the difference in effects obtained in Experiments 1 and 6. However, quite why this is the case is not entirely clear.

The prediction of an interaction between Constancy and Eccentricity was surprisingly not supported ($F\,(2,28) = 1.6, p > .1$). It was anticipated that there would be a difference between the changing and the constant distractors at central presentation, but that there would be no differences between the changing and the constant distractors at either of the peripheral distractor locations. This was what was found for Experiments 1 and 2.

No interaction was obtained between Constancy and Distractor Type ($F < 1$), and no prediction was made for this Interaction since it was anticipated that any Constancy effects would be the same for all Distractor Types.

6.4.5: Three-way Interaction

A three-way interaction between Constancy, Eccentricity and Distractor Type ($F\,(4,56) = 3.7, p < .05$) was obtained. For ease of exposition the data corresponding to the three-way interaction are plotted in the bar graph given in Figure 9. Note that this figure also includes the data from the no distractor condition separated by type of distractor used in the block although these data were not included in the ANOVA reported for this experiment. The inclusion of these data within the graph serves to illustrate that they follow the same broad pattern as that shown for the different distractor types, and also shows how they differ from conditions where a distractor is presented simultaneously with a target. A further analyses which takes into account the baseline no distractor measure for each Distractor Type will be reported following the results from the current ANOVA.

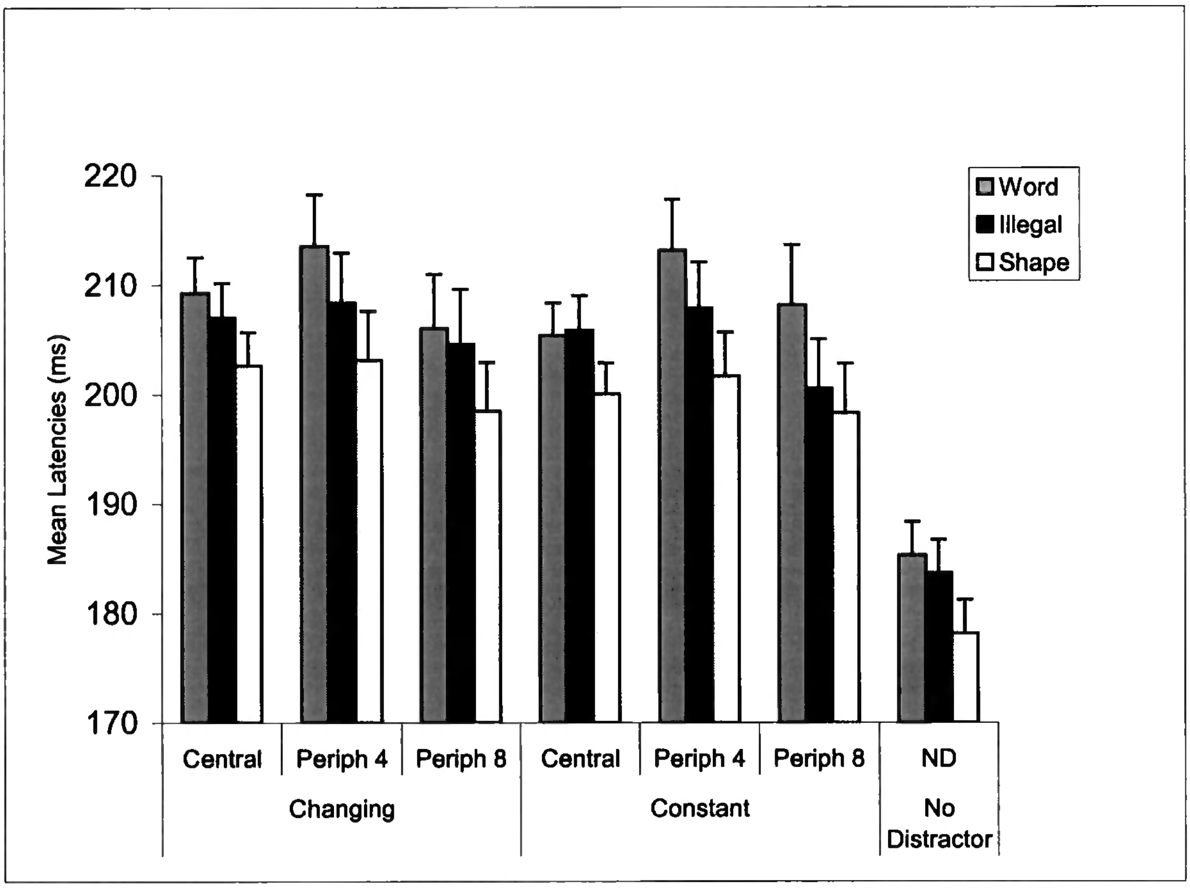


Figure 9: *The mean saccade onset latencies for each of the three Distractor Types, at each of the three Eccentricities, for both Changing and Constant distractors in Experiment 6. Error bars denote one standard error from the mean.*

For the Constancy, Eccentricity and Distractor Type interaction (Figure 8) means comparisons were computed to compare differences between the three Distractor

Types at each of the three distractor Eccentricities for both Changing and Constant distractors.

Changing distractors

For the changing distractors the following was found. For central presentation of a distractor there was no difference between words (mean = 209.3ms) and orthographically illegal strings (mean = 207.0ms), ($t(1,14) = 3.1, p =.08$). There was however a difference between words and shape strings ($t(1,14) = 26.9, p < .001$), with words producing significantly longer saccade onset latencies than shape string distractors (mean = 202.7ms). Similarly, the orthographically illegal strings also produced significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 11.7, p < .001$). Thus at central presentation shape strings produced significantly shorter saccade onset latencies than both word distractors and orthographically illegal distractors, which in turn, both produced equivalent onset latencies at central presentation of the distractor. The findings for each type of distractor at the central location are in line with the predictions.

For changing distractors at the intermediate peripheral presentation of 4 degrees there was a difference between words (mean = 213.5ms) and orthographically illegal strings (mean = 208.3ms; $t(1,14) = 16.4, p < .001$), with words producing significantly longer saccade onset latencies at this presentation location than orthographically illegal strings. There was also a difference between words and shape string distractors ($t(1,14) = 66.5, p < .001$), with words also producing significantly longer saccade onset latencies than shape string distractors (mean = 203.2ms). Similarly, the orthographically illegal strings also produced significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 16.8, p < .001$). Thus when distractors are changing and are presented at the intermediate peripheral location at 4 degrees eccentricity, again the shape string distractors produce significantly shorter saccade onset latencies than both word distractors and orthographically illegal distractors. However at this location there is also a difference between words and orthographically illegal strings, with words producing significantly longer saccade onset latencies. Again, these findings are in line with the predictions for Experiment 6.

For the changing distractors at the far peripheral presentation of 8 degrees there was no difference between words (mean = 206ms) and orthographically illegal strings (mean = 204.6ms) ($t(1,14) = 1.3, p > .05$), with words producing equivalent saccade onset latencies at this presentation as those produced by orthographically illegal strings. There was a difference between words and shape string distractors ($t(1,14) = 34.9, p < .001$), with words producing significantly longer saccade onset latencies than shape string distractors (mean = 198.5ms). Similarly, the orthographically illegal strings produced significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 22.9, p < .001$). Thus when distractors are changing and are presented at the far peripheral location at 8 degrees eccentricity, the shape strings produced significantly shorter saccade onset latencies than both word distractors and orthographically illegal distractors. There was no difference between the two types of linguistic distractor.

To summarise, for the changing distractors, a pattern of saccade latencies was observed which supported entirely the predictions made at the outset of Experiment 6 for the three-way Interaction. Non-linguistic distractors always produced significantly shorter saccade onset latencies than both types of linguistic distractor. The pattern for words and illegal strings showed that there was no difference between these two types of distractor at central presentation of a changing distractor. Words had a greater influence upon saccade latencies than the orthographically illegal distractors at the peripheral 4 degree distractor presentation. At the peripheral location of 8 degrees there was no difference between the saccade onset latencies for the two types of linguistic distractor. Therefore the predictions for the changing condition are entirely upheld.

Constant distractors

For the constant distractors the following was found. For central presentation of a distractor there was no difference between words (mean = 205.4ms) and orthographically illegal strings (mean = 205.9ms), (F <1). There was however a difference between words and shape string distractors ($t(1,14) = 17.5, p < .001$), with words producing significantly longer saccade onset latencies than shape string distractors (mean = 200.1ms). Similarly, the orthographically illegal strings produced significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 20.8, p < .001$). Thus at central presentation constant shape string distractors produced significantly shorter saccade onset latencies than both constant word distractors and constant orthographically illegal distractors, which in turn both produced the same saccade onset latencies of the distractors. These findings support the predictions for this distractor location.

For the intermediate peripheral presentation of 4 degrees there was a difference between words (mean = 213.1ms) and orthographically illegal strings (mean = 207.9ms; $t(1,14) = 17, p < .001$), with words producing significantly longer saccade onset latencies at this distractor location than orthographically illegal strings. There was also a difference between words and shape string distractors ($t(1,14) = 80.5, p < .001$), with words producing significantly longer saccade onset latencies than shape string distractors (mean = 201.7ms). Similarly, the orthographically illegal strings produced significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 23.6, p < .001$). Thus when constant distractors are presented at the intermediate peripheral distractor location of 4 degrees eccentricity, again the shape strings produced significantly shorter saccade onset latencies than both word distractors and orthographically illegal distractors. However at this location there was a difference also between words and orthographically illegal strings, with words producing significantly longer saccade onset latencies. This pattern is also consistent with the predictions for this experiment.

For the far peripheral presentation of 8 degrees there was a difference between words (mean = 208.1ms) and orthographically illegal strings (mean = 200.6ms) ($t(1,14) = 35.9, p < .001$), with constant words producing significantly longer saccade onset latencies at this distractor location than constant orthographically illegal strings. This was inconsistent with the pattern shown for the changing distractors, where no difference was observed between words and orthographically illegal strings at this distractor location. Furthermore, this finding was not in line with the predictions. No such difference was anticipated at this eccentricity. There was a difference in the predicted direction between words and shape string distractors ($t(1,14) = 60.2, p <$

.001), with words producing significantly longer saccade onset latencies than the shape string distractors (mean = 198.3ms), however the orthographically illegal strings did not produce significantly longer saccade onset latencies than the shape string distractors ($t(1,14) = 3.1$ $p = .08$). Again, the lack of difference between illegal letter strings and shape strings in the constant condition at the 8 degree peripheral distractor location was inconsistent with the predictions.

To summarise, for the constant distractors, a pattern of saccade latencies was observed which supported most of the predictions made at the outset of Experiment 6 for the three-way Interaction. In particular, all predictions were met for the central and peripheral 4 degree distractor locations. Non-linguistic distractors produced significantly shorter saccade onset latencies than both types of linguistic distractor at the central and the peripheral 4 degree location. There was no difference between the word strings and the orthographically illegal strings at the central distractor location, and word string distractors produced longer saccade onset latencies compared to the orthographically illegal distractors at the intermediate peripheral distractor location. However, at the 8 degree peripheral distractor location two of the predictions were not upheld for the constant distractors. There was only a marginal ($p = .08$) difference between the orthographically illegal distractor strings and the non-linguistic shape strings (albeit in the right direction). The word string distractors produced significantly longer saccades than the orthographically illegal distractors at this location.

6.4.6: Single Target Trial Latencies

A further aspect of the results that deserves comment is the data for the no distractor conditions shown in Figure 8. The pattern observed for the single target trials shows striking similarity to the overall pattern for the different Distractor Types. Namely, single target trials in the word distractor block (mean = 185.3ms) results in longer saccade latencies compared to the single target trials presented in the orthographically illegal distractor block (mean = 183.6ms), and the single target trials in the orthographically illegal distractor block produce longer saccade latencies than those produced for the single target trials in the shape string block (mean = 178.1ms). Although paired samples t-tests revealed that these differences were not statistically reliable (*t's* <1.5), the overall pattern is still quite compelling and illustrates that the difference occurs even when the distractors are not there. The pattern is indicative of a within block effect that is in some way strategic.

The design of Experiment 6 was such that each of the three different Types of Distractor were separated into individual blocks of trials, and each block included a single target set of trials where no distractor was presented. Consequently RDE magnitudes could be computed for each Distractor Type using the corresponding baseline single target trial latencies for each Distractor Type. . These were calculated on an individual participant basis. Table 10 shows the mean RDE magnitudes (Latency increases compared to the no distractor trials) for each Distractor Type

Table 10: Mean RDE magnitudes (with standard deviations in parentheses) for each Distractor Type.

Type of Distractor

Word	Illegal	Shape
24.1 (13.7)	22.1 (15.0)	22.6 (5.7)

A one way ANOVA for the variable Distractor Type, with three levels corresponding to each Type of Distractor was computed. This revealed no significant differences between any of the three types of distractor on RDE magnitudes ($F < 1$). The previous analyses of the saccade onset latencies revealed that although there was no main effect of Distractor Type, the shape string distractors produced consistently shorter saccade latencies compared to the linguistic distractors. This was not reflected in the RDE magnitude means, from which it can be seen that all Distractor Types are producing equivalent RDE magnitudes.

The analysis of the RDE magnitudes by Distractor Type has shown that the difference observed for saccade onset latencies between the linguistic and the non-linguistic distractors does not apply to the magnitude of the RDE. The RDE analysis takes into account the single target trial latencies for each condition. If there are any differences between the latencies for the single target trials which are systematically related to the Type of Distractor presented in the distractor trials within that block, then in order to say whether one Type of Distractor is having more of a modulating effect on the RDE magnitudes than another, the baseline single target latencies must be taken into account. This experiment was designed so that separate single target trials would be available for analyses, and the analyses of these has revealed importantly that although there may complex cognitive distractor effects upon saccade onset latencies, such effects do not modulate the RDE.

6.4.7: Summary of Results

A main effect of Constancy was found which supported the consistent finding in the preceding Experiments of increased saccade latencies for changing distractors compared to constant distractors. No main effects were observed for Distractor Type or Eccentricity. A main effect for Distractor Type was anticipated and so the lack of a main effect for this prediction was somewhat surprising, particularly given the reliable differences between the non-linguistic distractors and both types of linguistic distractors employed. No interactions between Constancy and Distractor Type were predicted, since the changing and the constant distractors for each Distractor Type were expected to produce a similar pattern of latencies. This was upheld. It was not expected that a main effect would be observed for Eccentricity, but a two-way Interaction between Constancy and Eccentricity was predicted. It was expected that changing distractors would produce significantly longer saccade latencies, compared to constant distractors at central presentation, and that no differences would be observed between changing and constant distractors at the two peripheral distractor locations. This was not supported and the pattern of saccade latencies for the three-way Interaction shows that whilst word distractors and shape distractors do support the prediction, the orthographically illegal distractors do not. There was no difference between changing and constant central orthographically illegal strings, and conversely, there was a difference between changing and constant orthographically illegal strings at the peripheral 8 degree location. Only a *post hoc* explanation can be put forward for this in the discussion for Experiment 6.

The pattern of saccade onset latencies observed in the three way interaction showed that non-linguistic distractors (shape strings), consistently produced shorter saccade onset latencies than linguistic string distractors at all distractor eccentricities, and this was not dependent upon whether the distractors were changing or constant. Thus both types of linguistic distractors had a greater effect upon the time taken to move the eyes to a target, compared to when a non-linguistic distractor was presented. For the changing distractors the predicted pattern of there being no difference between the two types of linguistic string at both central and at the far peripheral distractor location was supported, as was the prediction that words would produce longer saccade onset latencies compared to the illegal strings at the peripheral 4 degree location. For the constant distractors the same pattern was observed between words and orthographically illegal strings at the central and peripheral 4 locations, but in this condition an unexpected difference of words producing longer saccade latencies than the orthographically illegal strings occurred.

The analyses of the RDE magnitudes showed that modulation of the RDE was similar for both linguistic and non-linguistic distractors.

6.4.8: Supplementary Analyses

In Experiment 6 one of the important new manipulations was the introduction of a 4 degree peripheral distractor. In all of the preceding experiments only central and 8 degree peripheral distractor eccentricities were employed. This meant that for the peripheral distractor presentation in the preceding experiments the target could only appear at an equidistant eccentricity on the opposite side of the display, and for the central distractors targets were always 8 degrees to the right or the left of the midline of the display. Targets were therefore always presented at an eccentricity of 8 degrees. A decision therefore had to be made in the design of Experiment 6 as to whether the symmetry of the distractor and target relationship should be maintained for the peripheral distractors, or whether the saccade target length from the previous experiments should be maintained. This latter option would have introduced an asymmetry between distractor and target for the peripheral 4 distractor. A further option would have been to present the peripheral 4 distractor with targets at both 4 degrees and 8 degrees eccentricity, and to present the peripheral 8 degree distractor with targets at both 4 degree and 8 degree eccentricities. In order to keep the number of conditions in Experiment 6 to a manageable level it was decided to maintain the symmetrical relationship between peripheral distractors and targets.

In Experiment 6 therefore, each time a peripheral 4 degree distractor was presented, there was a corresponding 4 degree target on the opposite side of the display. Additionally, as in the preceding experiments, every time a peripheral 8 degree distractor was presented, there was a simultaneous 8 degree target presented on the opposite side of the display. For central presentation of a distractor in Experiment 6, a saccade target could appear at either 4 degrees on the left or the right of the midline, or at 8 degrees on the left or the right of the midline. Saccade targets of 4 degrees and 8 degrees left and right of the midline were also presented for the condition where no distractor was present. The analyses of the data in Experiment 6 collapsed across these two target eccentricities, since there was no reason to believe that saccade target length would influence saccade onset latency. Data in the literature which have been analysed (Findlay, 1983; Kalesnykas & Hallett, 1994), suggests that there are no systematic latency differences with eccentricity.

However the availability of the data from Experiment 6 provided a valuable opportunity to directly examine whether saccade target eccentricity had any systematic effects on eye movement latencies. A valid comparison could be made as to how long it took to program an eye movement to either a 4 degree saccade target, or an 8 degree saccade target, for the central changing and central constant distractors, with targets at 4 degrees and at 8 degrees eccentricity. Additionally the data from the no distractor condition could be separated into conditions where the target appeared at 4 degree and 8 degree eccentricities. Finally the variable of Distractor Type was also included to investigate whether it modulated any saccade magnitude effect. Since the different types of distractor were blocked it was also possible to examine the single target trials separately for each Distractor Type.

Thus, for the saccade target eccentricity data analyses a 3 (Constancy) by 2 (Eccentricity) by 3 (Distractor Type) ANOVA was carried out on the mean saccade onset latencies. In these analyses the 3 conditions in the Constancy variable were changing distractors, constant distractors and a no distractor present condition. For the Eccentricity variable the two conditions were, target at 4 degrees and target at 8 degrees. Data from the three types of distractor (words, orthographically illegal strings and shape strings) were also included. Figure 10 shows the mean latencies for the target eccentricity latencies for each condition.

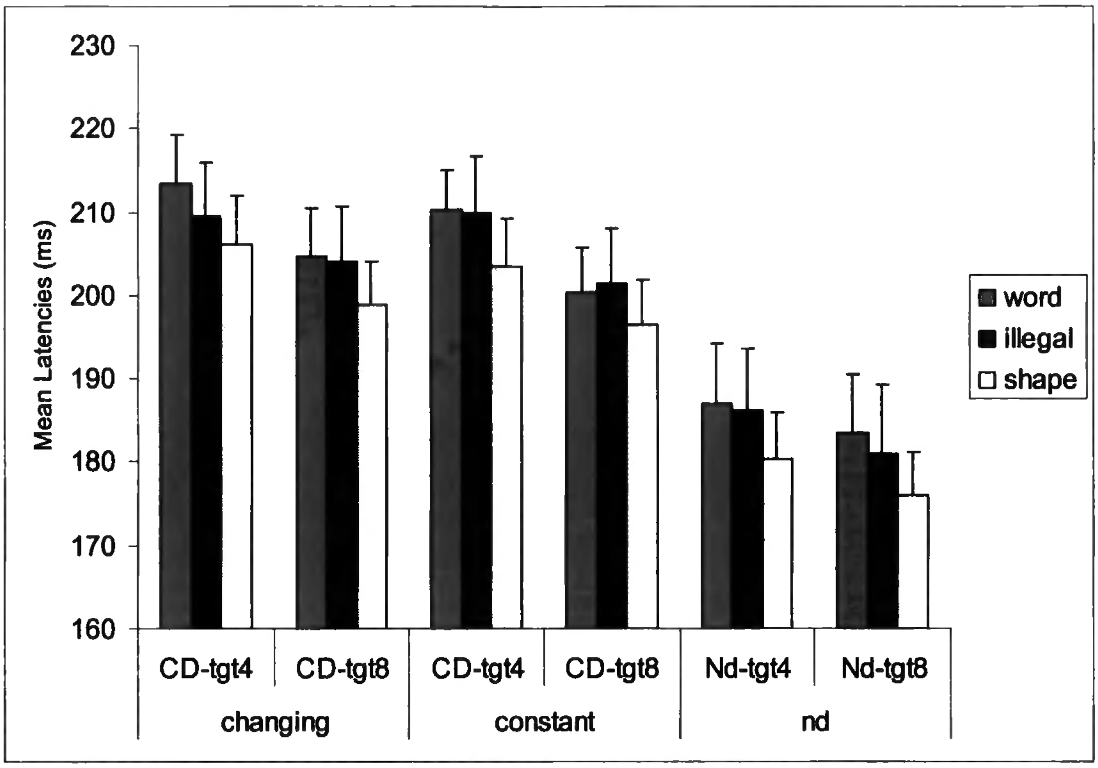


Figure 10: *The mean saccade target onset latencies for central distractors and for the single target condition. Targets were positioned at 4 degrees and at 8 degrees. Data is shown for each of the three Distractor Types at each of the three Eccentricities for both Changing and Constant distractors.*

Analysis of the saccade target eccentricity data revealed that there was a significant main effect of Constancy (F (2, 14) = 28.4, p < .001), with changing distractors producing longer saccade latencies (mean = 206.2ms) compared to constant distractors (mean = 203.7ms) and compared to the no distractor present condition (mean = 182.3ms). This result reflects the same finding obtained in the main analyses conducted for Experiment 6. There was a significant effect of saccade target Eccentricity (F (1, 14) = 11.1, p < .005) with 4 degree target saccades producing significantly longer saccade onset latencies (mean = 200.7ms) than 8 degree target saccades, (mean = 194.1ms). No reliable effects were obtained for Distractor Type (mean word = 199.9ms, mean illegal = 198.7ms and mean shape = 193.6ms), (F <1.1). Furthermore, no interactions were obtained between any of the variables, (F's < 1.7).

The main finding for the saccade target eccentricity analysis shows that shorter saccade latencies are produced when targets are positioned at the far peripheral location of 8 degrees eccentricity, than when they are positioned at the near peripheral location of 4 degrees eccentricity. This holds for all distractor types, and for both changing and constant distractors, and remarkably, even when there is no distractor present.

Means comparisons were performed on the mean saccade onset latencies between the pairs of different saccade target eccentricities for the changing condition, the constant condition, and the no distractor present condition. Paired samples t-tests were carried out to determine whether the effects were reliable for all three conditions. For the changing condition there was a reliable difference between the 4 degree saccade target (mean = 209.7ms) and the 8 degree saccade target (mean = 202.7ms), (t (1, 14) = 3.0, $p < .01$). For the constant condition there was also a reliable difference between the 4 degree saccade target (mean = 207.9ms) and the 8 degree saccade target (mean = 199.5ms), (t (1, 14) = 3.5, $p < .01$). For the no distractor condition there was also a reliable difference between the 4 degree saccade target (mean = 184.4ms) and the 8 degree saccade target (mean = 180.1ms), (t (1, 14) = 2.3, $p < .05$). These results formally confirm what can be seen from figure 10. There is a consistent pattern of longer saccade latencies to a 4 degree target compared to an 8 degree target when there is either a central changing or a central constant distractor, and, a smaller but statistically reliable finding between the two is observed when no distractor is present with the target.

The findings from these supplementary analyses raise a number of questions, not least of these may be, Why does it take longer to make an eye movement to a 4 degree target than an 8 degree target, both when a single target is presented, and when a distractor is presented simultaneous with a target? One possible explanation is that the 4 degree target may be having an effect upon the fixation zone. Recall that it was suggested by Walker *et al.,* (1997) that distractors closer to the fovea have more of an influence on saccade latencies because of increased activity in the fixation zone of the superior colliculus. It could therefore be argued that this effect also applies to the eccentricity of targets. There is some published evidence in the reading literature (Rayner, 1978) which also shows that it takes longer to make a shorter saccade than a longer saccade in a word naming condition (words were presented at 1, 3 or 5 degrees eccentricity).

In light of the finding, from these supplementary analyses, that saccade target eccentricity independently influences saccade onset latencies, the data for Experiment 6 were plotted again, separating the central distractor data into a 4 degree target presentation and an 8 degree target presentation. Figure 11 shows the means for each condition. The primary concern here is whether these supplementary analyses have anything further to contribute to the interpretation of the results for Experiment 6.

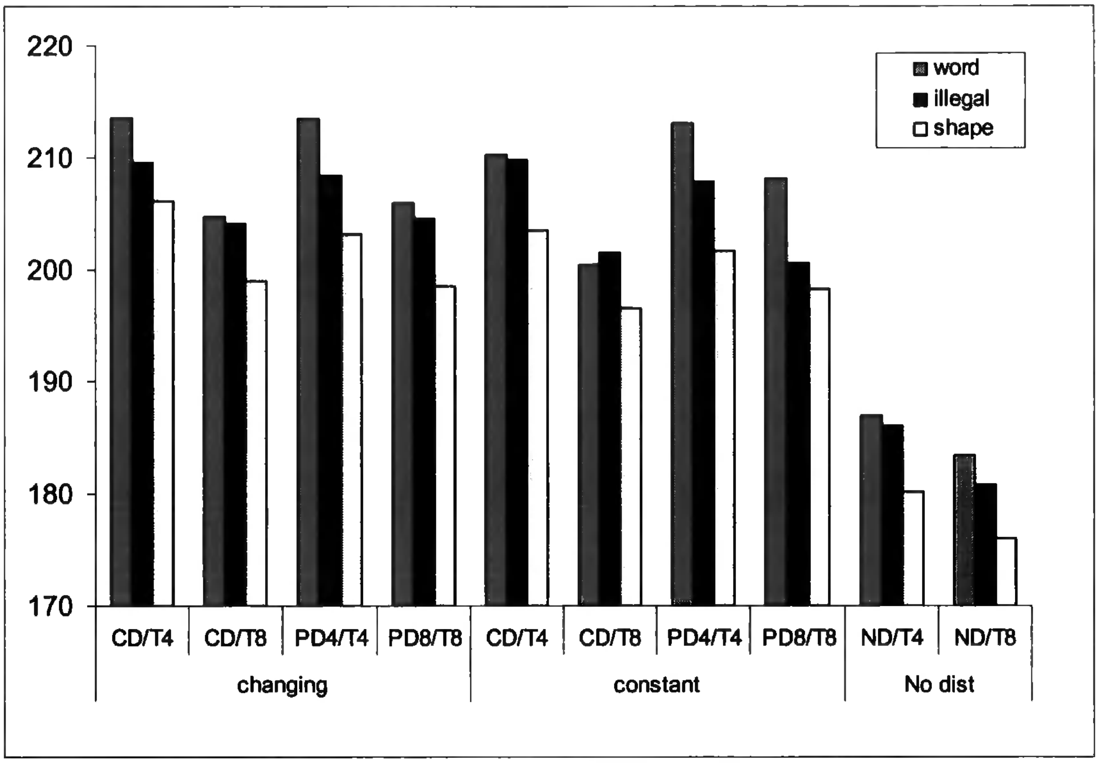


Figure 11: *The mean saccade onset latencies separated by saccade target eccentricity for each of the three Distractor Types at each of the three Eccentricities for both Changing and Constant distractors in Experiment 6.*

The most important thing to say about the figure is that the separation of the onset latencies for the central distractor presentation show clearly the difference between the 4 degree targets and the 8 degree targets, for this distractor position, for both the changing and the constant distractors conditions and also for the no distractor condition. The pattern overall however, remains the same as that shown in Figure 9 for Experiment 6. Shape strings produced consistently shorter saccade onset latencies than the linguistic distractors. These differences though are now only reliable for words versus shapes for both changing ($t\ (1, 14) = 2.0, p < .05$) and constant ($t\ (1, 14) = 1.7, p < .05$) distractors when a central distractor is presented with a 4 degree target.

No differences are observed for words versus shapes for both changing, (t <1.3, p > .1) and constant distractors, (t < 1, p > .2) when a central distractor is presented with an 8 degree target. There are no differences between orthographically illegal distractors and shape string distractors when a central distractor is presented with either a 4 degree target or an 8 degree target, irrespective of whether the distractors are changing or constant, in all cases (t's <1.4). What should be noted here is that the data in Figure 12 clearly pattern in the same way as the data in the main analyses of Experiment 6. The fact that no reliable differences are found for some of the comparisons for the shape strings versus the linguistic strings in this analyses is likely to be a result of a reduction in the power available for the statistical test.

The comparisons between the linguistic distractors showed the same result as the main analyses for Experiment 6 for central presentation of the distractors, irrespective of whether these were presented with a 4 degree target or an 8 degree target. There was no difference between word strings and orthographically illegal strings at central presentation for both the changing and the constant conditions. In all cases (t's <1.1). The separation of the data into discrete saccade target eccentricities for the central distractors has not radically altered the pattern of data obtained in the original analyses and it therefore seems reasonable to conclude that the effects discussed previously are being driven by the intended manipulations rather than saccade target eccentricities.

6.5: Discussion

A clear set of predictions was made for the outcome of this Experiment. These were based on the findings from the preceding experiments. Many of the predictions were supported and detailed analyses of the data provided interesting insights into how complex distractors can have differential effects upon saccade onset latencies and RDE magnitudes. There were also new and surprising findings showing that type of distractor produced systematic effects upon saccade onset latencies for single target trials. This discussion will focus firstly on the findings that supported the predictions. Explanations as to why some predictions were not supported will be offered and a final comment will be made concerning the supplementary analyses for Experiment 6.

A main effect of Constancy was found which supported the consistent finding in the preceding Experiments of increased saccade latencies for changing distractors compared to constant distractors. One of the aims of this experiment was to see if the constancy effect which has been consistently found throughout the experiments reported so far, would hold if the changing and constant distractors belonged to the same category of distractor. This was supported and a small but highly reliable effect of constancy indicated that constant distractors produced shorter saccade onset latencies than changing distractors, even in a situation where the changing and the constant distractors were from the same category.

As was predicted, the constancy effect was weaker than in the previous experiments and this was possibly caused by presenting the constant distractor amidst a set of changing distractors that were all of the same category type. Thus when the relationship of the constant and the changing distractors was altered such that the difference between the two was minimised on a categorical level, the result still held. This finding is particularly important since it confirms that the constancy effect is not specific to cross category distractor presentation. What the findings show is that the constancy effect can be modulated by systematically manipulating the category status of the changing and the constant distractors. What can now be concluded with regard to the constancy effect is that it is a robust emergent property that results from one stimulus type achieving the status of familiarity during the course of its presentation within a brief experimental session, and this has been observed both in Experiment 6 and in the previous experiments.

A further aim of the experiment was to see if the introduction of an intermediate location peripheral distractor would yield results for the different types of linguistic distractors, which were different from those found for the central distractor location and the far peripheral distractor location of 8 degrees. An interaction between Eccentricity and Distractor Type was predicted, and was obtained. This interaction showed three things. Shape strings produced the shortest saccade onset latencies compared to the linguistic strings at all eccentricities. There was no difference between words and orthographically illegal strings at central presentation but words produced longer saccade latencies compared to the illegal strings at the peripheral 4 degree location and the peripheral 8 degree distractor locations. The difference at the 8 degree distractor location was not predicted and the findings for the two-way interaction were qualified by a three-way interaction between Constancy, Eccentricity and Distractor Type.

There were plausible theoretical grounds for expecting that there would be differences between words and the orthographically illegal strings at the 4 degree distractor location, but based on the results of the earlier experiments, no differences were expected at central presentation or at the far peripheral presentation location of 8 degrees. As was suggested in the introduction to Experiment 6, the presentation of any type of linguistic string at central fixation location will initiate processing of that string to the extent that all types of string will have the same effect upon saccade latencies. The finding at central presentation of no difference between words and orthographically illegal strings for both changing and constant distractors supports that position. It was also suggested that at an intermediate location of 4 degrees the possibility of observing any differences between the different types of linguistic strings would be increased, since at this eccentricity, some control over the processing of that string, either an ability to quickly or not so quickly discontinue processing (dependent upon the type of string), would enable any differences between the different types of linguistic string to become apparent. The finding that words produced longer saccade onset latencies compared to illegal non-words at this eccentricity for both changing and constant distractors therefore supports the view that words are processed in a qualitatively different way to illegal strings, at this eccentricity.

However, the findings for the far peripheral presentation of 8 degrees are inconsistent with the proposed theoretical standpoint. What was predicted for this location was that there would be no difference between any of the types of linguistic strings, because at this eccentricity all types of linguistic string would be visually degraded to the same extent, making it almost impossible to discriminate between any of them. The findings in Experiment 6 for the changing condition supports this, in that there were no differences between the different types of linguistic strings, but the finding for the constant condition does not. Here a difference between words and illegal strings was observed, with words having a greater effect than the illegal strings at both peripheral distractor positions.

It is not clear why constant words produced increased saccade onset latencies compared to constant orthographically illegal non-word distractors. It is unlikely that this finding reflects a real difference between the two distractor types at this eccentricity, since this would not be supported either by the findings for the 8 degree peripheral distractors in the previous experiments, nor would it be predicted by any theoretical assumption for this eccentricity. There is though the possibility that chance design factors could have produced this result. It could be that the constant word (JUMP) had attributes that made it more salient at the far peripheral distractor location, than would have been predicted. No items analyses were conducted since each block contained both constant and changing items, therefore this possibility cannot categorically be ruled out.

A further observation from the Constancy, Eccentricity and Distractor Type interaction was that the non-linguistic strings showed consistently shorter saccade onset latencies than all the linguistic strings at all the presentation locations. This suggests that the linguistic remote distractors employed in this experiment had a greater disruptive effect upon saccade onset latencies. Recall that the inclusion of the shape strings in this Experiment 6 was designed to act as a control to show any differential effects of non-linguistic versus linguistic distractors. Such effects have been observed in the previous experiments. The adoption of the blocked design in Experiment 6 was to try to ensure that if a specific type of processing was activated by the presentation of the distractor, then it should remain active throughout the entirety of each block and participants would not have to alternate between any different types of processing that could have occurred for the different types of distractors presented within a block in the previous experiments.

There was however, no main effect of Distractor Type in this experiment. This is somewhat surprising given the reliable differences between the non-linguistic distractors and the linguistic distractors at all eccentricities for both changing and constant distractors. Clearly, the linguistic distractors produce longer saccade onset latencies. However an analyses of the RDE magnitudes for each Distractor Type revealed that the non-linguistic distractors produced equivalent RDE magnitudes to the linguistic distractors.

This analyses was possible due to the blocked design of Experiment 6. The differential Distractor Type effects for saccade onset latencies and RDE magnitudes is interesting as it suggests that although there may be higher level cognitive influences on saccade onset latencies in this experiment, but that these saccade latency influences do not impact in the same way upon RDE magnitudes. To take this a step further, what is being, tentatively put forward, is the idea that RDE modulating influences may be independent of saccade latency influences, but the only way that these may be revealed will be by the adoption of a blocked design, similar to that used in Experiment 6. The important thing to note here also is that there are systematic influences on the saccade latencies for the single trial targets which are dependent upon the Distractor Type block that they are presented within and only when these are taken into account can a true measure of any RDE modulating effects be computed.

The predicted interaction between Constancy and Eccentricity for this experiment was not supported. The comparison between changing and constant distractors showed that both words and shape distractors resulted in longer saccade onset latencies for changing distractors at central presentation, with no differences observed between changing and constant distractors for the peripheral presentation of these two types of distractor. The illegal strings however did not follow this pattern. There was no difference between changing and constant illegal distractors at central presentation, and there was a difference at the peripheral location of 8 degrees, with changing distractors having a greater effect than constant distractors on saccade onset latencies. The finding of no difference between changing and constant distractors at central presentation for the orthographically illegal distractor could be a result of the linguistic status of the distractor, since the predicted difference was found for the shape strings, and these distractors have no linguistic status. It could be that the orthographically illegal strings don't produce a constancy effect at central presentation because for this type of distractor, the constant distractor in the set will be processed to the same level as the changing distractor. That is, each orthographically illegal distractor at central presentation will have to go through the same amount of processing, before this processing can be discontinued, whether it is a changing or a constant distractor. For orthographically illegal non-words it is not possible to override the processing for the constant distractors at central presentation, in the same way that is possible for the constant words, and the constant shape strings. It is more difficult to provide an explanation as to why constant orthographically illegal strings may have produced the observed shorter saccade latencies, compared to changing orthographically illegal strings, at the peripheral 8 degree location. Since the changing and the constant distractors were presented in one block it could be that the visual attributes of the constant distractor made it discriminable from the changing distractors at the far peripheral distractor location, and this may have produced the shorter latencies. This though would not explain why the same thing did not occur for the shape string block and the word string block at this eccentricity.

A supplementary analyses on saccade target length revealed that it takes longer to make a 4 degree saccade than it does to make an 8 degree saccade even for single target trials. The finding is interesting since it implies that any observed effects between different distractor eccentricities may simply reflect the fact that it takes longer to saccade to a near rather than a far target. Therefore any claims about peripheral distractor effects upon the RDE must in the future control for possible saccade target eccentricity effects.

In Conclusion, the constancy effect from the previous experiments was upheld when the same category changing and constant items were presented together. Additionally, non-linguistic distractors consistently produced shorter saccade onset latencies than linguistic string distractors at all distractor eccentricities, and this was not dependent upon whether the distractors were changing or constant. Thus both types of linguistic distractors had a greater effect upon the time taken to move the eyes to a target, compared to when a non-linguistic distractor was presented. However, this difference between the linguistic and the non-linguistic distractors was not mirrored in the RDE magnitudes, which showed a similar order for words, orthographically illegal non-words and shape strings. Therefore, in this experiment, saccade onset latencies, but not RDE magnitudes, were influenced by Distractor Type. The prediction of greater saccade onset latencies for words compared to orthographically illegal non-words at the peripheral 4 degree distractor location was supported, suggesting that differences between the different types of linguistic distractors may only become apparent at parafoveal presentation, where some control over the time taken to discontinue processing linguistic information may occur. A supplementary analyses looked at the effects of saccade target eccentricity and whilst the pattern of data from the original analyses for Experiment 6 remained the same, it was found that it takes longer to produce a 4 degree saccade than an 8 degree saccade, and remarkably this holds in the control condition where no distractor is presented with a target. This shows that latencies for single target trials are influenced by the type of distractor that is presented in the distractor trials within the same block. What the pattern of single target trial latencies have shown in this experiment is that that there may be strategic effects from the distractor trials which carry over into the no distractor trials, highlighting long term influences upon the saccadic system.

Chapter 7

General Discussion

The experiments reported in this thesis have yielded a number of interesting findings showing how complex distractors influence saccade onset latencies in the RDE paradigm. Briefly, these were as follows. First, a robust 'constancy effect' was consistently observed. This showed that constant (repeated) distractors produced shorter saccade onset latencies compared to changing distractors. This effect was invariably found with centrally presented distractors and was more variable when peripheral distractors were tested. Second, a Remote Distractor Effect was obtained in all experiments. That is, there was an increase in saccade onset latencies to targets that were presented with a remote distractor, compared to single target trials. However, magnitude of the RDE was not, as predicted on the basis of Walker *et al.*, (1997), always greatest for central distractors and smallest for peripheral distractors. Such an effect was only obtained when targets were presented unilaterally, whereas bilateral randomised target presentation sometimes resulted in a greater RDE magnitude for peripheral than central distractors. There was some evidence to suggest that modulation of the RDE magnitude may be constrained to low-level visual variables only, whereas saccadic onset latencies were influenced by many distractor variables including higher-level linguistic variables. Third, linguistic distractors produced longer saccade onset latencies compared to non-linguistic distractors, and a differential effect between words and orthographically illegal non-words was observed for distractors presented at parafoveal locations. Fourth, the type of distractor presented within a block systematically influenced latencies on single target control trials even though no distractor was present. Fifth, a supplementary analyses showed that saccade target eccentricity influenced saccadic reaction times. All of these findings will be discussed in detail with reference to the particular experiments within which they were observed. Suggestions for new lines of investigation will be given during or at the end of each section. The final sections of the discussion will attempt to explain any implications of the findings for models of oculomotor control, and a description of how some of the findings map onto the neurophysiology of the saccade generation system will be given.

7.1: Constant versus Changing Distractors

A constancy effect, whereby changing distractors, (e.g. varying from trial to trial) produced significantly longer saccade onset latencies, compared to constant (repeated) distractors, has been consistently found throughout this set of experiments. Findings from the earlier experiments showed this 'constancy effect' when constant distractors were embedded in a set of changing distractors which belonged to a different category from the constant distractor (Experiments 1, 2 & 5, shape strings versus linguistic strings), and the finding was upheld when the constant distractors were embedded in a set of changing distractors from the same category (Experiment 6).

The 'constancy effect' has emerged as one of the major research interests in this thesis as a result of rigorous testing of an unexpected finding that occurred for one of the distractor strings in Experiment 1. The original aim of Experiment 1 was to examine whether linguistic distractors would produce a bigger effect upon the magnitude of the RDE compared to non-linguistic distractors, and, to investigate whether there would be any differential effects between the different types of linguistic distractors. In this experiment it was found that all four types of linguistic distractors resulted in prolonged saccade onset latencies for central distractor presentation, compared to peripheral distractor presentation. The non-linguistic shape string distractor did not show the same pattern and no significant differences were observed between central and peripheral presentation for this distractor. The latencies for the non-linguistic distractor were smaller at central presentation, compared to the linguistic distractors at central presentation. Consideration of the materials indicated that apart from the linguistic differences between the shape string distractor and the linguistic distractors, there was also the fact that the non-linguistic shape string had been repeatedly presented throughout the experiment, whereas the linguistic distractors changed on every trial. This could have meant that the finding was a result of either linguistic differences between the non-linguistic and the linguistic distractors, or it could have resulted from differences between repeatedly presented distractors and changing distractors.

Experiment 2 orthogonally manipulated the changing status of the distractor and the linguistic status of the distractor. Constant (repeated) distractors produced shorter saccade onset latencies compared to changing distractors, regardless as to their linguistic status, and there was no difference between saccade latencies for central and peripheral distractor locations for constant distractors, whereas changing distractors resulted in longer saccades for central, compared to peripheral distractor locations. Thus, the 'constancy effect' emerged along with a puzzling interaction between constancy and eccentricity. Linguistic strings produced longer saccade onset latencies, compared to non-linguistic strings.

Experiment 5 investigated whether the 'constancy effect' would also emerge under unilateral target presentation, and, whether the observed differences for the linguistic and the non-linguistic distractors used in Experiment 2 would also be found with unilateral target presentation. The findings for this experiment showed that the 'constancy effect' is found with unilateral target presentation, and also that under unilateral target presentation conditions, the expected RDE eccentricity effects (from Walker *et al.,* 1997) were shown for both constant and changing distractors. No differences in saccade onset latencies were observed between the linguistic string distractors and the non-linguistic distractors. Pre-specified unilateral target presentation resulted in independent effects for constancy and distractor eccentricity.

It was reasoned at this point that the 'constancy effect' should be investigated further, since there was the possibility that the effects could have resulted from across category differences between the changing and the constant distractors. Additionally, it was reasoned that the introduction of an intermediate peripheral distractor location would provide an opportunity to further investigate one suggestion as to why no differential effects had been observed between the different types of linguistic distractors in Experiment 1. Experiment 6 addressed these issues using bilateral target presentation, since no differences on saccade latencies are observed between distractor types under unilateral target presentation conditions (Experiment 5). Analysis of the data for Experiment 6 revealed a number of interesting findings. Many of these will be discussed in detail in the following sections. What is important here is to say that the 'constancy effect' was replicated, but was somewhat smaller in size than in the previous experiments. It was however highly reliable and it was suggested at the outset to the experiment that decreasing the similarity between the constant and changing distractors, by presenting both changing and constant distractors from the same category together, would result in a reduced size of effect.

Thus, the 'constancy effect' appears to be modulated by the relationship between the changing and the constant distractors. If both types of distractor are from a different category the effect will be stronger, and if they are from the same category the effect is weakened, but still highly reliable (Experiment 1 mean difference between changing and constant distractors = 4.4ms, Experiment 2 mean difference between changing and constant distractors = 3.1ms, Experiment 5 mean difference between changing and constant distractors = 5ms, Experiment 6 mean difference between changing and constant distractors =1.4ms). The constancy effect is found for both bilateral target presentation (Experiments 1, 2 & 6) and for unilateral target presentation (Experiment 5). The finding is restricted to central presentation of the distractors and no differences are observed between constant and changing distractors presented in the periphery (apart from Experiment 6 for orthographically illegal distractors).

The findings overall show that the 'constancy effect' whereby repeated distractors result in a decrease in saccade onset latencies compared to those shown for changing distractors is robust. It can be modulated by systematically manipulating the visual and the category status of the changing and the constant distractors. Repeated stimuli appear to become familiar during the course of the experimental trials and as such they are processed in a different way from non-repeated stimuli. The differential effects for constant and changing distractors on saccade onset latencies are not specific to across category differences between the changing and the constant distractors. This is an important finding, since it suggests that there is some implicit learning of the repeated item during testing that makes it more discriminable from the changing items. Whether this occurs in a completely automatic fashion, or is a result of some sort of strategic learning remains to be addressed.

The constancy findings may be related to the 'priming of pop-out' findings in the visual search literature. 'Priming of pop-out' (Maljkovic & Nakayama, 1994, 1996, 2000) is an effect whereby repetition of the pop-out feature in a discrimination task leads to speeded responses to that feature through facilitation of attentional shifts, and also eye movements (McPeek, Maljkovic and Nakayama, 1999). These studies demonstrated that attentional shifts and eye movements are affected by a short term memory system which operates at an unconscious automatic level and facilitates orienting toward targets which share a common visual feature (e.g. shape or colour) with visual targets which have recently been attended. Although the RDE paradigm employed for the experiments reported in this thesis is quite different from a visual search paradigm, there was a facilitative effect for repeated distractors compared to changing distractors which was similar to that obtained in the 'priming of pop-out' studies, in that, saccadic reaction times to targets decreased for repeated distractors. This suggests that the 'constancy' effect may be a consequence of an automatic learning mechanism similar to that responsible for 'priming of pop-out' and may serve to free up attentional processing resources during visual tasks. New lines of enquiry might focus on the time course of the emergence of the constancy effect and whether the time course differs for different types of stimuli. It is also interesting to investigate whether the effect is enduring or whether it diminishes over time. Since the constancy effect is observed mainly with central presentation, it is more appropriate to describe it as modulating saccade latencies rather than the RDE. What will be discussed next are the eccentricity effects of remote distractors upon RDE magnitudes.

7.2: The RDE, unilateral and bilateral target presentation

The magnitude of the RDE is calculated as the difference in saccade onset latency between single target trials and trials where a distractor is presented with the target. It was anticipated at the outset of this work that modulation of the RDE magnitude might be shown for the different types of distractors used in the experiments. What was not anticipated was that there would be any modulatory effects upon the magnitude of the RDE by the unilateral or bilateral presentation of the target.

To be clear, this discussion will focus on the RDE magnitude differences, which occur for central and peripheral distractors, as a direct result of whether targets are presented to a pre-specified unilateral side of a display, or whether targets are randomly presented to both sides of a display. Other differences, such as error rates and anticipatory saccades will also be discussed. The possible role of attention for the two types of target presentation will be highlighted and explanations of the RDE will be reconsidered in light of the findings that have been presented for the experiments reported in this thesis. Findings from some other experiments that have used either or both types of target presentation to look at the effects of distractors on saccadic reaction times, or saccadic inhibition effects will also be discussed.

In Walker *et al.*'s (1995) experiments, the saccade onset increase for distractor trials compared to single target trials was no different when the target and the distractor were presented bilaterally, and participants were free to choose which one to saccade to, compared to when participants were instructed as to the side of the display the target would be presented at. In Walker *et al.*'s (1997) experiments a systematic pattern was shown between eccentricity of the distractors and magnitude of the RDE. Central distractors produced the longest saccade onset latencies, and a linear reduction in saccade onset latencies was observed as distractors were moved into the periphery. The mean RDE magnitude was about 40ms for central distractors, and for peripheral distractors with mirror symmetrical targets it was about 15ms.

On the basis of these findings it was expected that central distractors would always produce a greater RDE magnitude compared to peripheral distractors. It was apparent however from some of the experiments reported in this thesis that this was not the case. Furthermore, it was apparent from a comparison of the RDE magnitudes for central and peripheral distractors in Experiment 1 with those reported by Walker *et al.*, (1997), that the magnitude of the RDE in Experiment 1 was a substantially bigger effect than that obtained by Walker *et al.*, (1997). The biggest discrepancy between the comparisons occurred for the peripheral distractors. Appendix D contains tables showing the RDE magnitudes for all experiments.

In Experiment 2 a similar finding for the RDE magnitudes for peripheral distractors as that shown in Experiment 1was observed. Also in Experiment 3 where only the constant non-linguistic shape string distractor was presented, the RDE magnitude was actually greater for peripheral distractors compared to central distractors. Clearly these findings are different from those of Walker *et al.*, (1997). In order to try to replicate the findings of Walker *et al.*, (1997) for central and peripheral distractors, the constant uniform shape string distractor that had been presented in Experiment 3, was presented again in Experiment 4 but this time unilateral target presentation was adopted. Under unilateral target presentation conditions the RDE magnitudes for the central and the peripheral distractors were more in line with Walker *et al.'s* (1997) findings. Similarly, in Experiment 5, which again used unilateral target presentation but also reintroduced the changing and constant distractors used in Experiment 2, the RDE magnitudes were of a similar order for both central and peripheral distractors to those reported by Walker *et al.,* (1997). In the final experiment where bilateral target presentation was adopted, there were no overall differences between the RDE magnitudes for the three different distractor eccentricities employed. In comparison to Walker *et al.,* (1997) the RDE magnitudes for Experiment 6 were on average 17ms smaller for centrally presented distractors, for the intermediate peripheral distractor the RDE was 11ms greater and for the far peripheral distractor the RDE magnitude was 5 ms greater. The important point about the discussion on RDE magnitudes is that for this set of experiments there were unanticipated effects of peripheral distractors that clearly demonstrated that the saccadic system is influenced by prior knowledge of the target location or by the need to perform an additional discrimination task. Thus although the RDE has been described as a low-level oculomotor effect, it is sensitive to task demands.

The main differences between bilateral and unilateral target presentation were as follows; unilateral target presentation produced an RDE magnitude for central and peripheral distractors that was equivalent to that found by Walker *et al.*, (1997). No interactions with linguistic variables were found for unilateral presentation but such effects did occur with bilateral presentation. Also no erroneous saccades are directed to the distractors, but a proportion of anticipatory saccades were made towards the target.

Bilateral target presentation produced RDE magnitudes for central and peripheral distractors that were not equivalent to those which would be predicted from the Walker *et al.*, (1997) findings. In Experiments 1 and 2 peripheral distractors produced a much bigger RDE magnitude compared to Walker *et al.*, (1997), although in that condition saccade onset latencies were greater for central distractor presentation compared to peripheral distractor presentation. This saccade latency eccentricity effect was observed only for the changing distractors in those experiments. No differences were observed between saccade onset latencies for the constant distractors for the central and peripheral distractor eccentricities. In Experiment 3 which looked at the effect of presenting only a constant distractor the RDE magnitude was again greater for the peripheral distractor, compared to Walker *et al.*, (1997), but the central distractor RDE magnitude was smaller than would have been predicted. In Experiment 6 central and peripheral distractors produced equivalent RDE magnitudes, and, compared to Walker et al., (1997) central distractors produced a smaller RDE magnitude and peripheral distractors produced a greater RDE magnitude than would have been predicted.

It is important to try to offer some explanation for the differences in the magnitudes of the RDE's that occurred between the two types of presentation in the reported experiments. What will be discussed here are the possible effects of distractor size, an additional discrimination task for the bilateral presentations and attentional factors operating for the two types of target presentation.

In both types of target presentation the distractor was always bigger than the target. It is possible therefore that this could be a factor that contributed to the discrepancies between the peripheral magnitudes of the RDE's obtained the present series of experiments and those obtained by Walker *et al.,* (1997). In bilateral target presentation it is also necessary to discriminate between the target and distractor in order to saccade to the target, whereas in a unilateral target presentation the target location is pre-specified, therefore, no discrimination process is needed to complete the task. This discrimination process could also be a likely candidate for producing the discrepancy in RDE magnitudes observed for the peripheral distractors in the bilateral target presentation task, since additional time would be needed to carry out the discrimination process before saccading to the target. It is also feasible to assume that activation of attentional processes differed for the two types of target presentation, and this could also have had an effect. For example, in the unilateral presentation task, attention may have already been allocated to the pre-specified side of the display for the target presentation, and as such the contralateral peripheral distractor would not capture attention to the same extent as in a bilateral target presentation. Additionally, in the case of bilateral target presentation it could be that two saccades are programmed; an exogenous saccade to the peripheral distractor and an endogenous saccade to the target. It is suggested here that an exogenous saccade is programmed to the peripheral distractor as the peripheral distractor is more visually salient than the peripheral target due to the difference in the size of the target and distractor. The process of inhibiting the execution of one saccade in favour of executing the other could also offer some account for the larger RDE magnitudes in the present studies for peripheral distractors in the bilateral target presentation task compared to Walker *et al.*, (1997). Each of these possibilities will be discussed in turn.

It was suggested that the differences in RDE magnitudes for the peripheral distractors in these experiments, compared to those of Walker *et al.*, (1997) could have resulted from size differences between the targets and distractors. Since the distractors were made up of four letters or symbols, and the target was a single +, then the distractors were much more visually salient than the targets. However, the size difference alone is an inadequate explanation since the peripheral distractors in a unilateral pre-specified target presentation condition produced an RDE magnitude that was in the order of what would be predicted by Walker *et al.*, (1997). This suggests that prior knowledge of the target location reduces the effect of peripheral distractors upon the RDE magnitude. In unilateral target presentations the relationship between eccentricity of the distractor and magnitude of the RDE was observed, regardless of the fact that there was a size difference between the distractors and the target.

Another possibility for the unilateral and bilateral differences between the RDE magnitudes for the peripheral distractors was that for bilateral target presentation there is an additional discrimination process between the target and the distractor. This discrimination process is only necessary for the peripheral distractor trials, since when central distractors are presented there is no need to discriminate between the two. A study by Weber and Fischer (1994) looked at saccade latency increases for conditions where targets and distractors were either presented randomly to the left and right of the display (bilateral target presentation), and a condition where participants were instructed as to which of two possible targets they should saccade to (unilateral target presentation). For the bilateral presentation task it was found that express saccades (saccades with latency < 80ms) were completely eliminated and increases in saccade onset latencies were observed even for the single target control condition. Furthermore, directional errors were made to the distractor on about 25% of the trials and these were considered to be reflexive, but they showed prolonged latencies because of the simultaneous appearance of the target acting as a competing stimulus with the distractor. In the unilateral target presentation an increase in saccade latency in the order of 30ms occurred for some distractor trials compared to single target trials. In the unilateral condition express saccades were shown in both single target trials and in a reduced number in the distractor trials. What is important here is that Weber and Fischer (1994) concluded that it is the discrimination process, rather than a decision element that results in increased saccade latencies for bilateral presentation tasks. This could explain why in Walker *et al.*, (1995) there were no differences between RDE magnitudes for bilateral and unilateral target presentation tasks, since in those experiments the targets and the distractors were the same and in the bilateral presentation task participants were free to saccade to either one. Although, in a sense, a decision had to be made between the two possible targets, no discrimination process was necessary to complete the task. It is likely that the discrimination process for the bilateral experiments in this thesis has contributed to the greater than anticipated RDE magnitudes for the peripheral distractors.

The error data are also important here, since no directional errors are observed in a unilateral target presentation task. This suggests that either attention has already been allocated to the side of the display prior to the appearance of the target, or that since participants do not have to discriminate between the target and the distractor prior to saccading to the target no decision process is required. It could be that directional errors to the peripheral distractors result from oculomotor or attentional capture to the more salient peripheral stimulus in the bilateral target presentation task. Approximately 25% of erroneous saccades to the distractor occurred in bilateral target presentation in the present studies. It is suggested that in this case the peripheral distractors have an effect that is similar to that observed in the oculomotor capture paradigm (e.g. Theeuwes *et al.*, 1998, 1999). Errors are made only in bilateral target presentation conditions where the location of the target and distractor (which side of the display each appears at) is randomised across trials. In the unilateral target condition a proportion of anticipatory saccades are produced. These saccades could also be a result from activation in the exogenous orienting system. It appears that when prior knowledge of the target location is given it is not always possible to maintain fixation at the centre of the display until the target is actually presented. On about 20% of trials it was found that participants saccade toward the target prior to its presentation.

Godijn and Theeuwes (2002) have suggested that in the RDE paradigm endogenous saccades must be programmed since participants are instructed as to the nature of and the location of the target. This would necessarily induce activation of the endogenous orienting system. According to the Godijn and Theeuwes model (2003) it is possible to program both endogenous and exogenous saccades in the same saccade map and if this occurs the resulting saccade will be the winner of competition between the activation at the two locations in the saccade map. In the case of correct first saccades to the target, the reason why the findings from the bilateral target presentation task for the peripheral distractors show a bigger RDE magnitude compared to Walker *et al.*'s

(1997) findings could be because in this condition both an exogenous and an endogenous saccade are programmed together, and the increase in saccade latencies occurs because the exogenous saccade has to be cancelled in favour of executing the endogenous saccade to the target. In the case of errors the programming and execution of an exogenous saccade to the distractor could not be cancelled by voluntary inhibition of the exogenous saccade in favour of making an endogenous saccade to the actual target. This may be analogous to the countermanding studies on saccadic inhibition (e.g. Hanes & Schall, 1995, 1996). In the countermanding studies the control condition is the same as the control condition in the RDE studies, and the visual stop signal (a signal to inhibit a saccade) is like a remote distractor in those trials where participants do erroneously make a saccade. The difference is that participants have to inhibit a saccade to the target under these conditions whereas in the RDE they have to ignore a remote distractor on some trials and saccade to the target. The results from the countermanding studies have demonstrated that saccades can be inhibited voluntarily, but not always. Furthermore there is a pattern of neuronal activity in the FEF for the presentation of a stop signal that is restricted to fixation and movement neuron activity. Visual response neurons do not show this pattern (Hanes & Schall, 1995). Inhibition of an eye movement to the distractor is not necessary under unilateral target presentation conditions as attention has been pre-allocated to the target location. Under these circumstances though, inhibition of an eye movement toward the pre-specified target location prior to its appearance cannot always be accomplished and this results in a proportion of anticipatory saccades. It has been shown that anticipatory saccades occur if there is high predictability for both when and where a target will be presented (Wenban-Smith & Findlay, 1991). The point is that a similar proportion of anticipatory saccades are obtained in a unilateral target presentation as the proportion of errors obtained in a bilateral target presentation. Clearly inhibition plays an important role in oculomotor control. In particular, for bilateral presentations inhibitory processes successfully prevent saccades to the distractor and in unilateral presentations they prevent saccades from being initiated prior to target onset.

It is suggested that the randomisation of the location of targets and distractors (left and right of the display), in Experiments 1, 2, 3 and 6, resulted in the increase in the RDE magnitude (compared to Walker *et al.'s*, 1997 study) for the peripheral distractors. Here it is thought that two saccades are programmed, one to the distractor and one to the target, and in addition to having to cancel one of these in favour of the other, a discrimination process between the two possible competing targets must be performed prior to saccading to the target. Two saccades would not have to be programmed for the central distractors in either a bilateral or a unilateral target presentation task, and nor would two saccades have to be programmed for the peripheral distractors in a unilateral presentation task, since the target location is pre-specified. A further suggestion is that the peripheral distractor captures attention, perhaps because of its increased size compared to the target, and in this case it could be argued that the capture of attention could either be overt and result in an erroneous saccade to the distractor, or it could be covert and the time taken to reallocate attention and the eye to the target may have some impact on the observed increases in RDE magnitudes for the peripheral distractors.

The discussion on the effects of bilateral target presentation versus unilateral target presentation highlights the many differences between the two with respect to the production of saccades. It appears that the role of attention is quite different in the two types of target presentation and this has a direct influence on performance that is reflected not only in the error data but also on any modulating eccentricity effects upon saccade onset latencies and RDE magnitudes. Future work might look at whether there are bimodal distributions of saccade onset latencies for both central and peripheral distractors in bilateral target presentation conditions and in unilateral target presentation conditions. If distractors impact upon saccade onset latencies for some trials but not others, clearly these need to be separated in order to properly analyse eccentricity effects upon RDE magnitudes.

The previous discussion has centred on RDE magnitudes for central and peripheral distractors in bilateral and unilateral target presentation conditions. What will now be addressed is whether or not there were any differences between saccade onset latencies and RDE magnitudes between linguistic and non-linguistic distractors.

7.3: Linguistic versus non-linguistic distractors

One of the original aims in this thesis was to examine whether linguistic distractors differed from non-linguistic distractors in the RDE paradigm, and whether different types of linguistic string had differential modulating effects upon the RDE.

Experiment 1 examined the effect of different types of linguistic distractor strings on eye movement response latencies to simple targets. It was argued that any influences of linguistic material on a non-lexical task would be an indication of cognitive processing of that material and it was thought that the automatic nature of visual word recognition (Stroop, 1935) might impact upon the saccade onset latency system in the

RDE paradigm. Although the distractors were irrelevant to the task, the linguistic nature of them would mean that they were automatically processed, and the effects upon saccade latencies would be a result of how long it took to discontinue such processing and move the eye to the target. This in turn would be related to the type of linguistic distractor presented. It was assumed that as the linguistic status of a distractor string increased towards the level of a word, that this would have a greater effect upon saccade onset latencies. Well established findings from the literature have shown that the more like a word a letter string is, the more difficult it is to reject this string in a lexical decision task (e.g. Forster & Chambers, 1973). Four types of linguistic distractors were presented (words; orthographically legal non-words; orthographically illegal non-words and uniform letter strings). In addition there was a non-linguistic uniform shape string distractor. The final assumption for Experiment 1 was that the presentation of the non-linguistic distractor would have less of an effect upon saccade onset latencies, compared to all types of linguistic distractor strings. This was because letter string distractors are symbolic to a degree that the shape string distractors are not. Specifically, it was anticipated that while participants would automatically attempt to extract linguistic meaning from the letter strings, no such automatic linguistic processing would be possible for the shape strings. Since the biggest effects of remote distractors had been shown for central presentation (Walker *et al.*, 1997) of distractors, and since effects of orthographic status have been shown for lexical decision tasks that have presented material at fixation (e.g. Coltheart, Davelaar, Jonasson & Besner, 1977) it was anticipated that an effect of remote distractors would be stronger for central presentation of a distractor, and also that any differential effects for the different types of linguistic distractors would be observed at this presentation location.

The findings from Experiment 1 showed that, for central presentation, the linguistic distractors produced reliably longer saccade onset latencies compared to the non-linguistic distractors but the prediction of a differential effect for the different types of linguistic distractors was not obtained. Although there was a systematic effect for all types of letter string distractor (between central and peripheral presentation of these), no differences were observed between the different types of letter string at either distractor eccentricity.

Experiment 2 was designed to address whether the observed decrease in saccade onset latencies for centrally presented non-linguistic distractors in Experiment 1, compared to all types of linguistic distractors, resulted from linguistic processing effects, or whether it resulted from repeatedly presenting the same non-linguistic distractor, as opposed to presenting changing linguistic distractors. Recall that in the introduction to Experiment 1 it was suggested that any differences observed between the uniform linguistic string and the uniform non-linguistic string could only be attributed to the effects of abstract linguistic information associated with the representation of a letter, compared with an arbitrary shape. These two types of distractor were presented in the second experiment and there was a reliable difference between them such that the linguistic distractors produced longer saccade onset latencies compared to the non-linguistic distractors. In Experiment 5, which employed the same stimuli but under unilateral presentation conditions no main effect of distractor type was observed. Therefore in a pre-specified unilateral target presentation both the linguistic distractors and the non-linguistic distractors were processed in the same way. This was not the case for the bilateral target presentation in Experiments 1 and 2.

It was suggested that one of the reasons for not obtaining any differential effects between the different types of letter string in Experiment 1 could have been caused by presenting all types of letter string together. In theory this should not have made a difference if different types of letter string are processed differently. However it is possible that processing effects for each type of string had carry over effects to the others, and this could have prevented any subtle differences between the different types of linguistic distractors from being observed. A further reason for not observing any differences between the different types of linguistic strings at central presentation in Experiment 1 could have been a result of 'ceiling effects' operating for central presentation. Since the word identification system is automatised and highly specialised it could be argued that at central presentation all types of letter strings had the same effect upon saccade onset latencies because at this location the mandatory nature of linguistic processing was such that any cost on the processes associated with computing a saccade that occurred in parallel with word identification processes would not be detectable. By contrast at the peripheral distractor location 'floor effects' may have resulted due to the visual degradation of the distractors at this eccentricity. At this eccentricity the linguistic status of the letter strings may not have been discriminable and therefore all the different distractor types (both linguistic and non-linguistic) would have had the same influence on the oculomotor system.

The design of Experiment 6 permitted a further examination of whether linguistic distractors had a differential impact upon the saccade latency system, compared to non-linguistic distractors, and it also afforded the opportunity to re-examine whether there were any differential effects for different types of linguistic distractors. In Experiment 6 the linguistic distractors were words and orthographically illegal non-words, and the non-linguistic distractors were made up of four different shapes. An intermediate distractor eccentricity was introduced to test the hypothesis of a 'ceiling' effect for centrally presented linguistic distractors. An intermediate distractor location of 4 degrees was introduced in an attempt to enhance the possibility of observing any differences between the different types of linguistic strings, since at this eccentricity the linguistic strings are visually degraded to such an extent that automatic lexical identification processes are slowed. However the degradation is not so severe that such processes are completely ineffectual, as is the case for the letter strings presented in the periphery.

The design of Experiment 6 was complex and a number of predictions were made, and it should be noted that these were mainly supported. For the purpose of this discussion only the effects between linguistic and non-linguistic distractors will be reported, along with differential effects between the two types of linguistic distractor. It was anticipated that word distractors would produce the longest saccade onset latencies, followed by the orthographically illegal distractors, followed by the shape string distractors. There was however, no main effect of Distractor Type in this experiment, but there were reliable differences between the non-linguistic distractors and the linguistic distractors at all eccentricities for both changing and constant distractors. The linguistic distractors produced longer saccade onset latencies compared to the non-linguistic distractors. This has been consistently found for the bilateral presentation studies in the experiments reported in this thesis. Although it is tempting to conclude that it is easier to ignore non-linguistic task irrelevant distractors in the RDE paradigm than it is linguistic distractors, this is not necessarily the case. Analyses of the RDE magnitudes (as opposed to saccade onset latencies) for each

Distractor Type revealed that the non-linguistic distractors produced equivalent RDE magnitudes to the linguistic distractors. The differential Distractor Type effects for saccade onset latencies and RDE magnitudes is interesting as it suggests that although there may be higher level cognitive influences on saccade onset latencies in this experiment, these saccade latency influences do not impact in the same way upon RDE magnitudes, at least not in a bilateral target presentation task.

The introduction of the intermediate distractor location in Experiment 6 resulted in a differential effect being observed between the saccade latencies for the different types of linguistic distractors. Words produced longer saccades compared to the orthographically illegal distractors, at the parafoveal distractor location. The finding at this eccentricity was shown for both changing and constant distractors and this therefore supports the view that words are processed in a qualitatively different way to illegal strings, at this eccentricity. This provides evidence for the suggestion that the presentation of any type of linguistic string at central fixation location will initiate automatic processing of that string to the extent that all types of string will have the same effect upon saccade latencies. No differences were observed between words and orthographically illegal strings for both changing and constant distractors at central presentation. However, the findings for the far peripheral presentation of 8 degrees were inconsistent with the proposed theoretical standpoint. What was predicted for this location was that there would be no difference between any of the types of linguistic strings, because at this eccentricity all types of linguistic string would be visually degraded to the same extent, making it almost impossible to discriminate between any of them. The findings in Experiment 6 for the changing condition supports this, in that there were no differences between the different types of linguistic strings, but the finding for the constant condition does not. Here a difference between words and illegal strings was observed, with words having a greater effect than the illegal strings at the peripheral distractor position. It is possible that this unpredicted finding resulted from the fact that words that are consistently repeated in a peripheral location may become recognisable over trials during the experiment and are therefore more salient in the periphery than repeated orthographically illegal distractors and shape string distractors. If this tentative explanation is correct, then the increased saccade latencies for repeated peripheral words, compared with shapes and orthographically illegal letter strings, could be explained by lexical processing effects.

What can be concluded from the findings from these experiments with respect to the effects of linguistic variables is that linguistic distractors produce longer saccade onset latencies compared to non-linguistic distractors in bilateral presentation tasks. However, non-linguistic distractors produce RDE magnitudes of a similar order to the linguistic distractors. Additionally, there are effects of orthography for the linguistic distractors that are manifest at parafoveal distractor locations. This is in some ways consistent with the findings from the reading literature that show that parafoveal linguistic information is extracted and used in the production of, and in the guidance of saccades (e.g. Murray, 1998; see also Murray & Rowan, 1998).

Since the linguistic differences were observed for both saccade onset latencies and RDE magnitudes in a bilateral target presentation this suggests that higher-level linguistic variables do impact upon the low-level oculomotor behaviour in a bilateral target presentation paradigm. Future work might explore whether the difference obtained at parafoveal presentation between the word distractors and the orthographically illegal distractors holds for unilateral target presentation conditions and furthermore whether it holds for different linguistic distractor manipulations, other than orthography. Additionally, future work might step out the eccentricity of the distractors to try to see just how far out they need to be to pick up an effect, and at what eccentricity does the effect disappear at. This would give an indication of how far into the periphery linguistic information effects could be obtained and thus would contribute to the literature on parafoveal and peripheral processing of linguistic information. Lexical processing is thought to be early, fast acting and automatic. The findings from the studies reported here suggest that, at least under certain circumstances, this processing can influence the initiation of saccades. Linguistic variables do have an influence upon saccade onset latencies but not upon RDE magnitudes. Differences in saccade onset latencies between the different types of linguistic distractors may be contingent upon the eccentricity of the position of the linguistic distractor.

What have been discussed up to now are the findings for the three main variables in the experiments conducted in this thesis. The effects of 'Constancy', Distractor Eccentricity and Distractor Type have been summarised and some explanation has been given to account for the findings. Two supplementary analyses were carried out on the data set from Experiment 6. The first looked at the single target trial latencies, and the second looked at saccade target eccentricity effects. The findings for each of these will be discussed next.

7.4: Influences on single target trials

A further important observation from Experiment 6 was that the pattern of saccade onset latencies observed for the single target trials showed a striking similarity to the overall pattern for the different Distractor Types, even though no distractor was present. Since the design of Experiment 6 was such that each of the three different Types of Distractor were separated into individual blocks of trials, and each block included a single target set of trials where no distractor was presented, it was possible to observe a pattern of saccade onset latencies for the single target trials which was clearly related to the Type of Distractor Block within which they were presented. This pattern showed that saccade onset latencies in the single target trials were longest for words, followed by orthographically illegal non-words, followed by the non-linguistic shape string distractors. Although the differences were not all statistically reliable it is clear that there is some carry over effect from the distractor trials to the no distractor trials. This may be strategic and serves to illustrate that the saccadic system is subject to long-term influences. Furthermore, although the analyses of the saccade onset latencies in Experiment 6 indicated that non-linguistic distractors produced shorter saccades compared to linguistic distractors, an analysis of the RDE magnitudes using the corresponding baseline single target trial latencies for each Distractor Type for all conditions showed that the differences observed for saccade onset latencies between the linguistic and the non-linguistic distractors did not apply to the magnitude of the RDE. This is important as it emphasises the need take account of the single target trial data for each Distractor Type when making RDE magnitude comparisons. If there are any differences between the latencies for the single target trials which are systematically related to the Type of Distractor presented in the distractor trials within that block, then in order to say whether one Type of

Distractor is having more of a modulating effect on the RDE than another, these must be taken into account when computing an analysis of the variance between each Distractor Type. Importantly, this analysis has shown that although there may complex cognitive distractor effects upon saccade onset latencies between linguistic and non-linguistic distractors, such effects may not be modulating the RDE.

7.5: Saccade target eccentricity effects

In order to keep the number of conditions in Experiment 6 to a manageable level it was decided to maintain the symmetrical relationship between peripheral distractors and targets that existed for the earlier experiments. In Experiment 6 therefore, each time a peripheral 4 degree distractor was presented, there was a corresponding 4 degree target on the opposite side of the display. Additionally, as in the preceding experiments, every time a peripheral 8 degree distractor was presented, there was a simultaneous 8 degree target presented on the opposite side of the display. However, for central presentation of a distractor in Experiment 6, a saccade target could appear at either 4 degrees on the left or the right of the midline, or at 8 degrees on the left or the right of the midline. Thus although peripheral distractors were always presented with a mirror symmetrical contralateral target, central distractors were presented with targets at both 4 degree and 8 degree eccentricities as were targets in the single target trials.

The main analyses of the data in Experiment 6 collapsed across these two target eccentricities, since there was no reason to believe that saccade target length would influence saccade onset latency. In Walker *et al.'s* (1995) study it was reported that saccade latencies were not affected by target eccentricity and the data was collapsed across the two possible target eccentricities of 4 and 8 degrees. However, there is some published evidence in the reading literature (Rayner, 1978), which shows that it takes longer to make a shorter saccade than a longer saccade in a word naming condition (words were presented at 1, 3 or 5 degrees eccentricity).

Since the data were available it was decided to examine whether there were any saccade target eccentricity effects for the central distractor presentation condition in Experiment 6. A valid comparison could be made as to how long it took to program an eye movement to either a 4 degree saccade target, or an 8 degree saccade target, for the central changing and central constant distractors. The main finding for the saccade target eccentricity analysis showed that shorter saccade latencies occur when targets are positioned at the far peripheral location of 8 degrees eccentricity, than when they are positioned at the near peripheral location of 4 degrees eccentricity. The target eccentricity effect was observed when a central distractor was presented, and remarkably, when no distractor was presented (i.e. in the single target trials). Moreover the effect was observed across all experimental conditions. Specifically, it was shown for both changing and constant distractors, and for the three different types of distractor (words, orthographically illegal non-words and shape strings).

This is interesting and has obvious implications for claims made about the effects of remote distractors, since these may reflect saccade target eccentricity effects rather than distractor eccentricity effects. One possible explanation for the target eccentricity effects is that the 4 degree target could be having an effect upon the fixation zone. Recall that it was suggested by Walker *et al.,* (1997) that distractors closer to the fovea have more of an influence on saccade latencies because of increased activity in the fixation zone of the superior colliculus. It could therefore be argued that this effect could also apply to target eccentricity. Claims about distractor eccentricity RDE effects must in the future control for possible saccade target eccentricity effects.

The findings from the supplementary analyses for Experiment 6 have provided further insight into influences upon the saccadic system. They also serve to stress the importance of careful design if any inferences are to be drawn about remote distractor effects upon either saccade onset latencies or RDE magnitudes.

What will be discussed next are the possible implications of the findings for models of oculomotor programming and a brief discussion of how some of the findings from the reported experiments may relate to what is known about the neural circuitry of eye movement control will be presented.

7.6: Implications of the findings for models of oculomotor programming

The saccade generation models outlined in the introduction to this thesis do not offer an explanation for the 'constancy' effect obtained in these experiments. Models of oculomotor control will therefore need to be adapted to incorporate a learning mechanism for material that becomes familiar as a result of repeated presentation, and as such has an impact upon the saccade latency generation system. The findings from these experiments suggest that less processing of repeated distracting items is required, compared to unfamiliar distracting items, in order to free the eye to move to the target more quickly (i.e. ocular disengagement). Although Findlay and Walker's (1999) model suggests that the level 2 fixate centre in the 'when' pathway can be influenced quickly and directly by centres of cognitive processing at level 4 in the 'when' pathway, they provide no mechanistic account for how this actually occurs, but state that the processes operating at this level are automated in the sense that they are not subject to conscious awareness. They also suggest that the role of implicit learning and memory may be significant at this level, but again do not say exactly how this would have any systematic effect upon saccade onset latencies.

Important questions concern when and how stimuli become familiar and why does the effect occur for central stimulation only? Also, the intrinsic saliency box at level 4 in the 'where' model of Findlay and Walker (1999) exists, but no explanation as to how something becomes intrinsically salient is given, and it is suggested that intrinsic salience has no effect upon the 'when' system, although it has a direct effect upon the level 2 move system, which, through the reciprocal cross-connections, can affect activity in the level 2 fixate centre in the 'when' system. Thus, what is not known is whether the constancy effect observed in these experiments results from the repeated stimuli reducing activity in the level 2 fixate centre as a result of an influence at the level 4 in the 'when' system, or whether it results from a reduction in the level 2 move centre as a result of an influence of activity at the level 4 intrinsic salience box in the 'where' system. Such questions will no doubt provide a future line for behavioural investigation. It is known for example that foveally presented information has an effect upon fixation durations (for a review see Rayner, 1998) and as such, fixation durations for centrally presented information have been used as indicators of processing load. It is suggested that the centrally presented repeated distractors in the experiments reported here result in a reduction of processing load.

It is also interesting to explore whether the neurophysiology of the eye movement system can offer anything in the way of explaining why saccade latency decreases as a result of being presented with centrally repeated task irrelevant distractors. Where in the neural circuitry does a learning effect manifest? There is some work which suggests that firing rates for neurons in the FEF are suppressed for learned distractors, and as such a learning effect is manifest, but it is not yet known at what stage and time this occurs (Schall & Thompson, 1999). However, since the FEF both receives and sends information to other brain areas involved in the production of saccades, such as the SC and the brainstem circuitry, it is plausible that the 'constancy' effect observed for central distractors results from a direct influence from FEF signals upon activity in the central fixation zone of the SC which is mediated by differences in firing rates in the FEF for the learned repeated distractors and the changing distractors.

The findings for the RDE magnitudes in these experiments also have implications for models of oculomotor control. The Findlay and Walker (1999) model suggested that the RDE results from a direct effect of the distractor upon the collicular fixation zone, even for peripheral distractors. Their argument is that there is a paradoxical route in the model whereby level 3 activation in the 'where' system for peripheral onsets has a direct influence upon level 2 fixation activity in the 'when' system. Findlay and Walker (1999) advocated an extended collicular fixation zone from the central foveal area out to 10 degrees into the periphery. There is some neurophysiological evidence to support this claim since it has been found that stimulation of cells in the more caudal area of the superior colliculus respond to stimuli within about 10 degrees. However, although this explanation seems to give an adequate account for the latencies observed under unilateral target presentation, it cannot account for the findings from the bilateral target presentation conditions in these experiments. The model cannot explain why in bilateral target presentation RDE magnitudes for peripheral distractors are greater than those that were found in the Walker *et al.,* (1997) study. Criticisms of the model's explanation of RDE effects in terms an extended fixation zone in the SC have been raised by Olivier Dorris and Munoz (1999) who point out that in addition to only a small proportion of fixation neurons in the SC having visual receptive fields that reach out as far as 10 degrees of visual angle in the contralateral hemifield (Everling, Paré, Dorris & Munoz, 1998), a more likely explanation for the RDE effects is that presentation of remote distractors results in activation of a second population of saccade related neurons in the salience map. The delay in saccade latency would therefore result from lateral inhibitory interactions within the salience map at level 2 in the Findlay and Walker model.

Also, it has been shown that peripheral distractors sometimes have an effect on saccadic reaction times (produce increased saccade latencies to the target compared to single target trials), and sometimes they do not (Weber & Fischer, 1994). This finding was from a pre-specified target location experiment and therefore, the systematic decline shown by Walker *et al.,* (1997) for central versus peripheral distractor effects upon the magnitude of the RDE, may simply be a result of central distractors having a disruptive effect on every trial, and peripheral distractors having a disruptive effect only on some trials.

In a bilateral target presentation task it could be argued that what is being observed is not the effect of remote distractors on the production of saccades, but rather, the effects of competitive influences between the simultaneously presented peripheral distractors and targets. In this case the model of Godijn and Theeuwes (2002) offers a more plausible explanation of the data. The assumption here is that both exogenous and endogenous saccades are programmed in parallel in the same saccade map. If both endogenous activation (target – related) and exogenous activation (distractor-related) occur together, then whichever reaches the activation threshold first will determine where the saccade is directed to. Erroneous saccades to the distractors result from the exogenous activity reaching the threshold first. Correct saccades to the target result from activity in the endogenous system reaching the threshold first, but in this case saccade latency is increased as a result of lateral inhibition from the distractor related activity. This account provides a plausible explanation for the increased RDE magnitudes for the peripheral distractors in the experiments reported here for the bilateral target presentation conditions.

Godijn and Theeuwes (2002) suggest that the integration of both exogenous and endogenous activation occurs in a common saccade map in the intermediate layers of the SC but the pathways by which each type of activation reaches the SC may be different. Several subcortical and cortical brain areas project to the SC and it has been suggested that the visual and posterior parietal cortices may provide the main input to the SC for visually guided saccades. Both the suppression of reflexive saccades and the generation of voluntary saccades are controlled to some extent by the direct and indirect (via the basal ganglia) projections from the FEF to the SC (Munoz, 2002). Since the SC receives direct inputs from several higher-level areas it is possible that they can influence the pre-motor processing and ultimately behaviour (Munoz, 2002). Higher-level areas have been shown to have a role in fixation control. In particular the FEF has been shown to play a role in the inhibition of saccades (Schall, 1995). Therefore, although activity in the SC may ultimately mediate the effects observed for the peripheral distractors in the bilateral presentation tasks, it is likely that this is not a direct result of activity in an extended fixation zone but could be a result of inhibitory effects from control signals from the FEF to the SC.

The differential effects for the bilateral versus the unilateral target presentation are important and may have implications for inferences that have been made from the many studies (e.g. Walker *et al.,* 1997) of the effects of simultaneously presented targets and distractors. Some of the double onset studies only presented peripheral distractors (e.g. Weber & Fischer, 1994) and so a comparison between effects for central and peripheral distractors could not be made. What is being suggested here is that reports of systematic latency increases or indeed any lack of these, for these and other studies may be related to whether or not targets were presented bilaterally in a random fashion, or whether they were presented unilaterally to a pre-specified location. Moreover, it is not known whether both exogenous and endogenous saccades are produced to the target under either unilateral or bilateral target presentation, or for both of these conditions, though clearly exogenous attentional capture occurs quite often for peripheral distractors under bilateral target presentation. It is also unclear from the literature as to whether peripheral distractors have a distracting effect on every trial, or only on some trials for either or both types of target presentation. All of these issues need to be addressed in future work on the effects of remote distractors on saccade latency.

Findlay and Walker suggest that there are only very small effects of spatial selection on saccade latency but there are studies which show that prior knowledge of target location affects saccade latency (e.g. Abrams & Jonides, 1988; Weber & Fischer 1994) and indeed in both of those studies increased latencies and high error rates were reported (20 – 25%) for a condition where neither direction nor amplitude were cued compared to a condition where one of these was pre-cued. The independence of two separate processing streams in the Findlay and Walker model is questioned as a result of the findings from these experiments and those reported in this thesis for bilateral target presentation.

The oculomotor models of eye movement control presented in the introduction to this thesis offered accounts for low-level oculomotor effects and were not intended to offer specific explanations for higher-level cognitive influences on eye movement latency. As such they can offer no detailed account for the differential effects upon both saccade onset latencies and RDE magnitudes for the linguistic distractors presented at parafoveal locations in Experiment 6. What can be said about this finding is that clearly under some conditions higher-level linguistic variables do impact on low-level oculomotor behaviour in what is assumed to be a low-level oculomotor paradigm. This is interesting as it suggests that the oculomotor system is not modular since it is not entirely informationally encapsulated with respect to linguistic information. Additionally, the error data for linguistic versus non-linguistic distractors can offer something to the eye movement models in terms of their impact upon the 'where' aspect of eye movement control. In Experiment 1 no differences were observed between the linguistic and the non-linguistic distractors upon error rates. This would indicate that the 'where' system was unaffected by the different types of distractor and as such the influence of the distractors on the 'where' system was independent from their influence on the 'when' system, providing support for Findlay and Walker's model. However in Experiment 2 the linguistic distractors produced significantly more errors compared to the non-linguistic distractors. This therefore indicates that the distractors are impacting on both the 'when' and the 'where' systems and this is not advocated in Findlay and Walker's model, but does however support Godijn and Theeuwes model whereby it is hypothesised that the spatial and the temporal aspects of eye movements are integrated in a common saccade map.

The findings from the supplementary analyses for Experiment 6 have provided additional insights into the saccade latency system. Firstly, the finding that it takes longer to produce a saccade to a nearer rather than a further target is intriguing and is found not only when a central distractor is present, but also when no distractor is present. Surely this suggests that there is some effect of activity in the 'where' system which is impacting upon activity in the 'when' system in a way which would not be predicted by the Findlay and Walker (1999) model. In the case of a central distractor being presented simultaneously with the target it is possible that the target at 4 degrees eccentricity has a greater impact upon saccade latency because it produces a greater level of activity in the fixation zone of the SC than activity in this area for a target presented at 8 degrees eccentricity. This is however only a tentative explanation, and it is not clear whether the same effect is found under unilateral target presentation conditions. It is interesting though that the effect is also observed for single target trials. Latencies for single target trials in Experiment 6 were influenced by the type of distractor within the block that they were presented in. Such carry over effects are not predicted in any specific way by either the Findlay and Walker model or by Godijn and Theeuwes model. Clearly any differential inhibitory effects for the different types of distractor occurring at the level of the SC also apply for related single target trials.

The work on saccadic inhibition by Reingold and Stampe (e.g. 2002, 2003) is important here as it has demonstrated that transient onsets result in the inhibition of the production of saccades for a short time after onset, and moreover as a result of their findings the authors have suggested that in order to obtain RDE effects, the timing of the presentation of the target and distractor must be related to the saccade latency distributions in the single target trials. They offer, for example, an interpretation of findings from experiments investigating double target onset studies which suggests that the observed increases in saccade latencies for these experiments (Ross & Ross, 1980; Walker *et al.*, 1995) may be determined by both the timing delays between target and distractor onsets, and, the saccadic latency distributions for the single target conditions in these studies (Reingold & Stampe, 2002; 2003a; 2003b). Thus they argue that single target trials with long latency distributions will only show an effect on saccade latencies for remote distractors if there is a long target and distractor onset delay. Conversely, for short single target trial latency distributions, an effect of remote distractors will only be observed if there is a short target and distractor onset delay. The point about the preceding discussion is that single target trial latency distributions may influence whether or not RDE effects are observed for different onset delays.

7.7: Conclusion

Taken together, the findings for the six experiments reported in this thesis contribute to a variety of areas of research including visual processing, attentional allocation, models of eye movement control and automaticity of lexical processing. Detailed analyses of the data have provided insights into how complex distractors can have differential effects upon saccade onset latencies and RDE magnitudes, and to some extent the findings have raised as many interesting questions as they have answers. Whilst the findings do not exclusively support the use of the RDE paradigm for the study of the effects of higher level attentional and or cognitive influences that may play a part in oculomotor control, they do show that modulation of saccade onset latencies in the RDE paradigm can be sensitive to higher level cognitive factors under some conditions, and that this modulation is not entirely restricted to low-level visual effects.

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Appendices

Appendix A: Materials for Experiment 1

The materials used in Experiment 1 are shown in the table below. The size and font are not those used for presentation, see Chapter 2, materials for that information.

Type of Distractor

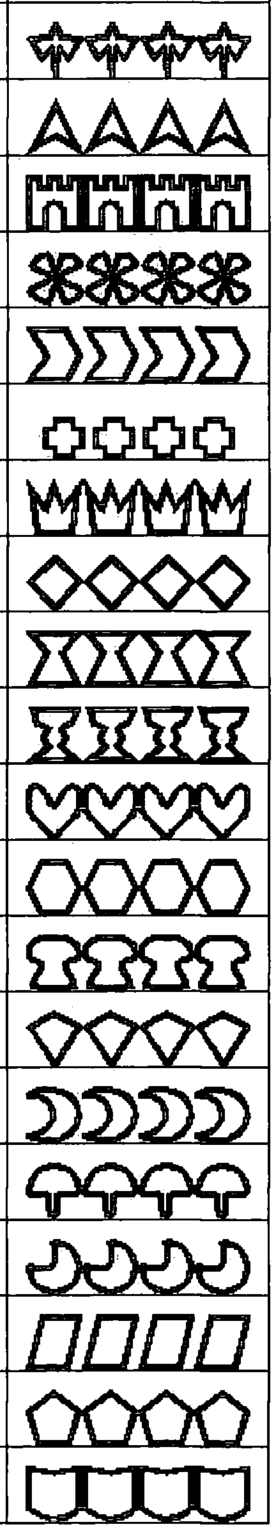
Word	Legal Non-word	Illegal Non-word	Uniform letter string	Uniform shape string
LOST	LUPT	LGNT	OOOO	□□□□
RANT	RELT	RDMT	AAAA	□□□□
NEST	NURT	NDHT	RRRR	□□□□
MARK	DURK	SFRK	VVVV	□□□□
PLAN	BLON	GLTN	QQQQ	□□□□
MEND	MING	MTNC	WWWWW	□□□□
FROM	KRIM	HRNM	ZZZZ	□□□□
CURL	DERL	NBRL	RRRR	□□□□
BEST	BUCT	BVGT	YYYY	□□□□
COST	CUSG	CBSW	PPPP	□□□□
LEFT	HOFT	CJFT	GGGG	□□□□
LONG	LANT	LDNC	ZZZZ	□□□□
DOWN	CAWN	HTWN	KKKK	□□□□
LIFT	LUFG	LMFN	YYYY	□□□□
FILM	FALG	FDLB	NNNN	□□□□
JUMP	SEMP	RFMP	AAAA	□□□□
PEST	PAFT	PGDT	CCCC	□□□□
STEP	STUG	STLR	AAAA	□□□□
DENT	DOPT	DKBT	FFFF	□□□□
FORD	NARD	TCRD	VVVV	□□□□
SHOP	THUP	BHWP	FFFF	□□□□
KART	KERN	KDRJ	BBBB	□□□□
PART	GORT	YKRT	SSSS	□□□□
CROW	CRIG	CRKB	BBBB	□□□□
FOND	DUND	SBND	LLLL	□□□□
OVER	UVIR	CVSR	JJJJ	□□□□
LEND	LONT	LBNR	MMMM	□□□□
REST	RUSB	RDSM	MMMM	□□□□
TALK	TIRK	TGHK	JJJJ	□□□□

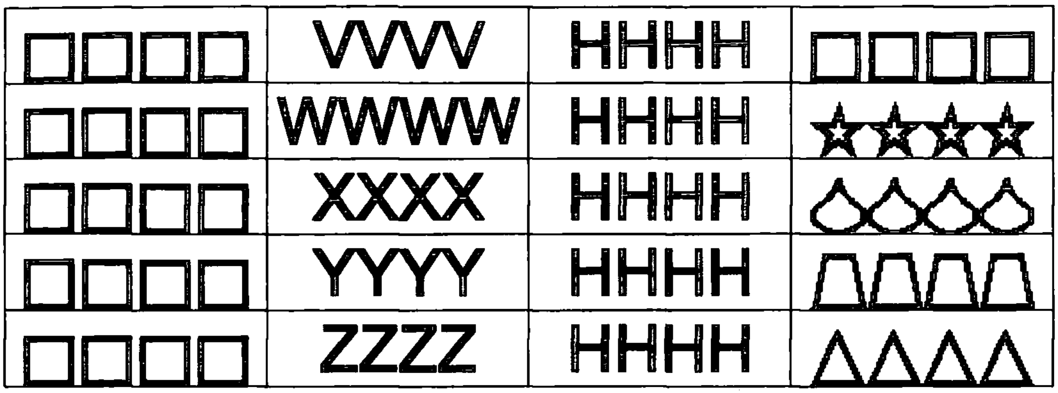
DENY	DOFY	DVKY	GGGG	□□□□
LAND	LENK	LWNF	TTTT	□□□□
KNOB	KALB	KCTB	EEEE	□□□□
MOST	MAWT	MNRT	PPPP	□□□□
GRAB	GLOB	GPHB	QQQQ	□□□□
BOWL	BARL	BNTL	NNNN	□□□□
RISK	ROLK	RNBK	EEEE	□□□□
PANT	PIFT	PBLT	DDDD	□□□□
BEND	BANT	BJNF	DDDD	□□□□
RAFT	ROFK	RJFH	HHHH	□□□□
HERB	HOLB	HFNB	SSSS	□□□□
FISH	FAGH	FCRH	CCCC	□□□□
SOFT	SEFK	SDFR	OOOO	□□□□
SPOT	SCET	SGBT	WWWW	□□□□
FIND	FURD	FMCD	TTTT	□□□□
MEAN	MION	MDFN	HHHH	□□□□
FAST	FOSC	FDSG	LLLL	□□□□
SEND	KOND	FTND	XXXX	□□□□
LIST	LESC	LNSG	BBBB	□□□□
TICK	JECK	GDCK	UUUU	□□□□
WALK	WULN	WTLP	KKKK	□□□□
MUST	MECT	MHKT	UUUU	□□□□
KIND	KERD	KSGD	XXXX	□□□□

Appendix B: Materials for Experiments 2 and 5

Type of Distractor (approximately same size as for the displays)

Constant shape string	Changing letter string	Constant letter string	Changing shape string
□□□□	AAAA	HHHH	
□□□□	BBBB	HHHH	
□□□□	CCCC	HHHH	
□□□□	DDDD	HHHH	
□□□□	EEEE	HHHH	
□□□□	FFFF	HHHH	
□□□□	GGGG	HHHH	
□□□□	HHHH	HHHH	
□□□□	JJJJ	HHHH	
□□□□	KKKK	HHHH	
□□□□	LLLL	HHHH	
□□□□	MMMM	HHHH	
□□□□	NNNN	HHHH	
□□□□	OOOO	HHHH	
□□□□	PPPP	HHHH	
□□□□	QQQQ	HHHH	
□□□□	RRRR	HHHH	
□□□□	SSSS	HHHH	
□□□□	TTTT	HHHH	
□□□□	UUUU	HHHH	



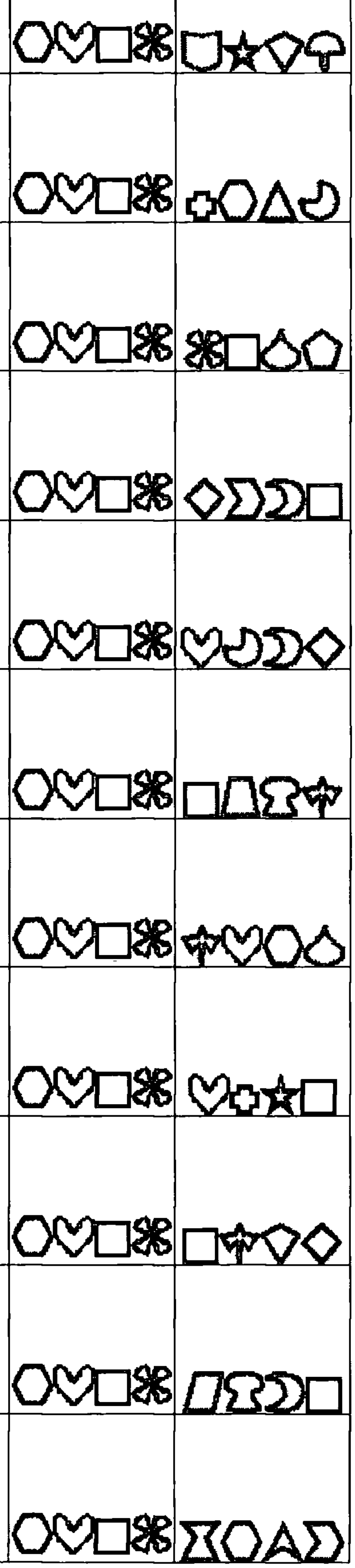

VVVV
HHHH
WWWW
HHHH
XXXX
HHHH
YYYY
HHHH
ZZZZ
HHHH

Appendix C: Materials for Experiment 6

Type of Distractor (size is about 80% of actual size in displays)

Constant word	Changing word	Constant illegal string	Changing illegal string	Constant shape string	Changing shape string
JUMP	CROW	RFMP	CRKB		
JUMP	SOFT	RFMP	SDFR		
JUMP	FROM	RFMP	HRNM		
JUMP	FISH	RFMP	FCRH		
JUMP	GRAB	RFMP	GPHB		
JUMP	DOWN	RFMP	HTWN		
JUMP	LOST	RFMP	LGNT		
JUMP	MARK	RFMP	SFRK		
JUMP	FORD	RFMP	TCRD		

JUMP	PART	RFMP	YKRT
JUMP	REST	RFMP	RDSM
JUMP	LEND	RFMP	LBNR
JUMP	HERB	RFMP	HFNB
JUMP	BEST	RFMP	BVGT
JUMP	KIND	RFMP	KSGD
JUMP	STEP	RFMP	STLR
JUMP	LIST	RFMP	LNSG
JUMP	NEST	RFMP	NDHT
JUMP	LONG	RFMP	LDNC
JUMP	FAST	RFMP	FDSG



JUMP	OVER	RFMP	CVSR		
JUMP	MEAN	RFMP	MDFN		
JUMP	SPOT	RFMP	SGBT		
JUMP	KNOB	RFMP	KCTB		
JUMP	TALK	RFMP	TGHK		

Appendix D: The RDE magnitudes for all Experiments

The tables below show the eccentricity and type of distractor (column 1), the mean eye movement latencies (column 2), the RDE magnitudes (column 3), the baseline single target latency (column 4) and the RDE magnitude discrepancy, between the results for these experiments and those reported by Walker *et al.*, (1997) for central (40ms) and peripheral (15ms) distractors (column 5).

Expt 1

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	233	53	180	13
PERIPH	220	40		25
CH.CENT	235	55		15
CH.PERI	220	40		25
CON.C	225	45		5
CON.P	221	41		26

Expt 2

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	212	42	171	2
PERIPH	208	37		22
CH.CENT	215	45		5
CH.PERI	208	37		22
CON.C	209	39		-1
CON.P	208	37		22

Expt 3

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	251	24	227	-16
PERIPH	262	36		21

Expt 4

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	224	32	192	-8
PERIPH	205	13		-2

Expt 5

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	223	33	190	-7
PERIPH	204	14		-1
CH.CENT	226	36		-4
CH.PERI	206	16		1
CON.C	226	36		-4
CON.P	201	12		-3

Expt 6

Dist	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	205	23	182	-17
PERIPH 4	208	26		11
PERIPH 8	203	20		5
CH.CEN	206	24		-16
CH.P4	208	26		11
CH.P8	203	21		6
CON.CEN	204	21		-19
CON.P4	208	25		10
CON.P8	202	20		5

word	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	207	22	185	-18
PERIPH 4	213	28		13
PERIPH 8	207	22		7
CH.CEN	209	24		-16
CH.P4	214	28		13
CH.P8	206	21		6
CON.CEN	205	20		-20
CON.P4	213	28		13
CON.P8	208	23		8

illegal	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	206	23	184	-17
PERIPH 4	208	24		9
PERIPH 8	203	19		4
CH.CEN	207	23		-17
CH.P4	208	25		10
CH.P8	205	21		6
CON.CEN	206	22		-18
CON.P4	208	24		9
CON.P8	201	17		2

shape	mean Lat	Dist-ND	nd	Discrepancy
CENTRAL	201	23	178	-17
PERIPH 4	202	24		9
PERIPH 8	198	20		5
CH.CEN	203	25		-15
CH.P4	203	25		10
CH.P8	198	20		5
CON.CEN	200	22		-18
CON.P4	202	24		9
CON.P8	198	20		5