2009

Effects of Context on Target Localization

Cheryl M. Lavell
Wilfrid Laurier University

Recommended Citation

Lavell, Cheryl M., "Effects of Context on Target Localization" (2009). *Theses and Dissertations (Comprehensive)*. 939.
http://scholars.wlu.ca/etd/939

Library and Archives Canada
Bibliothèque et Archives Canada

Published Heritage Branch
Direction du Patrimoine de l'édition

395 Wellington Street
Ottawa ON K1A 0N4
Canada

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 978-0-494-54234-7
Our file Notre référence
ISBN: 978-0-494-54234-7

NOTICE:

The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

AVIS:

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

Canada

EFFECTS OF CONTEXT ON TARGET LOCALIZATION

by

Cheryl M. Lavell

Wilfrid Laurier University

THESIS

Submitted to the Department of Psychology

in partial fulfillment of the requirements for

Master of Science, Brain & Cognition

Wilfrid Laurier University

Author: Cheryl Lavell
Cognition in Action Laboratory
Department of Psychology
Wilfrid Laurier University
Waterloo, Ontario, Canada

Supervisor: Dr. Sukhvinder S. Obhi
Cognition in Action Laboratory
Department of Psychology
Wilfrid Laurier University
Waterloo, Ontario, Canada

Advisory Committee: Dr. Jeffery A. Jones
Cognitive Neuroscience of Communication Laboratory
Department of Psychology
Wilfrid Laurier University
Waterloo, Ontario, Canada

Dr. William E. Hockley
Memory Laboratory
Department of Psychology
Wilfrid Laurier University
Waterloo, Ontario, Canada

Dr. James Danckert

Danckert Attention and Action Group

Department of Psychology

University of Waterloo

Waterloo, Ontario, Canada

Abstract

The purpose of this thesis was to investigate how the presence of non-target objects can influence the planning of a movement towards a remembered target location. One specific aim was to examine how the temporal effects of the task could affect movement planning. The final aim of this thesis was to examine whether or not the mere presence of extrinsic cues can suppress the encoding of intrinsic cues.

It was found that when non-target objects are presented simultaneously with the target, interference occurs; however, if the non-target objects are presented at least 250 ms in advance of the targets performance improved. The results also revealed that uncertainty regarding trial type altered participants' response strategy. It appears as though when participants can anticipate when the response is required, they plan the movement as the trial progresses, however, it appears as though when there is uncertainty participants either suppress their movement plan or hold the representation of target location and only plan the movement when uncertainty has been resolved. Furthermore, the results of Experiments 3 and 4 indicated that participants automatically encode target location within an extrinsic reference frame when non-target objects are available. The principal conclusion was that movement planning is clearly affected by the presence of non-target objects.

Keywords: Context, Landmarks, Distractors, Movement Planning, Reliability, Response Competition, Motor Control

Acknowledgements

First and foremost, I would like to thank my advisor Dr. Sukhvinder S. Obhi who provided me with the opportunity to pursue research in psychology. His expertise, guidance and many constructive comments have greatly improved this work.

This thesis could not have been completed without the assistance of all members of the Cognition in Action Lab. A special thank you to Dr. Lars Strother for our many discussions, your insight has greatly influenced this thesis. I would also like to thank Shannon Matkovich; this experience would not have been the same without you. Thank you for your advice, encouragement and most importantly your friendship. And to Michelle Murry, Kristin Murch, Tiffany O'Conner, Preston Hall, and Bobby Frazer: thank you for your friendship and support throughout this project.

I would like to express my appreciation to my family for their unconditional love and support. Finally, to Paul Sniuolis, for reminding me that I should be working on my thesis; thank you.

The work presented in this thesis was conducted in the Cognition in Action Laboratory at Wilfrid Laurier University. This work was financially supported by the Ontario Graduate Scholarship (OGS), thank you to Dr. Jim Lyons and Dr. Tim Lee for their help in obtaining this funding.

Table of Contents

List of Figures

GENERAL INTRODUCTION

The work described in this thesis concerns the influence of visual information on the planning and execution of movements. Almost all of our movements occur in the presence of visual information; however, much of the visual information available is irrelevant to the planning and execution of those movements. In order to make an accurate movement towards a target object, we must be able to distinguish between relevant and irrelevant visual information. The aim of the research presented in this thesis is to broaden our collective knowledge regarding the use of contextual information, information obtained from the presentation of non-target objects in the visual display, during the planning of a movement

Although context has been shown to influence the corrective phase of a movement, this is not the focus of this thesis. Rather, this work will focus primarily on the planning stages of the movement. In order to address the planning aspect of movement, all but one of the studies in this thesis involve occluding participants' vision as soon as their movements have begun. Participants however, have full vision in the third experiment as it is a partial replication of a previous experiment by Sheth and Shimojo (2004), who did not occlude participants' vision during their movements. To reiterate, for three experiments reported in this thesis, visual feedback is removed in an attempt to isolate the planning stages of the movement. The aim of this thesis is to address various ways in which context can affect the planning of movement. It seeks to expand upon the current understanding of how movements are produced when external stimuli are present.

Through an examination of the existing literature I will address temporal and spatial effects of context on planning movements. This thesis will then outline the methods, results, and provide a brief discussion of four novel experiments that examined the role of context on movement planning. The first two experiments address temporal effects of context and a comparison of the results from these experiments will be discussed at the end of their individual sections. The final two experiments address the spatial and reliability effects of context. Finally a discussion of all four experiments will be presented.

Temporal Effects of Context

As mentioned, two of the four experiments will address the temporal effects of context on target localization. The first experiment will examine how the timing in which stimuli are presented can affect how a movement is planned and the second experiment will address how the time in which participants respond can affect motor preparation.

A clever series of experiments by Tipper and colleagues (Tipper, Lortie, & Baylis, 1992; Meegan & Tipper, 1998; Meegan & Tipper, 1999) have addressed how non-target objects presented simultaneously with targets affect the planning and execution of movements. It has been demonstrated that when targets appear simultaneously with non-target objects, participants have a difficult time in quickly and accurately pointing to the target location: participants will often require a longer time to respond to a movement cue or they will point to a location midway between the two objects. Tipper and colleagues (1992, Meegan & Tipper, 1998) were able to demonstrate that the location of non-target objects affects the response times of participants. In their experiments, participants were required to reach to the target (a button with a red light) that could occur randomly at one of nine locations; non-target objects (a button with a yellow light) could also occur at any of the possible target locations. It was found that non-target objects that occurred between the starting position of the hand and the target location produced the longest reaction times. The term "interference" has been used to describe the increase in reaction time or error when responding to a target while non-target objects are present (Tipper et al, 1992). In a continuation of this study, Meegan and Tipper (1998) showed that non-target objects in the hemispace ipsilateral to the hand being used also produce greater interference than non-target objects presented in the contralateral space. It has been argued that objects that occur ipsilateral to the target or that occur near the starting position of the hand result in greater error because the non-target objects create more competition with the target for motor output at these locations (Tipper et al., 1992; Meegan & Tipper, 1998). When participants were required to respond verbally instead of manually, the spatial effect of non-target objects was not shown, suggesting that interference is caused by some aspect of the response, which supports the notion of response competition (Meegan & Tipper, 1999).

The authors believe that motor programs are created in parallel for both the target and non-target objects and as such, movements towards the target will result in a biased position or increased reaction time due to the activation of motor programs for both objects. Under a late selection view of selective attention, all objects in the visual field are processed (within the capacity limits of the system) and as such, separate motor programs may be created for the hand to move towards both the target and non-target object. When the two objects appear simultaneously, the motor programs are thought to be created in parallel: as a result, either additional time is required to select the appropriate motor program or both motor programs are activated, resulting in a movement that is centered between the location of the two objects.

This spatial distortion of target location has been replicated and expanded upon by other researchers. It has been found that when a target is presented simultaneously with a non-target object and the non-target object is visible during the movement, participants' pointing endpoints are biased towards the direction of a non-target object (Diedrichsen, Werner, Schmidt, & Trommershauser, 2004). When looking at timing of these effects, the authors noticed that the spatial distortion is due to the presentation of the non-target object during the encoding phase of the task (Diedrichsen et al., 2004). In fact, when non-target objects were presented only during the movement phase, pointing endpoints were distorted away from the landmarks, a different pattern than was found during the encoding phase. The encoding phase of a movement is the period in time in which incoming stimuli are perceived and transformed into preexisting knowledge structures (Schacter, 1990). In the following experiments the encoding phase occurs when the target is presented along with the non-target objects.

The authors also found that spatial distortion was evident even with short retention intervals (the time between presentation of target and movement cue). Although distortion increased with increasing retention intervals, distortion was present at the smallest retention interval used (150 ms) (Diedrichsen et al., 2004). The increased distortion may result from an increased deterioration of the egocentric representation of the target. It has been shown that egocentric representations, wherein target location is encoded with respect to the observer (i.e., the observers' head, eye, or hand), quickly decay (Bridgeman, Perry, & Anand, 1997; Westwood & Goodale, 2003). When movements are made after a delay, we instead rely on allocentric representations of the world, wherein target location is encoded with respect to other objects in the visual scene (Goodale, Jakobson, & Keillor, 1994; Bridgeman, Perry, & Anand, 1997; Hu & Goodale, 2000; Westwood & Goodale, 2003).

Although it is well documented that non-target objects hinder performance when they are presented simultaneously with a target this phenomenon seems not to occur when non-target objects are presented prior to target presentation. It has been suggested that when the non-target object(s) is present before the onset of the target, response competition may diminish. For example, when two non-target objects were presented to participants for 1000 ms before the target appeared, it was found that the non-target objects significantly improved pointing accuracy, especially when a delay occurs before the movement may begin (Obhi & Goodale, 2005). The different degrees of accuracy between this experiment and those mentioned earlier suggest that response competition between a target and non-target object may diminish when the non-target is viewed in advance of the target. In this way, the non-target objects may provide a stable context for the motor planning process to operate within. However, it is currently unknown how long the non-target object must be viewed prior to target presentation to receive this benefit. The first experiment seeks to address that question: it asks at what point in time do non-target objects in the environment act as distractors and hinder performance, or as landmarks and facilitate performance.

While Experiment 1 addresses the time interval between the presentation of target and non-target objects, Experiment 2 focuses on whether context affects performance differently in immediate and delayed conditions. Movements that are made immediately after a display has been presented or that are made after a delay, are thought to be guided by different underlying neural processing streams. The dorsal stream, a processing stream originating at the primary visual cortex extending dorsally to the posterior parietal cortex, is involved in processing visual input to control one's actions (Goodale & Milner, 1992; Milner & Goodale, 1995; Goodale, Króliczak, & Westwood, 2005). Specifically, the dorsal stream has been suggested to compute the absolute metrics of a target within a coordinate system based on the effector (head, eye, hand, etc.). This processing stream is believed to explain how one is able to make accurate movements towards objects in our visual field. However, the representation of the dorsal stream is thought to decay soon after the target is removed from view (Elliot and Mandalena, 1987; Milner & Goodale, 1995). Thus, when one is required to make actions towards objects that have been removed from our visual field for an extended period (for instance over 2000 ms), the dorsal stream may not be responsible for guiding our actions. It is believed that in these situations, we are able to use a representation from the ventral stream to guide our movements. The ventral stream, which also originates at the primary visual cortex and progresses ventrally to the infero-temporal cortex, is thought to be involved in creating a perceptual representation of objects based on visual input (Ungerleider & Mishkin, 1982; Milner & Goodale, 1995). The ventral stream is thought to preserve the relationship between objects and their surroundings without respect to absolute metrics, which allows us to form a perceptual representation of the world (Milner & Goodale, 1995).

As mentioned, when movements are made to remembered target locations after a delay, it appears as though the dorsal stream, at least by itself, is not responsible for planning the movement. Studies involving visual illusions provide support for the notion that representations from the ventral stream are used to guide movements made after a delay. For instance, Westwood and Goodale (2003) found that when a delay occurred before the movement, participants were susceptible to a size contrast illusion whereas when they were required to make real-time movements they accurately responded to the veridical size of the objects. This finding implies that when the delay is present, the visuomotor system utilizes perceptual mechanisms presumably in the ventral stream to guide movements. In other words, when a delay was present, participants remembered the size of the target relative to the size of the non-target object. This relationship would not have been preserved by dorsal stream processing, however, the relationship between the target and non-target object would be preserved through ventral stream processing, suggesting that the representations from the ventral stream may be used to guide delayed movements.

Obhi and Goodale (2005) were among the first to examine whether non-target objects can affect performance differently depending on the time in which participants were required to respond. They found that the presence of landmarks (non-target objects) improved participants' accuracy in both delayed and immediate conditions and the precision of movements was improved in the delay condition only (Obhi & Goodale, 2005). The authors argue that precision was improved in the delayed condition, as participants rely more on extrinsic cues, the non-target objects, for delayed rather than immediate movements. Extrinsic cues are those aspects of the environment, separate from the target or the observer, which may be incorporated into a representation of target location whereas an intrinsic cue is an internal egocentric cue that may be incorporated into a representation of target location.

With the knowledge that movements are guided by different processing streams based on when a response is required, it was investigated whether a simultaneous presentation of target and non-target objects would have the same detrimental effect on immediate and delayed movements. As well, we were interested in investigating whether a large stimulus onset asynchrony (SOA) between the non-target objects and the target would benefit performance equally on the two types of movement. Taken together, these first two experiments seek to broaden our understanding of how context can affect performance based on the temporal features of the task.

Spatial and Reliability Effects of Context

The final two experiments in this thesis will address how context can affect the planning of movements based on the spatial features of the display and how reliable those features are. Based on work by Sheth and Shimojo (2004), the third experiment will address whether changes in the location of non-target objects will alter participants' ability to accurately recall target location. Building on this third experiment, the final study explores how context is used depending on how reliable the non-target objects are.

When extrinsic cues are available, it is possible to encode target location in an allocentric (Goodale & Milner, 1992), egocentric (McIntyre, Stratta, & Lacquaniti, 1998), or both allocentric and egocentric representation (Carrozzo, Stratta, McIntyre, & Lacquaniti, 2002). However, it appears as though participants preferentially encode the location of a target in an allocentric frame of reference. In experiments where the extrinsic cues shift location after the encoding phase, participants estimate the target location as being in the same direction and with relatively the same magnitude as the shift in extrinsic cue location (Lemay, Bertram, & Stelmach, 2004; Sheth & Shimojo, 2004). That is, endpoint location is biased by the shift in extrinsic cues. As well, Lemay and colleagues (2004) found that participants were more accurate when pointing to targets presented near the visual context. This finding implies that not only does the presence of visual context affect movement, but the location of visual context is also important.

Sheth and Shimojo (2004) completed a series of three experiments where participants were required to point, using a cursor, to a remembered target location. In the first experiment, the target was presented either in isolation or with a crosshair and a landmark, a " | ": it was found that participants were equally precise in the two conditions. In the following two experiments, the crosshair and landmarks were always present at the time when the target was encoded; however, the stability of the crosshair and landmarks were altered. It was found that if the crosshair and landmarks were removed or shifted after a delay period, the participants' estimate of target location was less precise. It is important to note that unless the non-target objects were removed, they were fully visible during movement.

The authors believe that when non-target objects are present, participants automatically encode the location of the target relative to the location of the non-target objects. On trials when the non-target objects remain stable, they serve as an accurate retrieval cue; however, when the non-target objects are removed or shifted after a delay, they no longer provide an accurate retrieval cue for the target's location and performance is negatively affected. Experiment 3 seeks to replicate the results found in Sheth and Shimojo's third experiment using a more natural situation – pointing with the finger, instead of a cursor. As well, Experiment 3 addresses whether participants' knowledge that the location of the non-target object may shift will affect the strategy used to encode and recall target locations.

Previous experiments that shifted or removed non-target objects prior to movement used a mixed trial design where the non-target objects were equally likely to shift or remain stable. In these situations, participants may have preferentially adopted a strategy to use an allocentric representation of the target in anticipation for the non-target objects to re-appear and serve as a reliable retrieval cue. Sheth and Shimojo (2004) argue that the mere presence of extrinsic cues dominates and suppresses the formation of an intrinsic representation of target location; however, this may not be the case. It is possible, that if participants are aware that the non-target objects are not stable, that they may selectively encode target location using only intrinsic cues. Experiment 4 seeks to address whether participants automatically encode target location in relation to extrinsic cues, or whether an intrinsic representation may be utilized in appropriate circumstances.

To address whether or not non-target objects are most beneficial during the movement planning phase of a movement or during the execution of the movement, Fischer, Pratt and Adam (2007) conducted an experiment where placeholders were presented either 500 ms before target onset, simultaneously with target onset, or at movement onset. They demonstrated that the allocentric information is most useful during the movement planning phase and that the presence of visual structure during movement planning has been shown to modulate either side of the speed-accuracy tradeoff (Fischer et al., 2007). As in the Experiments 1 and 2, the knowledge that visual structure is most beneficial at this time guides us to again focus on the planning of the movement. As mentioned earlier, Experiment 3 is derived from Sheth and Shimojo's third experiment, to ensure compatibility with their experiment, vision will not be occluded in this experiment. However, to ensure the planning phase of the movement is examined in Experiment 4 participants' vision was occluded immediately prior to their response. The open-loop nature of Experiment 4 provides the opportunity to focus on the planning of the movement without any major contribution of control mechanisms. As well, a recall delay of approximately two seconds will be used in Experiments 3 and 4. Because these experiments examine the role of context on behaviour we are using a recall delay to optimize the likelihood that extrinsic cues are incorporated into the representation of target location.

EXPERIMENTS

Effects of SOA and Response Delay on Target Localization

Experiment 1

It can be difficult to make a movement based on the characteristics of one object when a variety of objects are presented simultaneously. For example if you are playing Whac-A-Mole at a fair (a game where players seek to hit a mole that could appear at one of many locations) and objects other than the mole appear at the same time as the mole it is difficult to quickly hit the mole without hitting the other objects instead. However, if the other objects are always present and only the mole appears suddenly, it is much easier to hit the mole quickly. When non-target objects are presented at the same time as a target, they can distract us from the target and it is difficult to activate a motor program to act on the target alone. However, when the non-target objects are stable, they are no longer competing for attention or motor output. This first experiment seeks to address how long we need to view non-target objects in advance of the target to have this benefit in performance.

In order to determine the point in time where objects serve as distractors and hinder performance or act as landmarks and enhance performance the SOA was varied between the presentation of non-target objects and the target. SOA's beginning at 0 ms were used as it has been demonstrated that when targets and non-target objects are presented simultaneously the competition for motor output effectively ensures the non-target object will act as a distractor (Tipper et al., 1992; Meegan & Tipper, 1998). The largest SOA used was 700 ms as longer SOA's have been suggested to benefit movement planning (Obhi & Goodale, 2005).

As suggested earlier, it is believed that when non-target objects are presented simultaneously with targets, motor programs are created in parallel for each of the stimuli and response competition ensues to determine which movement is produced (Tipper et al., 1992; Meegan & Tipper, 1998; Meegan & Tipper, 1999). Through late selection, a process in which all objects in the visual scene are processed prior to selection, it is believed that this processing leads to activation of movement programs for all of the stimuli. However, in order for the participant to make a correct, goal directed movement, only one of these motor programs can be selected. Houghton and Tipper (1994) have proposed a model of selective attention to explain how one motor program is selected over the other. They suggest that a negative feedback loop is used to suppress the activation of a motor program for the distractor, whereas a positive feedback loop is used to activate the motor program for the target. It is proposed that this inhibition of irrelevant motor programs requires some processing time. It is possible that if the non-target objects are presented prior to the target, the activation and subsequent inhibition of inappropriate motor programs will occur before target presentation. Thus, when the target is finally presented only the correct motor program will be activated and the participant will be able to point quickly and accurately to the appropriate location.

It is expected that we will see a gradual change in reaction time and/or magnitude of error with larger error for trials that have shorter SOA's and smaller error for trials that have larger SOA's. It is hypothesized that the transition from distractor to landmark may be gradual in that as the SOA increases, the participant will increasingly be able to inhibit motor programs for non-target objects before the onset of the target thus gradually resolving response competition. If this hypothesis is true, one would expect to see errors largest at the 0 ms SOA and that the magnitude of error will decrease for each subsequent SOA. However, it may also be possible that a change in the magnitude of reaction time or error is not gradual; the results may show that reaction times or error levels are high and reasonably consistent until response competition has been fully resolved, at which point error levels would significantly decline. Under this scenario, all short SOA's would have a similar magnitude of error and all large SOA's would have a similar magnitude of error which would be much lower than that of the short SOA's. A final possibility is that neither response measures nor error will alter as a function of SOA. Although evidence from Obhi and Goodale (2005) would suggest this possibility is unlikely, this scenario would imply that the movement plan towards non-target objects could not be fully inhibited.

Methods

Participants. Twelve participants (4 male, 8 female) with a mean age of 20.5 years completed this experiment. All participants were right handed and received course credit for their participation. Procedures were in accordance with the Wilfrid Laurier University Research Ethics Board and participants provided written and informed consent.

Procedure. A manual pointing task was used in this experiment where participants were required to remember the location of a target and point to it after hearing an auditory movement cue. To test if the time course of events determines whether non-target objects acted as distractors or landmarks, the time between the presentation of the non-target objects and the presentation of the target (the SOA) was varied. Five SOA conditions (0 ms, 50 ms, 250 ms, 500 ms and 700 ms) were randomly presented to the participants, followed by a final block wherein the target was presented in the absence of non-target objects. The experiment was completed in a completely dark room to control the amount of visual information that was available to the participant.

Participants were given a verbal warning cue at the onset of each trial signaling to the participant that a new trial was about to begin. Approximately 1500 ms later, the two non-target objects were illuminated. Prior to the experiment, two independent observers ensured that no additional visual information was given when these two objects were illuminated (for instance on account of increased levels of illumination in the room). As displayed in Figure 1, after varying SOA's (0 ms, 50 ms, 250 ms, 500 ms and 700 ms) the target, a Light Emitting Diode (LED) placed within the display board, appeared randomly in one of four possible locations. The four possible target locations were dispersed evenly along an imaginary horizontal line between the two non-target objects. The whole scene, with the target and the two non-target objects remained visible for 100 ms. At this point in time an auditory cue was presented, vision was occluded, and participants were required to point to the remembered target location as quickly and accurately as possible. Each unique situation occurred ten times, resulting in 320 trials (8 SOA x 4 locations x 10 occurrences) and participants were given a break every 32 trials.

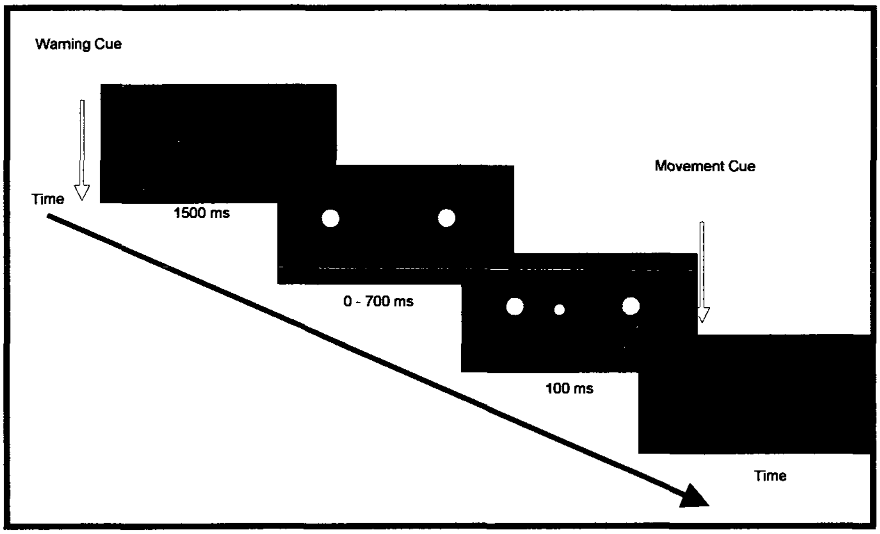


Figure 1. Order of events for Experiment 1; note the time between the presentation of the first and second screens depended on the SOA used in that specific trial.

In addition, a final block occurred in which the target was presented in the absence of any non-target objects. Figure 2 illustrates the timeline of events for trials in the final block. In these trials, approximately 1500 ms after a verbal warning stimulus, a target randomly appeared in one of four possible locations for 100 ms. An auditory cue was then presented, vision was occluded and participants were to point as quickly and accurately as possible to the remembered target location. This final block consisted of five trials for each of the four possible target locations, resulting in 20 trials where only the target was presented.

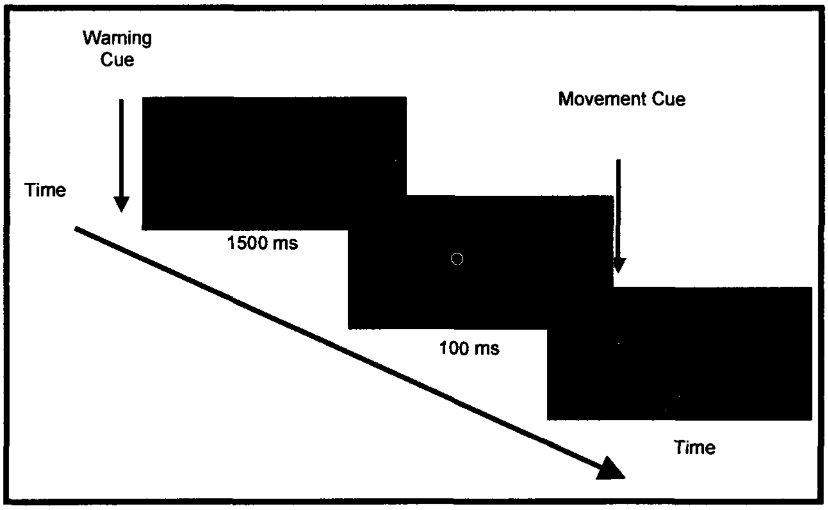


Figure 2. Order of events for the final block in Experiment 1.

All participants received 10 practice trials before the experiment began to become accustomed to the experimental protocol. Each SOA was presented twice and targets were presented randomly at all four target locations. Participants confirmed they were comfortable with the procedure before the experiment began.

All stimuli, aside from an auditory tone, were presented on a custom-made LED display board that lay horizontally in front of the participant. Participants wore liquid crystal goggles (PLATO Visual Occlusion Spectacles, Translucent Technologies, Toronto, ON) during the experiment so that responses were not influenced by visual feedback and all finger movements were recorded by an Optotrak motion tracking system

(Cedrus Optotrak, NDI, Waterloo, ON) through an Infrared Emitting Diode (IRED) placed on the tip of the participant's right index finger. Figure 3 illustrates the experimental set-up.

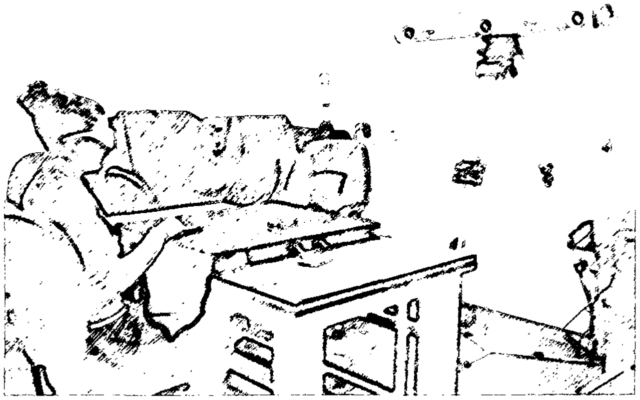


Figure 3. The experimental set-up.

Data Collection and Statistical Analysis. Kinematic data was recorded by an OPTOTRAK ™ optoelectronic movement recording system through an IRED placed on the top of the participant's right index finger. Data was recorded in x, y, and z coordinates and was sampled at 200 Hz. All data was collapsed across target locations.

Reaction time (RT), movement time (MT), error, and variability of error were calculated and subjected to statistical analysis. RT was identified as the difference in time between the movement (i.e., auditory) cue and the onset of movement. The onset of movement was defined as the point at which velocity of the right index finger exceeded 20 mm/s for five consecutive samples (Obhi & Goodale, 2005). MT was identified as the difference between the onset of movement and the completion of movement. In a similar fashion, the end of movement was defined as the point in which velocity of the right index finger fell below 20 mm/s for five consecutive samples. Participant's error was analyzed to determine where participants estimated the target to be located relative to its true position. Since target position was identified by a pair of x, y coordinates, a resultant vector for error was calculated for each participant's endpoint location for each trial. The resultant vector error was calculated as:

$$\text{Resultant Error}^{*} = \sqrt{(\text{endpoint } x \text{ position} - \text{target } x \text{ position})^{2} + (\text{endpoint } y \text{ position} - \text{target } y \text{ position})^{2}}$$

* for the remainder of the thesis the resultant error will be referred to simply as "error".

Finally, variability of error, the standard deviation of error, was measured. Repeated measures ANOVAs were calculated for RT, MT, Error, and variability of error and pair wise comparisons were made for all significant ANOVA's. Note that Greenhouse-Geiser corrections were used throughout the analysis.

Trials were excluded from analysis if RT was below 200 ms (deemed as an anticipatory response) or above three standard deviations away from the median RT in that condition (deemed as missed trials). As well, trials were excluded if error was greater than three standard deviations away from the median of each condition. Median measures were obtained for each participant in all conditions as the data from a number of participants presented a skewed distribution and a group mean was established from these values (Gravetter & Wallnau, 2004).

Results

Reaction Time. Data was entered into a one factor repeated measures ANOVA and yielded a significant main effect of SOA in RT: F (1.325, 14.570) = 6.906, p = 0.014. In particular, planned comparisons (uncorrected two tailed t-tests) demonstrated that there was no significant difference between the SOA 0 and SOA 50 conditions in RT (t (11) = 1.569, p = 0.145). However, planned comparisons between SOA 0 ms and all other SOA conditions revealed significant differences in RT (i.e., SOA 250 ms: t (11) = 2.646, p = 0.023; SOA 500: t (11) = 2.202, p = 0.050; SOA 700: t (11) = 2.118, p = 0.058). The same was true for planned comparisons between SOA 50 ms and all other SOA conditions (250 ms: t (11) = 3.387, p = 0.006; 500: t (11) = 2.572, p = 0.026; 700: t (11) = 2.318, p = 0.041). Additionally, planned comparisons yielded no significant difference in RT between SOA 250 and SOA 500 (t (11) = -1.154, p = 0.273), SOA 250 and SOA 700 (t (11) = -0.191, p = 0.852) or between the SOA 500 and SOA 700 conditions (t (11) = 0.844, p = 0.417). Figure 4 illustrates the mean RT for all participants in each condition.

Planned comparisons also revealed a significant difference in RT between the No Landmark Condition and all other conditions, except for 250 ms (0 ms: t (11) = 3.503, p = 0.005; 50 ms: t (11) = 4.918, p<0.000; 250: t (11) = 2.122, p=0.057; 500: t (11) = 2.607, p = 0.024; and 700: t (11) = 1.788, p = 0.101).

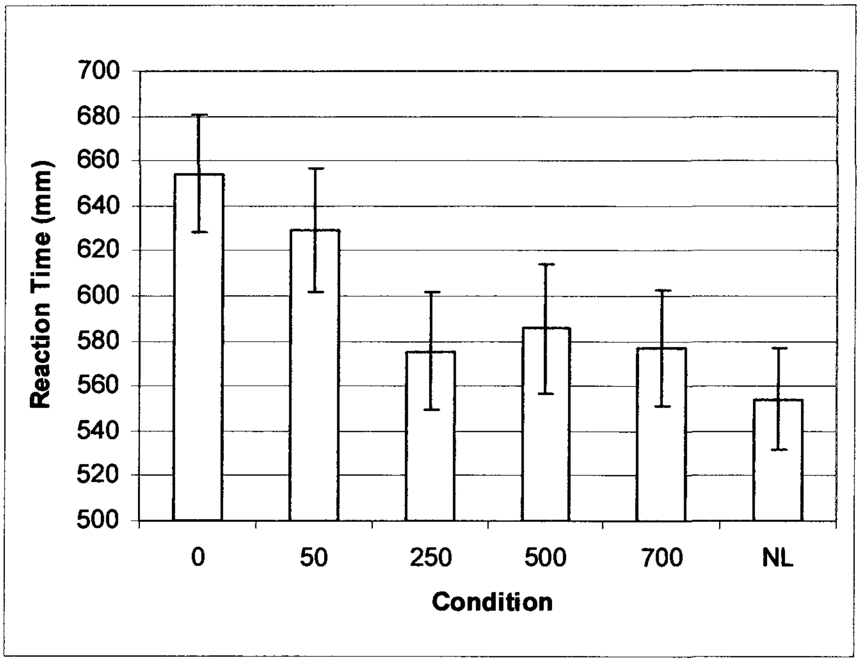


Figure 4. The effect of SOA on reaction times (in ms) for each condition; error bars indicated standard error.

Movement Time. The one factor repeated measures ANOVA revealed no significant main effects of SOA on movement time (F (1.012, 11.137) = 0.724, p = 0.414).

Error. As well, no main effect of SOA was observed in the error measure (F (1.328, 14.613) = 2.044, p = 0.173).

Variability of Error. A one factor repeated measures ANOVA demonstrated no main effect of SOA in variability of error (F (1.219, 14.171) = 2.765, p = 0.112).

Discussion

By looking at the response time and magnitude of errors, this experiment sought to address whether the time course of events can cause a non-target object to act as a distractor, and hamper performance, or a landmark, and improve performance. Specifically, the question asked was whether presenting non-target objects in advance of a target (at varying SOA's) would hinder or facilitate performance on this task. The results indicate that when non-target objects are presented simultaneously with or immediately before the presentation of the target, participants are slower to react to the movement cue compared to when the non-target objects are presented at least 250 ms before the target. These results show that non-target objects negatively affect movement planning when presented in close temporal proximity to a target and however, when the non-target objects are presented in advance of the target participants are able to ignore the non-target objects more efficiently. It appears as though this competition can be resolved when non-target objects are presented between 50 ms and 250 ms before the target. This result confirms the hypothesis that presenting non-target objects in advance of a target will improve performance relative to when all objects are presented simultaneously. The effect of SOA was exclusively related to RT; neither MT nor errors were affected by the differing SOA's. Interference was also exclusively observed in RT by Tipper and colleagues (1992) and Meegan & Tipper (1998). By subtracting the RT in each condition from the RT in a baseline No Distractor condition, they determined the amount of interference for each condition. Again they found the most interference, the longest RT, occurred when the non-target object was presented simultaneously with the target object in a location closest to the hand or that was ipsilateral to the responding hand.

As Tipper and colleagues discussed, when non-target objects are presented simultaneously with targets, response competition may occur. If all objects in the environment are processed, and a motor program is created for each of these objects as soon as they appear, then a certain amount of time would be required to inhibit motor programs for irrelevant objects and to activate the motor program for the target object. This theory could well explain why RT was longer for trials in which the non-target objects were presented in close temporal proximity to the target. In these trials, participants had very little time to select the appropriate motor program before the movement cue occurred. However, in trials in which the SOA was greater than 250 ms, participants may have been able to inhibit the motor program for the non-target objects before the target appeared, thus at the time of the movement cue there was no competition for motor output.

Another possible explanation is that when non-target objects are presented simultaneously with targets, the objects compete for attention. The target and non-target objects may have been perceptually grouped due to their close temporal and spatial proximity in which they were presented. When this occurs, it is difficult to isolate one element from the display and as such, it would take longer for participants to create a motor program for one element of the display (Julesz, 1975). However, when the non-target objects are presented in advance of the target, it is thought that perceptual grouping would not occur, thus participants would be able to react faster in these conditions.

Additionally, when non-target objects are presented in close temporal proximity to the target, attention may have been distributed more broadly across the display (Eriksen & St. James, 1986). Again, a certain amount of time would be required to focus on the target and create a motor program to move towards it. While attention may be widely distributed during short SOA, a longer SOA may actually serve to focus attention on the relevant location. When non-target objects are presented in advance of the target, participants may be able to narrow their focus of attention towards the space between the two objects, the area in which all targets were located. Murphy and Eriksen (1987) demonstrated that when an object is presented in advance of a target, attention is concentrated to the precued location. The authors suggested that during short SOA's attention was distributed evenly over the entire display area with a parallel processing of all stimuli; however, as the SOA between a cue and the target increased, processing efficiency for nearby stimuli increased.

The results found that in Experiment 1 participants were faster to respond in the No Landmark condition than any other condition, with the exception of the 250 ms SOA, which only approaches significance. This finding is contrary to the findings of Sheth and Shimojo (2004) who suggested that performance was equal when non-target objects were always present and never present. However, a critical difference between the results of Sheth and Shimojo (2004) and that of Experiment 1 is the dependent measure used. In Experiment 1, the main effect of condition was in RT whereas the only reported difference in Sheth and Shimojo (2004)'s experiment was in error. It is possible that the difference in measures may explain the discrepancy between the findings of the two experiments. It may also be that some level of response or attentional competition occurs even in the longer SOA conditions which prevents participants from responding as quickly as when the target is presented in isolation. Neither response competition nor perceptual grouping could occur in the No Landmark condition; however, both of these processes could occur during the SOA conditions. To some degree either, or both, of these processes may be occurring in all SOA conditions which could cause a slower RT than the No Landmark condition.

Conclusions

When non-target objects are presented in close temporal proximity to targets, the presence of these objects hinders performance on a manual pointing task. It is suggested that this decline in performance is attributed to competition for attention or motor output in that time is required to focus on a target or to inhibit a motor program towards non-target objects. This competition is believed to be resolved within 250 ms as illustrated by an improvement in performance during long SOA's compared to short SOA conditions.

Experiment 2

In the previous experiment, a manual pointing movement was made to a remembered target location immediately after the target disappeared. However, it has been well established that non-target objects have different effects on pointing movements when the movement is delayed compared to when it is made immediately (Hu & Goodale, 2000; Obhi & Goodale, 2005; Westwood & Goodale, 2003). Due to this difference, the second experiment addresses the question of whether or not the effect of SOA between presentation of non-target objects and target objects affects performance equally in immediate and delayed movement conditions.

The differing effects of non-target objects on delayed and immediate actions are thought to be due to different underlying neural processing in the two tasks. Specifically, the dorsal stream has been suggested to compute the absolute metrics of a target within a coordinate system based on the effector (head, eye, hand, etc.) and this stream is thought to guide movements made immediately to a target. This processing stream is believed to explain how we are able to make accurate movements towards objects in our visual field; however, the representation in the dorsal stream is thought to guide actions in real time, this representation is thought to decay over time (Elliot & Mandalena, 1987; Milner & Goodale, 1995). Thus, when we are required to make actions towards objects that have been removed from our visual field for an extended period (for instance over 2000 ms), the dorsal stream may not be responsible for guiding our actions. It is believed that in these situations, one is able to use a representation from the ventral stream to guide movements. The ventral stream is thought to preserve the relationship between objects and their surroundings allowing us to form a perceptual representation of the world (Milner & Goodale, 1995).

Using a similar paradigm to the first experiment, Obhi and Goodale (2005) found that participants were more precise when making a delayed movement compared to an immediate movement in a condition where non-target objects were presented 1000 ms prior to target presentation. It was suggested by the authors that when a delay is present, participants rely more on information from non-target objects than when the movement is made immediately at target offset. Thus, participants benefit from the incorporation of non-target objects into their representation of target location when a delay occurs.

Experiment 1 of this thesis required participants to make immediate movements and as such, it is believed that these movements were guided by processing in the dorsal stream. By adding a delay condition to this task, we are examining whether the processing of non-target objects is different in immediate and delayed movement conditions. To minimize the number of conditions, only two SOA's were used in this experiment: 50 ms and 700 ms. It is hypothesized that the effect of SOA seen in Experiment 1 will be present in the immediate condition, but not in the delayed condition. That is, for immediate movements, RT is predicted to be longer in the 50 ms SOA condition than in the 700 ms SOA condition, whereas RT is expected to be constant for both SOAs in the delay condition. It is thought that the delay will provide the processing time required to resolve competition or attention or motor output. Following the results of Obhi and Goodale (2005), it is further hypothesize that delayed conditions would result in faster or more precise movements. When the movement is made after a delay, it is believed that the ventral stream, which preserves the relationship between objects, would play a larger role in guiding the movement. As well, a perceptual representation utilized in the delay condition may reduce the amount of response competition by incorporating the non-target objects into a single representation with the target as opposed to competing stimuli. However, one may see that there is no difference between time of response (immediate or delayed movements), which would imply that effect of SOA as seen in Experiment 1 has no bearing on the different processes used for these two types of movements. It is possible that for both immediate and delayed movements a motor program is planned as soon as the target is available and is held, without modification, until the movement cue occurs and that the effect of SOA may persist throughout the delay.

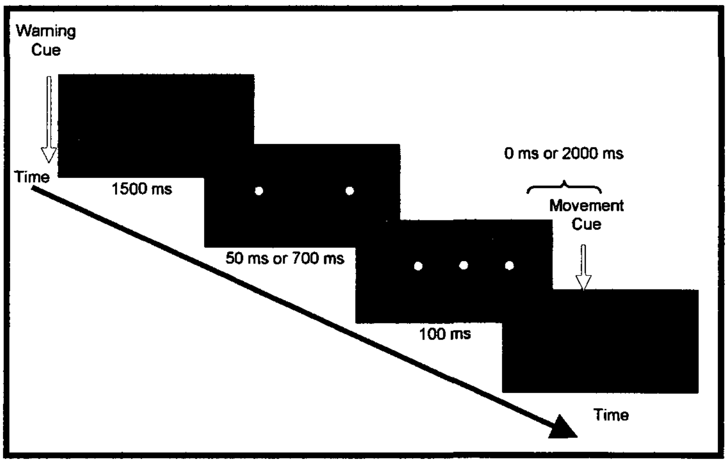
Methods

Participants. Twelve participants (3 male, 9 female) with a mean age of 26.25 years completed this experiment. All participants were right handed and received course credit for their participation. Procedures were in accordance with the Wilfrid Laurier University Research Ethics Board and participants provided written and informed consent.

Procedure. A similar manual pointing task as used Experiment 1 was used here, where participants were again required to remember the location of a target and point to it after hearing an auditory movement cue. To test if the effect of SOA between the presentation of non-target objects and a target is produced in delayed movements as well as immediate movements, participants were presented with a similar task; however, the type of trials were altered. In the previous experiment, the trials differed only in SOA, here the trials differed on two levels: the SOA and the time of response (immediate or delay). As a significant difference in RT was seen between the SOA 50 and SOA 700 ms conditions in the Experiment 1, those conditions were again used in this experiment. As well, the time of response varied in this experiment: the movement cue could be presented immediately after the target disappeared (in the immediate condition which has the same timing of events as in the previous experiment), or a delay of 2000 ms could occur before presentation of the movement cue (the delayed condition). All trials were randomly presented to the participants, followed by a final block wherein only the target was presented, and there were never any non-target objects. As in the previous experiment, this task was completed in a completely dark room to control the amount of visual information available to the participant.

Participants were given a verbal warning cue at the onset of each trial signaling to the participant that a new trial was about to begin. Approximately 500 ms later, the two non-target objects, two red LED's were illuminated. As displayed in Figure 5A, after the SOA (50 ms or 700 ms) the target, an LED placed within the display board, appeared in one of four possible locations for 100 ms along with the two non-target objects. The four possible target locations were again dispersed evenly along an imaginary horizontal line between the two non-target objects. Only in the delay trials was a delay of 2000 ms then inserted after the non-target and target objects had been removed. Thereafter, an auditory cue was presented, vision was occluded, and participants were required to point to the remembered target location as quickly and accurately as possible. The target location, SOA and time of response occurred randomly in each trial and participants were given a break every 32 trials. Each unique situation occurred ten times, resulting in 160 trials (2 SOA x 2 response times x 4 locations x 10 occurrences).

A.



B.

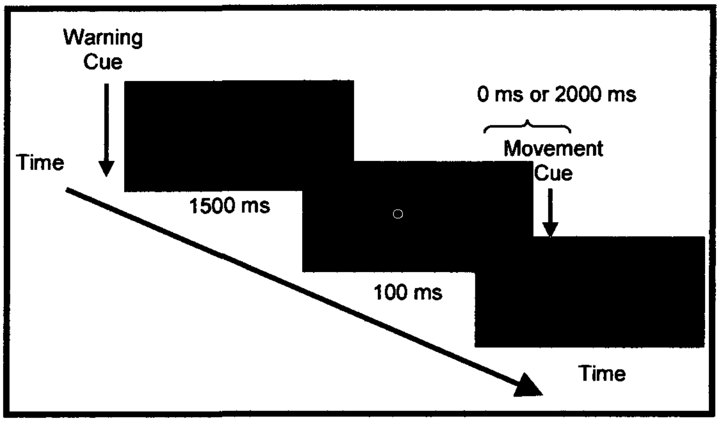


Figure 5. Order of events for Experiment 2: the time between the presentation of the first and second screens depended on the SOA used in that specific trial as well the time between the removal of visual stimuli and movement cue also varied according to trial type.

In the final block, approximately 1500 ms after a verbal warning stimulus, a target randomly appeared in one of four possible locations for 100 ms. An auditory cue was presented either immediately at target offset or after a delay of 2000 ms. Vision was then occluded and participants pointed as quickly and accurately as possible to the remembered target location. Figure 5 B illustrates the timeline of events for trials in this block. This final block consisted of five trials for each of the four possible target locations for both immediate and delayed conditions, resulting in 40 trials where only the target was presented.

All participants received 12 practice trials before the experiment began to become accustomed to the experimental protocol. The practice trials consisted of three trials for each of SOA 50- Immediate, SOA 50 – Delay, SOA 700- Immediate, and SOA 700 – Delay conditions and the targets were presented randomly at all four target locations (three trials for each location). Participants confirmed they were comfortable with the procedure before the experiment began.

Again, all stimuli, aside from an auditory tone, were presented on a custom-made LED display board that lay horizontally in front of the participant. Participants wore liquid crystal goggles (PLATO Visual Occlusion Spectacles, Translucent Technologies, Toronto, ON) during the experiment and all finger movements were recorded by an Optotrak system (Cedrus Optotrak, NDI, Waterloo, ON) through an IRED placed on the tip of the participant's right index finger.

Data Collection and Statistical Analysis. Data collection was the same as in Experiment 1: Kinematic data was recorded by an OPTOTRAK ^{TM} optoelectronic movement recording system through an IRED placed on the top of the participant's right index finger. Data was recorded in x, y, and z coordinates and was sampled at 200 Hz. All data was collapsed across target locations.

The same RT, MT, error and variability of error of error measures were used in as Experiment 1. Repeated measures ANOVAs were calculated for RT, MT, Error, and Variability or Error and a series of planned pair wise comparisons were made. Note that Greenhouse-Geiser corrections were used in the MT analysis.

Trials were excluded from analysis if the RT was below 200 ms (deemed as an anticipatory response) or above three standard deviations away from the median RT in that condition (deemed as missed trials). As well, trials were excluded if the error was above three standard deviations away from the median of that condition.

Results

Reaction Time. Data entered into a 2x3 repeated measures ANOVA yielded a significant main effect for time of response (immediate or delayed movement) on RT (F (1, 11) = 9.357, p = 0.011). However, no main effect was seen for SOA on RT (F (1.229, 13.524) = 2.045, p = 0.175).

Planned comparisons (uncorrected two tailed t-tests) revealed a significant difference in RT between immediate and delay conditions for each level of SOA: SOA 50 immediate compared to SOA 50 delay t (11) = 3.216, p = 0.008; SOA 700 immediate compared to SOA 700 delay t (11) = 3.144, p = 0.009; No Landmark immediate compared to No Landmark delay t (11) = 2.430, p = 0.033. In all cases, the RT was greater in the immediate condition. Figure 6 illustrates the mean RT for each condition.

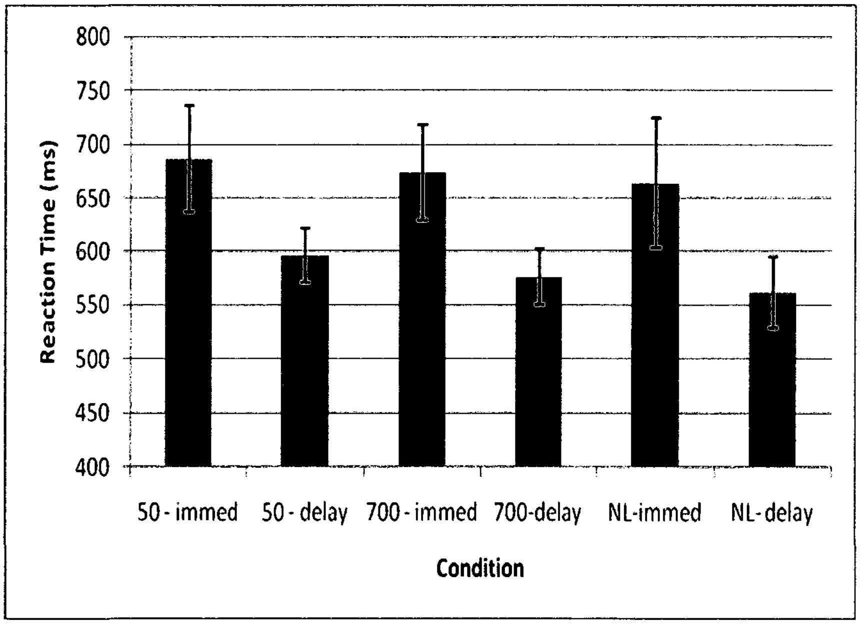


Figure 6. Reaction times as a function of SOA and time of response. NL represents No Landmark conditions, immed represents the immediate conditions and error bars represent standard error.

Movement Time. As in the previous experiment, no main effect of SOA or time of response (immediate or delay) was found in MT for this experiment: SOA (F (1.016, 11.171) = 0.130, p = 0.729, time of response (F (1, 11) = 0.545. p = 0.476).

Error. In contrast to RT, there was no significant main effect of time of response (immediate or delay) on error (F (1, 11) = 0.135, p = 0.720). However, a main effect of SOA was observed in error (F (2, 22) = 6.956, p = 0.005). Planned comparisons revealed that, when error was collapsed across time of response, a significant difference was seen between SOA 50 and No Landmark conditions (t (23) = -2.939, p = 0.007) as well as between SOA 700 and No Landmark Conditions (t (23) = -2.127, p = 0.044). However, no difference was seen between the SOA 50 and SOA 700 Conditions (t (23) = -1.214, 0.237). As illustrated in Figure 7, the mean error in No Landmark Conditions (71.9 mm) is much greater than error in both SOA 50 and SOA 700 conditions (52.6 mm and 53.7 mm respectively).

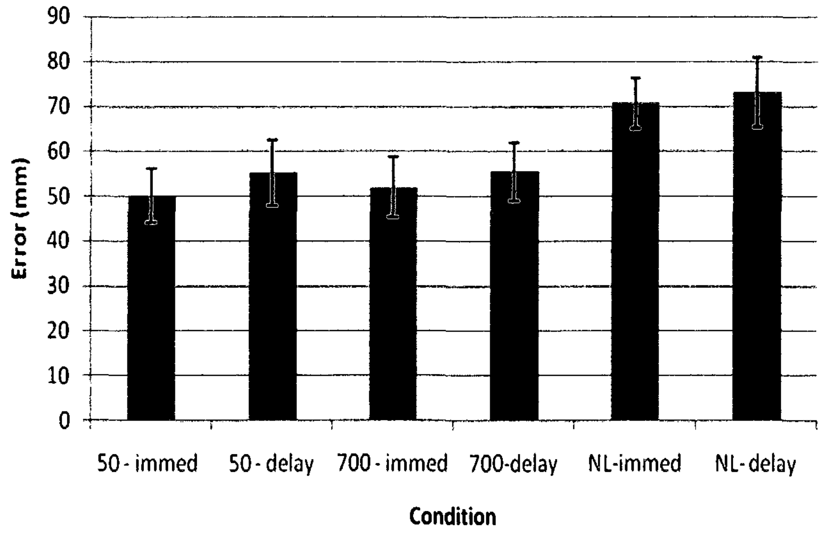


Figure 7. Error in mm as a function of SOA Condition and time of response. Notice that the No Landmark condition is significantly different from both SOA conditions. Error bars are SEM.

Variability of Error. A significant main effect of SOA was found for variability of error (F (2, 22) = 8.819, p = 0.002); however, no main effect of Time of Response was found (F (1, 11) = 1.024, p = 0.333). When data were collapsed across time of response (immediate and delayed conditions), planned comparisons revealed a significant difference between the No Landmark condition and SOA 50 and SOA 700 conditions (t (23) = -2.886, p = 0.008 and t (23) = -3.833, p = 0.001 respectively). No difference was seen between SOA 50 and 700: t (23) = 1.519, p = 142. As Figure 8 illustrates, the mean variability of error of 20.3 mm and 20.6 mm for No Landmark immediate and delay conditions were greater than the mean variability of error in the conditions where non-target objects were presented (16.4 mm, 17.7 mm, 15.6 mm, and 16.5 mm in the SOA 50 immediate and delay and SOA 700 immediate and delay conditions).

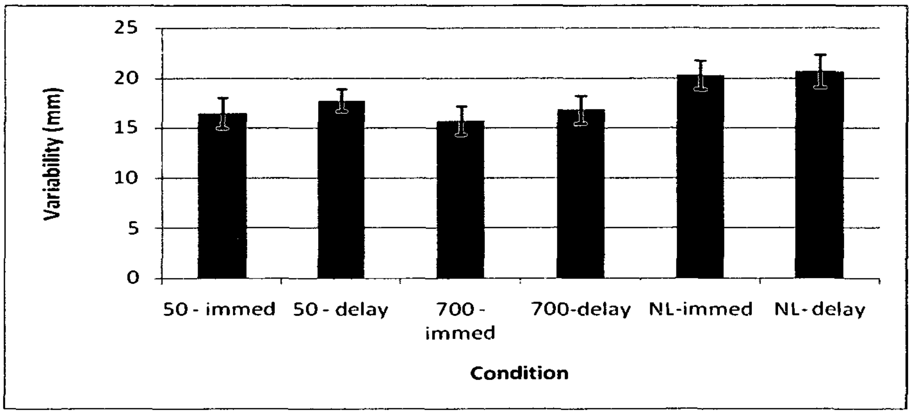


Figure 8. Variability of error in mm for each condition; error bars represent standard error.

Discussion

This current experiment sought to address whether the effect of SOA between the presentation of the non-target objects and target objects is affected by the time at which participants are required to respond. In this experiment, participants responded either immediately after target presentation or after a 2000 ms delay. Results indicate that although participants are faster to respond after a delay, neither the presentation of non-target objects (landmarks or no landmarks) nor the SOA between the presentation of non-target objects and the target affect the RT of participants on this task. As well, it was shown that only the presence of non-target objects affected the errors of the participants: performance was significantly improved in all conditions where non-target objects were presented compared to when the target was presented in isolation.

Although the initial analysis did not reveal the effect of SOA as seen in the previous experiment, the hypothesis regarding the time of response factor was supported: performance was improved when a delay was present prior to the movement cue. As previously mentioned, it is thought that the ventral stream, which maintains the relationships among objects, guides movements that are made after a delay. The inclusion of the non-target objects in the representation of target location may have been beneficial by providing additional cues to remember the target location. Additionally, the delay may have provided participants with time required to complete the movement planning process, so that when the movement cue was presented, participants were prepared to react. It has been shown that approximately 300 ms is required to plan a movement; however, once the movement has been planned, the motor program may be held until the response is required (Deubel & Schneider 2003). This advance movement planning would result in a short RT as very little processing would be required after the movement cue compared to the immediate condition where the majority of movement planning occurs after the movement cue.

It is interesting to note that both the magnitude of error and the variability of error were larger in both of the No Landmark conditions (immediate or delay) compared to all of the conditions where non-target objects were present. This finding suggests that the presence of non-target objects can improve performance. The results of Experiment 2 complement that of Obhi and Goodale (2005), who found performance on a pointing task improves when non-target objects are available during the encoding of target location. An increase in variability of error in the No Landmark conditions suggests that in these trials the increase in error is not simply due to a bias in a specific direction. It instead suggests that participants are less precise when the target is presented in the absence of any extrinsic cues. However, the two No Landmark conditions were presented in a separate block at the end of the experiment; it is possible that the results seen here are simply due to the presentation of this block at the end of the experiment.

Conclusions

The uncertainty of trial type strongly affects how movements are planned, however, when participants are given a 2000 ms delay before they are required to respond, they are able to use this time to accurately plan their movement to a remembered target location.

Comparison of Experiment 1 and 2

The two above experiments address the temporal effects of context in movement planning. Specifically, they both investigated how the time course in which objects are presented affects movement planning. An initial analysis of the data from Experiments 1 and 2 suggest that the effect of SOA between the non-target object and the target seen in Experiment 1 is not present in the Experiment 2. In Experiment 1, a significant difference was seen between the RT for short SOA's (0 ms and 50 ms) and long SOA's (those over 250 ms). However, a significant difference in RT was not seen between the SOA 50 immediate and the SOA 700 immediate conditions in the second experiment. Note that the timing of events in the SOA 50 immediate condition in the second experiment is essentially identical to the timing of events in the SOA 50 condition in the Experiment 1; the differences between the two trial types are the size of the non-target objects: the non-target objects were larger in the first experiment, and the likelihood that a response would be required immediately after target offset. As well, the significant main effect of SOA on error in the second experiment, where error was greater when the target was presented in isolation, was not seen in the first experiment. A closer evaluation of the data is presented below.

Reaction Time

Although a significant effect of SOA between the presentation of the non-target objects and the target was seen in the Experiment 1, this finding was not replicated in the initial analysis of Experiment 2. However, the mean RT of immediate trials in Experiment 2 follows the same pattern of RTs as Experiment 1. In Experiment 2 at an SOA of 50 ms, participants required 686.458 ms to react to the movement cue whereas the RT decreased to 673.542 ms when a SOA of 700 ms was used and to 663.75 ms when no landmarks were presented; these values are illustrated in Figure 9. Although there were no significant differences in RT between each of these conditions, the trend remains. It should be noted that overall RT was much larger in the second experiment than in the first perhaps indicating that RT is affected by increased uncertainty.

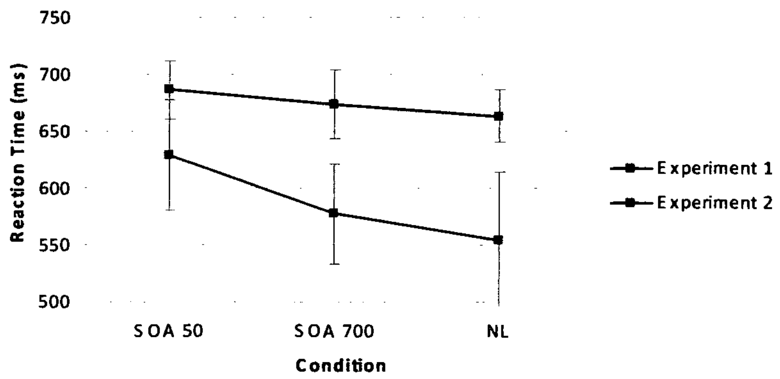


Figure 9. Mean RT in experiment 1 and 2; values from the second experiment represent the average of trials in which the movement was made immediately after the target was presented. Error bars indicate standard error.

The increased RT in Experiment 2 may suggest that movement planning is delayed in this experiment compared to Experiment 1; however, this difference may simply be a group effect due to different participants in the two experiments. I hypothesize that in Experiment 1 participants begin to plan their movements while the trial is progressing – in the large SOA conditions participants are processing and inhibiting movements to non-target objects so that movements can be made quickly and accurately towards the target upon presentation of the auditory tone. This explains why RT changes as a function of SOA: in larger SOA's the participants have more time to plan their movement and inhibit any unwanted motor programs before the movement cue is presented. However, it does not appear that this process occurs in Experiment 2.

In Experiment 1, shortly after the target appears, participants were required to respond – there was no uncertainty regarding *when* a response would be required – however, in Experiment 2, the presentation of the target provided no information as to when a response was required, as it was equally likely that the tone would occur immediately or after a 2000 ms delay. In other words, the presentation of the target provided a reliable temporal cue in the first experiment (the movement cue occurred 100 ms after the target was presented) however it was not a valid temporal cue in the second experiment. Thus participants may have adopted a different task set and different motor planning may have occurred in the two experiments. When an experimental block consists of mixed (immediate and delayed movement) trial types, participants perform differently than when trial types are blocked which suggests movements are planned differently based on the level of certainty in the block (Whitwell, Lambert, & Goodale, 2008). As well, it has been shown that participants respond faster when in predictable conditions, those in which the sequence of events can be anticipated, compared to a random condition which again suggests that the level of certainty in a given block can affect performance (Martens, 2004). It is thought that in the second experiment, participants are holding a representation of target location and only begin to plan their movement once uncertainty has been resolved either when the tone is delivered or once the delay has begun. That is, the uncertainty in Experiment 2 may have prevented participants from planning their movements until they were confident when the movement would be required (after the movement cue in immediate trials or once the delay had begun in the delay trials), thus, participants did not benefit from having a large SOA in the second experiment.

It could also be argued that the task employed in the second experiment was more complex than Experiment 1: not only was there more uncertainty in Experiment 2, but the size and colour of the non-target objects were identical to the targets. This increased complexity may also explain the difference in RT; as Figure 9 depicts, the mean RTs for all conditions are greater in the second experiment than the first. It has been well demonstrated that tasks that are more complex require a longer RT (Henry & Rogers, 1960). When the non-target objects were similar to the target objects, it is possible that perceptual grouping and/ or response competition may have been stronger and possibly could be unresolved by the 700 ms SOA which could diminish the benefit of SOA on RT in Experiment 2. This increased uncertainty and complexity may have negated the effect of SOA on RT.

Error

As Figure 10 demonstrates, the mean error in each condition, SOA 50, SOA 700 and No Landmark, is essentially the same for trials in the first experiment and immediate trials in the second experiment. Although Experiment 1 yielded no main effect of SOA on error, the mean value in the No Landmark condition is greater than the mean values for error in either the SOA 50 or SOA 700 conditions (SOA 50: mean error of 54.3 mm; SOA 700: mean error of 56.7 mm; No Landmark: mean error of 66.0 mm), which follows the same pattern as Experiment 2 (SOA 50 immediate condition: mean error of 50.0 mm; SOA 700 immediate condition: mean error of 52.0 mm; No Landmark immediate condition: mean error of 70.7 mm). As well, there was no difference between error in the SOA 50 and SOA 700 conditions in either of the experiments.

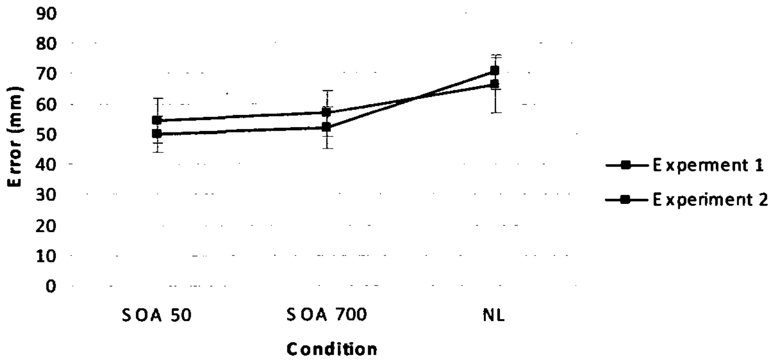


Figure 10. Mean error in experiments 1 and 2; values from Experiment 2 represent trials in the immediate condition. Error bars indicate standard error.

The increased variability of error in individual data in Experiment 1 may have prevented us from finding an overall main effect of error in the first experiment; however, planned t-tests revealed that participants are less accurate in both experiments when the target is presented in the absence of non-target objects. This finding suggests that the mere presence of the non-target objects provide beneficial information in the planning of a target directed movement.

Discussion of Experiment 1 and 2

The goal of the first two experiments was to explore the effects of context on planning a manual pointing movement. Specifically, it was asked if the presence of non-target objects affects performance differently based on when the stimuli were presented and when movement occurred. The findings supported the hypotheses that the presence of non-target objects does effect movement planning differently based on when they are presented to participants and when participants are required to respond. Specifically it was found that RT is affected by these temporal variables. When the SOA between the presentation of non-target objects and target objects varies, participants are faster to respond to a movement cue in a trial with a large SOA (250 ms or greater) compared to trials with a short SOA (50 ms or less). Likewise, it was found that participants are faster to respond when a delay is present before they are required to respond then when a response is required immediately after target offset; presumably, participants are able to plan their movement during this delay.

The presence of non-target objects affected error similarly in both experiments. Regardless of when the stimuli were presented or when participants responded, they were always more accurate when the non-target objects were present. Non-target objects provided participants with additional spatial information that may have allowed them to more accurately recall the location of the target or the non-target objects may have served as a cue to focus participants' attention to the location of the target. Additionally, the presence of non-target objects allowed participants to form an allocentric representation of target location; this form of representation could not occur when the target is presented in isolation. It is possible that participants used an allocentric representation of target location and this strategy may have provided a benefit to the participants.

Response Interference

The results of the first experiment support a prominent idea in the literature. When non-target objects are presented simultaneously with targets, performance is negatively affected. As demonstrated by Tipper and colleagues (1992; Meegan & Tipper, 1998) when targets are presented simultaneously with non-target objects, there is a systematic decline in performance due to the presence of non-target objects. It is believed that a parallel processing of motor programs to both the target and non-target objects causes this detrimental effect in performance. In the current experiment, participants required a longer time to respond in situations where the target is presented simultaneously with or shortly after the presentation of non-target objects. We are suggesting that response competition may explain the differences in RT seen between smaller SOA's (0 ms and 50 ms) and larger SOA's (those above 250 ms).

Under the idea of late selection, all stimuli in the visual field are initially processed and identified in parallel and then attentional limitations necessitate a process that determines which stimuli are relevant to the task and will be processed further, (i.e., to guide actions) (Deutsch & Deutsch, 1963; Posner, 1982). Erikson and Hoffman (1973) analyzed errors in a flanker task where the location of the target was cued in advance. They found that on trials where participants responded incorrectly, they were aware, even while they responded, that their response was incorrect. This finding suggested to the authors that selective attention is not able to eliminate the processing of non-target objects as participants knew in advance where to attend; however, they still processed irrelevant stimuli. Further evidence to support the idea that irrelevant stimuli can compete with target stimuli for motor output comes from studies investigating the Stroop effect (MacLeod, 1991; Duncan-Johnson & Koppell, 1981), further tests on Flanker tasks (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985), and the Simon effect (Simon, 1969). These additional studies support the idea of response competition using a variety of tasks wherein participants are required to select the appropriate response. The fact that in our experiment, as in other experiments (Eriksen & Hoffman, 1973; MacLeod, 1991; Duncan-Johnson & Koppell, 1981; Coles et al., 1985; Simon, 1969), non-target objects are able to influence performance suggests that even though they are irrelevant to the task they are still identified and processed.

Studies on negative priming suggest that active inhibition may be responsible for suppressing the internal representation of motor programs for non-target objects. For instance, a study by Tipper (1985) had participants respond to a red drawing while ignoring a green distractor; it was found that if the target was the same object as the distractor from a previous trial, the participants were slower to respond. This finding suggests that it is harder to activate a motor program for an object that has previously been ignored. In a model of selective attention, Houghton and Tipper (1994) argue that active inhibition arises from a mismatch between an object and an internal template of the target. This inhibition lowers the activation level for the motor program responsible for a movement to be made towards the distractor, allowing for activation of the motor program for the target (which has not been inhibited). As well, Houghton and Tipper

(1994) suggest that a positive feedback occurs in parallel with active inhibition to activate the appropriate motor program for the task. The results of the study suggest that some amount of time, between 50 ms and 250 ms, is required for this inhibition to occur.

When the targets are presented simultaneously with, or immediately after, the non-target objects, motor programs to all objects may be made in parallel. Given the short duration of target presentation, it would be unlikely that participants have fully inhibited motor programs for the non-target objects before the movement cue. As such, some cognitive processing would occur after the movement cue which would result in a long RT. When a longer SOA is present, the motor program for the non-target objects may have been inhibited before the target appears, thus, selection between motor programs would not occur after the movement cue, allowing the participant to react faster for trials in which the SOA was greater than 250 ms. Participants in this experiment appear to accurately select the appropriate movement program in all conditions; however, when the non-target objects appear in close temporal proximity to the target, the participant requires a longer time to select the appropriate movement plan most likely due to parallel processing of multiple objects in the visual scene.

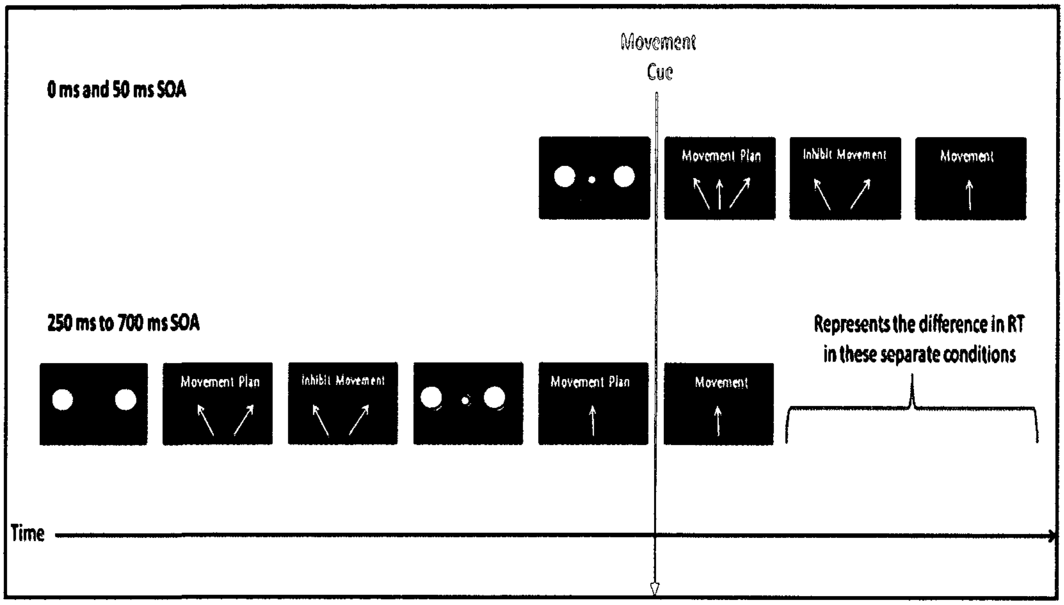


Figure 11. A suggested order of cognitive processing for the various conditions in the Experiment 1: Note that the relative amount of processing required to produce an accurate pointing movement after the movement cue is greater for short SOA's (0 ms and 50 ms) than for longer SOA's (250 ms, 500 ms, and 700 ms).

Figure 11 is a simplified schematic of the order of processing required to complete this task. It is hypothesized that participants are able to process and inhibit the motor program for non-target objects before the target is presented for the longer SOA's (greater than 250 ms). However, it is not assumed that all cognitive processing is purely sequential; the participants may be able to complete some cognitive processing in parallel (Kalaska & Crammond, 1992).

Perceptual Interference

Although the results of our first experiment may be attributed to response competition, it must also be acknowledged that earlier attentional processes may also explain why we are slower to respond when multiple objects are presented simultaneously. For instance, the simultaneous presentation of the objects causes them to be grouped perceptually. For instance, Julesz (1975) demonstrated that effort is required to identify individual elements from an array of items that has been perceptually grouped. The increased effort to identify one element from the display may cause the increased RT when a target is presented near simultaneously with non-target objects. Perceptual grouping may also explain the longer RT seen in Experiment 2; in Experiment 1, the non-target objects were much larger than the target whereas in Experiment 2 the non-target objects were the same size of the target. Presumably, perceptual grouping would be even greater for the SOA 50 condition in the second experiment. As well, it has been shown that smaller non-target objects, such as those used in the second experiment, have been shown to have detrimental effects on RT compared to larger non-target objects (Fischer & Adam, 2001).

Conversely, the simultaneous presentation of non-target and target objects may distribute attention throughout the display area, which may explain the longer RT in Experiment 1 during trials with a short SOA (0 ms or 50 ms) in Experiment 1. This situation would be compared to trials in which the non-target objects are presented well in advance of the target; in these situations, the non-target objects would no longer compete for participants' attention thus participants would be able to focus on the target as soon as it appears. As previously mentioned, the presence of a cue (a non-target object) in advance of the target has been shown to focus participants' attention on locations near the non-target object, which would benefit performance when a large SOA (250ms or greater) is presented (Murphy & Eriksen, 1987). The experiments presented in this thesis did not attempt to distinguish between attentional interference or response competition; however, future work may be done to examine this.

Immediate vs. Delayed Movements

In the second experiment, we see that although no effect of SOA was observed, there was a significant effect of time of response; participants were always faster to respond when a delay was presented prior to the movement. For every trial participants needed to resolve two levels of uncertainty: whether the target would appear immediately after the non-target object and when a response would be required. It appears as though participants did not plan their response until both levels of uncertainty had been resolved (at the time of movement cue in the immediate condition or as soon as the delay had begun in the delay condition). Because uncertainty had been resolved once the delay began, participants were able to use this time to plan their movement. This additional time prior to the movement cue may explain why RT was faster in the delay condition – less time is required to plan the response after the movement cue.

As well, movements that are made immediately or after a delay are believed to be guided by separate processing streams. The dorsal stream is believed to act in real time while the ventral stream is thought to guide movements made to a remembered target location (Milner & Goodale, 1995). These distinct processing streams appear to represent visual information in different ways: the dorsal stream, which is thought to guide movement during the immediate trials, would represent the target using absolute metrics based on the effector while the ventral stream, which would be active in the delay condition, represents visual information with respect to its surroundings (Ungerleider & Mishkin, 1982; Milner & Goodale, 1995). Sheth and Shimojo (2004) provide evidence that target location is encoded in a perceptual representation when a delay is used. In an experiment where non-target objects were presented before, during and after target presentation it was found that on trials when the non-target objects shifted location after the encoding phase, participants were biased in the direction of the shift, suggesting that when a movement is made after a delay, the location of the target is remembered with respect to the location of other elements in the display.

The different representations used in immediate and delayed movements may also explain why RT is faster in delay conditions. As Obhi and Goodale (2005) found, a beneficial effect is observed when a delay is present prior to movement onset. It was suggested that the benefit of non-target objects was more pronounced in the delay condition because only in this situation would the non-target objects be incorporated into the perceptual representation of target location.

Error

While the planning of a movement, as measured by RT, appears to be greatly affected by temporal aspects of the task, the accuracy of movements was not influenced by the temporal nature of the non-target objects: In all conditions, error is greater when the target is presented in the absence of non-target objects. This finding corresponds well to that of Obhi and Goodale (2005), using a similar task, they found that the presence of non-target objects improves accuracy. It is possible that the presence of non-target objects provides a stable frame of reference that may improve the encoding of target position.

Conclusions

When non-target objects are presented during the encoding phase, they provide additional cues to help remember the location of the target. However, how these objects affect our movement plans varies depending on the level of certainty in the experiment. We can see that varying the temporal aspects of visual structure provides varying effects on movement preparation. Although further experimentation is required to completely understand the relationship between the timing of events and their impact on performance, these studies illustrate the importance of the timing of presentation of target and context in a manual aiming task.

Spatial Effects of Context

Experiment 3

In an attempt to determine how visual information is used to represent spatial location, Sheth and Shimojo (2004) found that participants use the location of non-target objects, when present, to remember target location. As well, it was found that when non-target objects are moved from their original position, participants' estimate of target location is shifted in the same direction as the shift in non-target object position (Sheth & Shimojo 2004). That is, when the non-target objects shifted right, participants' estimated the target location to be to the right of the target's true location. The authors argue that their results demonstrate that extrinsic cues dominate and suppress the encoding of intrinsic cues. They stipulate that because participants do not use an intrinsic representation of target location, even though it is possible to accurately use intrinsic cues in this task, that this intrinsic representation has been suppressed by the presence of external cues. It is suggested that an extrinsic frame of reference may be more efficient on labour and memory as head, eye and body movements frequently occur over short periods of time, thus requiring intrinsic representations to be updated constantly whereas external objects generally remain stable. Thus under the assumption of a stable world, it would be most efficient to remember the location of a target relative to external objects in the scene. The results of their experiments are compatible with this assumption: when the non-target objects are shifted, people remember the target location to be shifted in the same direction as the shift in the location of the non-target object. However, the experiments conducted by Sheth and Shimojo (2004) have a few limitations.

In their experiment, Sheth and Shimojo (2004) had participants seated while looking at a computer monitor in the vertical plane. They were first presented with a crosshair and a landmark, a "|" symbol, followed by the presentation of the target, a small white dot. A delay was then presented and the two non-target objects were then re-presented, either in their original location or shifted to the left or right of the original location. One limitation of their study was that participants were required to produce a constrained response (a motion constrained by external contact, i.e., they used a cursor to point to the location where the target had been presented). The use of a constrained movement, a movement in which an external object such as a mouse cursor constrains the movement, has implications for generalizing the results of these experiments to more natural movements, as constrained movements require different motor control strategies (Desmurget, Jordan, Prablanc, & Jeannerod, 1997). Evidence for different control strategies is illustrated by the fact that the invariant features of the two movements differ. It has been shown that unconstrained movements yield a curved movement trajectory as opposed to the straight movement trajectory of constrained movements; constrained and unconstrained movements utilize proprioception differently; also, constrained movements yield an elongated average endpoint distribution and require longer movement latencies and durations (Desmurget et al., 1997). Because the control strategies used in constrained movements are somewhat different from natural movements, it is possible that in natural movements people are able to accommodate the shift during the planning stage of the movement and thus produce an accurate movement.

The use of a mouse cursor to indicate target location on a vertical plane also involves a sensorimotor transformation that is different from movements that are directly guided by a target. A sensorimotor transformation is a process in which the brain is able to transform information from visual stimuli into a motor response. A distinction has been made between standard sensorimotor tasks, where the stimuli themselves guide movement, and non-standard tasks, like that used by Sheth and Shimojo (2004) where an algorithm is required to relate visual input into the direction of movement (Wise, di Pellegrino & Boussaoud, 1996). In Sheth and Shimojo's task, participants were required to move a mouse in the horizontal plane in order to produce a movement on the vertical monitor; this transformation is more complex than the movement in the current experiment where participants are required to point directly to the target with their finger. Different patterns of cortical activity have been found between the two tasks, with the primary motor cortex, medial motor areas, superior parietal lobule, and lateral premotor cortex more active during non-standard tasks (Gorbet, Staines, & Sergio, 2007). Because of the different processes required when using a mouse or a hand movement, it is possible that the additional sensorimotor transformations that occur in non-standard tasks may lead to increased error in situations where the visual stimuli are not stable.

In addition, the participants in Sheth and Shimojo's experiments (2004) were not informed that the non-target objects would shift. It is possible that the shifts were not detected and thus participants were using the extrinsic cues provided by the non-target objects because they were thought to provide a stable frame of reference. The purpose of Experiment 3 was to determine if the results seen by Sheth and Shimojo (2004) could be replicated using a more natural movement.

Our task was similar to that of Sheth and Shimojo (2004); however, to see if their results were generalizable to a more natural movement, participants were required to make a manual pointing movement to the remembered target location with their right index finger as opposed to a cursor. As such, a larger display was used to accommodate the larger size of the finger: all stimuli and shifts were twice as large as Sheth and Shimojo's initial experiments. As well, an additional condition was included in the current experiment in which participants were informed that on some trials the landmark and crosshair would re-appear in a shifted position.

Two possible patterns may appear in the data: the participants may accurately estimate target location in all conditions or the participants may have a biased estimate of the target location in the direction and relative magnitude of the shift in non-target object location. If the participants are accurate in all conditions, we will have evidence that extrinsic cues do not necessarily suppress the intrinsic coding of target location. This pattern of results would instead suggest that at least for natural movements, we are able to remember a target's location based on an intrinsic representation of that target's location and that we are able to ignore irrelevant visual cues. However, if, like Sheth and Shimojo reported, participants inaccurately recall the target location to be shifted in same direction as the shift in non-target objects then we will have further support that the presence of extrinsic visual cues can cause an intrinsic representation to be suppressed. For the trials in which the non-target objects did not shift, participants could accurately use either an intrinsic or extrinsic representation; it is the trials in which the non-target objects shift locations that will be of most interest. If participants are able to use an intrinsic frame of reference, then it is expected that the magnitude and direction of error would be consistent across all trials. However, if on these trials, the participant does not recall the true location of the target, but instead points to a location in the same direction in which the non-target objects shifted in, that shows that they are no longer able to use the stored intrinsic representation; a possibility that is consistent with the idea of an intrinsic representation being suppressed by the presence of extrinsic cues.

Methods

Participants. Twelve participants, nine females and three male, completed this experiment (mean age 23.5 years). All participants were right handed and received course credit for their participation. Procedures were in accordance with the Wilfrid Laurier University Research Ethics Board and participants provided written and informed consent.

Procedure. To test whether or not participants are biased by a shift in non-target object location, participants were required to make a manual pointing movement to a remembered target location. Two independent variables were examined: the advance knowledge of the participant and the level of shift in non-target object location. The advance knowledge of the participant was divided into a no instruction condition, where participants were not informed of the shifts in non-target object location and an instruction condition where participants were explicitly told that on some occasions, the non-target objects would shift from their original location. This variable was blocked: the no instruction condition was presented prior to the instruction condition for all participants. As well, there were three levels of shift in this experiment: a "No Shift" condition where the non-target objects were always presented in their original locations, a "Small Shift" condition where the location of the non-target objects shifted 2° to the left or right of their original location, and finally a "Large Shift" condition in which the location of the non-target objects shifted 4° to the left or right of its original location.

All stimuli, aside from an auditory tone, were presented on a 42-inch Winmate Communication Incorporated touch screen (San-Chung City, Taiwan) that lay horizontally in front of the participants. All finger movements were recorded by an Optotrak camera system (Optotrak Cedrus, NDI, Waterloo, ON) through an IRED placed on the tip of the participant's right index finger.

All participants received 10 practice trials to become accustomed to the experimental protocol. The trials were equally likely to be No Shift or Shift trials and targets were presented randomly at all ten target locations. All participants confirmed they were comfortable with the procedure before the experiment began.

The experiment consisted of 120 trials. In the first 60 trials participants were given no instruction as to whether or not the non-target objects would re-appear in a shifted location following the presentation of a mask, (a white screen presented following the presentation of the target and non-target objects). A break was then given and participants were explicitly instructed that on some trials the non-target objects would reappear at a shifted location. Participants were then presented with the same 60 trials as before; however, they were instructed that on some trials the location of the non-target objects would shift after the mask. For each of these conditions, 30 trials were "No Shift" trials, 15 trials were "Small Shift" trials (in 8 trials the shift was to the left, in 7 trials the shift was to the right) and the remaining 15 trials were "Large Shift" trials (in 7 trials the shift was to the left, in 8 trials the shift was to the right). Trials were presented in a random order in both conditions.

Figure 12 outlines the procedure used in this experiment. At the onset of each trial, participants were given a verbal warning stimulus followed by the presentation of a crosshair and "|". Participants were instructed to fixate on the crosshair and to press down on a lift-off button when they had done so. Once this occurred, a target appeared for 50 ms followed by a mask (a white screen) for 60 ms. The crosshair and "|" then re-appeared for 2015 ms and participants were again required to fixate on the crosshair. However, only in the "No Shift" condition did the objects re-appear in their original location. In the "Shift" conditions, the objects were re-presented 2° or 4° to the left or right of their original location. Following this re-presentation, an auditory cue was presented and participants were required to point to the remembered target location as quickly and accurately as possible.

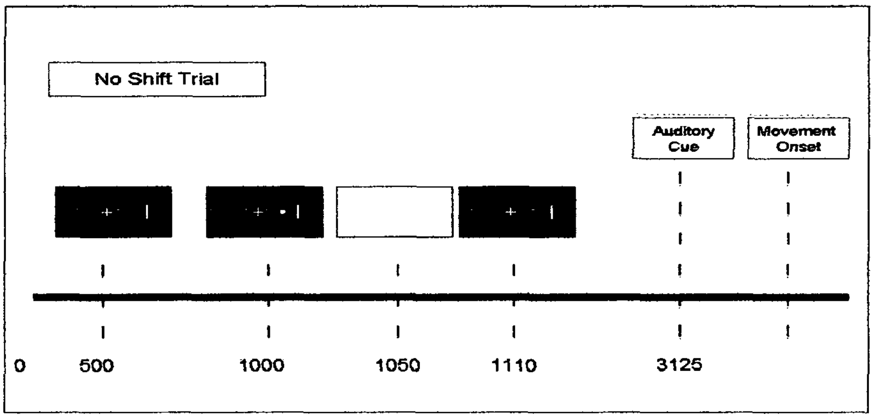


Figure 12. Timeline of events in the fourth experiment. (Note: the time interval between the original presentation of the crosshair and the " | " and the presentation of the target varies. In half of the trials the objects re-appear in a shifted position.)

All trials were presented randomly and a break was given every 30 trials. The ten target locations and fourteen crosshair and "|" locations used in this experiment were also presented randomly and were presented 0° to 8° from the centre of the screen. All stimuli were placed along a horizontal axis on the screen. The room in which the experiment was conducted in was dark to minimize the amount of possible visual information that could be used by participants to recall the location of the target.

Data Collection and Statistical Analysis. Data collection and analysis were completed as outlined in Experiment 1 and 2: Kinematic data was recorded by an OPTOTRAK ^{TM} optoelectronic movement recording system through an IRED placed on the top of the participant's right index finger. Movement data in x, y, and z dimensions was sampled at 200 Hz and stored on a computer for offline analysis. In addition, movement endpoints were analyzed in terms of their x and y coordinates as all shifts were in the horizontal direction. To do this, Constant Error (CE) was calculated in both the x and y direction

$$\text{CE} = \text{endpoint } (x \text{ or } y)\text{coordinate} \quad \text{target } (x \text{ or } y)\text{coordinate}$$

The variability of endpoint location was calculated as each participant's standard deviation of endpoint finger location

$$\text{endpoint finger location} = \sqrt{((\text{endpoing } x \text{ position} - \text{target } x \text{ position})^2 + (\text{endpoint } y \text{ positon} - \text{target } y \text{ pos}}$$

Knowledge of shift (no information or explicit information) and type of shift (No shift, Small Shift Right, Small Shift Left, Large Shift Right and Large Shift Left) were examined in each dependent variable. RT, MT, CE (x and y), and variability of error were calculated and a 2 x 5 repeated measures ANOVA was performed and planned pair wise comparisons were made for all comparisons of interest, for which a specific result was predicted. Note that Greenhouse-Geiser corrections were used in the analysis.

Trials were excluded from analysis if the RT was below 200 ms (deemed as an anticipatory response) or above three standard deviations away from the median RT of all trials (deemed as a missed trial). As well, trials were excluded if the error was greater than three standard deviations from the median of all trials.

Results

Reaction Time and Movement Time. A 2x5 repeated measures ANOVA yielded no main effects for instruction or shift in RT. Reaction time: F (1, 11) = 0.512, p = 0.489 (instruction), F (4, 44) = 1.162, p = 0.340 (shift). Movement Time: F (1, 11) = 0.261, p = 0.620 (instruction), F (2.554, 28.093) = 2.903, p = 0.060 (shift

Error in the horizontal (x) dimension. No effect of instruction was seen in CE (x) in the 2x5 ANOVA (F (1, 11) = 0.196, p = 0.666); however, a significant main effect of shift was revealed in CE (x) (F (2.410, 26.531) = 3.431, p = 0.040). No interaction between shift and instruction was seen (F (4, 44) = 1.285, p = 0.290). When data was collapsed across instructions, the average CE (x) for the large left, small left, no shift, small right and larger right conditions were -5.447mm, 5.162mm, 3.604mm, -0.617mm, and 9.081mm respectively. Planned comparisons (uncorrected two tailed t-tests) revealed a significant difference in CE (x) between a large shift left and a large shift right; t (23) = -3.894, p = 0.001, a small shift left and a large shift left t (23) = 4.313, p<0.0001, and a small shift right and a large shift right t (23) = -2.556, p = 0.018. No difference was seen in CE (x) between the two small shift conditions or between the no shift condition and small shift right or left: t (23) = 1.651, p = 0.112; t (23) = -1.540, p = 0.137; and t (23) = 0.839, p = 0.410 respectively. Figure 13 illustrates the CE (x) for each level of shift. A correlation was obtained between the level of shift and the CE (x) which confirmed this finding (r = 0.684).

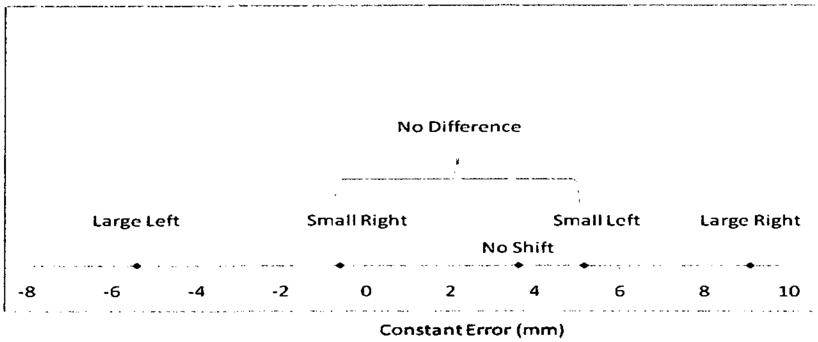


Figure 13. Constant Error. This figure shows the average Constant Error in the x coordinates. Positive values indicate participants estimated the target location as being to the right of the targets veridical location.

Error in the vertical (y) direction. No significant main effect of instruction or shift was seen in CE (y); F (1, 11) = 2.120, p = 0.173 (instruction) F (4, 44) = 1.457, p = 0.231 (shift) and F (1, 11) = 0.088.

Variability of Error. Data were entered into a 2 x 5 repeated measures ANOVA which demonstrated that there was no significant difference in instruction or level of shift for variability of error, the standard deviation around the mean of the participants endpoint location for each condition: F (1, 11) = 2.875, p = 0.118, F (1.940, 21.448) = 2.444, p = 0.112 respectively.

Discussion

The goal of Experiment 3 was to determine whether participants rely on non-target objects to recall target location. This work was inspired by Sheth and Shimojo's (2004) third experiment that showed that when participants were required to point to a remembered location of a target with a cursor, they relied on the location of non-target objects present during the encoding stage to recall the target's location. That is, when the non-target objects shifted from where they were located during the encoding stage, participant's estimate of target location was biased in the same direction as the shift. Using a more natural movement, and providing the participants with different levels of top-down information, Experiment 3 examined the same question.

As seen through the results, it appears as though participants are in fact less accurate when the location of non-target objects is altered. For the larger level of shift, participants recall the target to be located towards the left of its true location if there was a large shift left and towards the right if there is a large shift right. However, it appears as though the advance information regarding a shift in the non-target objects did not affect participants' performance on this task.

Effect of Top-Down Information. The results indicate that providing participants with explicit information that the non-target objects will shift on some trials did not affect their performance on this task. In all respects, performance was equal in the no information and information blocks. However, all participants acknowledged after the first block that they were aware that on some trials the non-target objects did in fact shift.

An awareness of the shift in non-target object location may allow the participants to partially compensate for the shift. It is possible that participants were only aware of the large shift, as they were given no information regarding the different levels of shift; it is also unknown what percentage of trials participants believe a shift occurred on, data on awareness of shifts was not collected for each trial.

Although the additional information presented in the second half of this experiment did not affect participants' performance, it is entirely possible that this information would be beneficial in situations where the shift was more discreet. Future experiments could examine the role of top down information such as was provided in the second half of this experiment on detectable and undetectable shifts. Because participants acknowledged that they were aware of the shifts in the first block, the added instruction given prior to the second block may have provided no new information

Effect of Shift in Non-target Object Location. The results of the current experiment indicate that shifts in non-target object location do in fact affect participant's estimates of target location. Participants are simply not as accurate pointing to a remembered target location when the non-target objects are located in a different position during retrieval than during encoding. It appears as though participants encode the location of the target relative to where the non-target objects are located. Even though participants were aware in the last block that the non-target objects were not stable, the extrinsic representation of target location seemed to dominate the intrinsic representation. Likewise, it appears as though participants always used the location of the non-target objects as a retrieval cue to recall the position of the target.

Error was broken down into the vertical (y) and horizontal (x) coordinates in Experiment 3 as all stimuli were presented on the same horizontal axis and all shifts were in the horizontal plane. As such, it is no surprise that errors in the vertical plane were relatively small and uniform throughout the various conditions. It is in the horizontal plane that greater error was expected when non-target objects shifted from their original location. It was expected that the direction of error would be in the same direction of the shift in non-target object location and the error to be of the same magnitude as the shift. In other words, it was expected that participants would use the new location of the non-target objects as a retrieval cue to recall target location. The results of Experiment 3 support this hypothesis.

Just as Sheth and Shimojo (2004) saw with cursor movements, participants in our task were less accurate in pointing to the remembered target location when the landmark and crosshair were shifted to a new position after the encoding stage. Participant's error was in fact in the direction of the shift in non-target object location, as well, the size of the error was related to the size of the shift: as both our mean values and our correlation show participants had a greater error for the large shift compared to the small shift and no shift locations. The errors in both of the small shift conditions were equal to the errors seen in the no shift condition. Although it is possible that participants were able to ignore the small shift and plan an accurate movement based on the target's true location, it is more probable that the size of the small shift was too small to detect visually.

Although the accuracy of the movement was affected by the shift in non-target object location, neither RT nor MT was affected in this experiment, indicating that there was no speed-accuracy trade-off operating. While RT and MT were statistically equivalent across the various conditions, participants' accuracy was not. Additionally, it is important to note that variability of error was also not significantly affected by either the instructions or the level of shift. The decreased accuracy seen in the large shift conditions was not simply a result of increased variability of error or to participants forgetting where to point and thus pointing to any given location, but instead, that the participants used a stable, albeit wrong, representation of target location.

By having a delay after target presentation the pointing action may be mediated by the ventral stream, in which the relationship between the target and non-target objects are preserved, which may explain why the extrinsic cues dominate. This phenomenon complements the work by Sheth and Shimojo (2004) as similar results were seen even though both the visual presentation of the stimuli and the response required by the participant were larger in our experiment. The size of the stimuli as well as the size of the shift in non-target location was increased two-fold in our experiment to accommodate the larger size of the finger compared to the cursor used by Sheth and Shimojo (2004).

Constrained Movements. The complementary nature of our results with those of Sheth and Shimojo (2004), suggests that the control strategy used during different types of movements, whether the response is constrained or unconstrained, is not critical in determining whether non-target objects are incorporated into the representation of target location. Although the degree to which endpoint location is affected by the shift may differ, the finding remains the same: participants estimates of target location are biased by the shift in non-target object location. The argument proposed by Sheth and Shimojo (2004) that differences between these movements are irrelevant to the task is supported;

that is, the increased error seen when the non-target objects shift is more likely to result from the spatial and memory components of the task then the motor control factors such as proprioception and movement trajectory. Thus, even though our movements may have been more natural than the cursor movements made by Sheth and Shimojo's participants, participants were still affected by the shift in non-target object location in this experiment.

Magnitude of Error. Our error results differ from Sheth and Shimojo (2004) in one regard, the magnitude of the error in our experiment was less pronounced than was seen in Sheth and Shimojo's experiment. The Sheth and Shimojo study demonstrated that participants estimated the target location to be 68% of the true shift; however, in our study, the participants' endpoint location was only 18% of the shift. This discrepancy may result from differing control strategies used in constrained and unconstrained movements or may be due to the increased size of the shifts. As mentioned earlier, the cursor response used by Sheth and Shimojo (2004) may not be relevant in our natural interactions with the environment. As well, participants in our experiment were aware, even without being informed, that the non-target objects shifted location on some trials. Sheth and Shimojo (2004) did not report whether or not participants were aware of the shift; however, it is possible that because smaller shifts were used in their experiment, that they may have been undetected. If this is true, a possible explanation for the differing magnitude of error may simply be that participants were able to use top down information regarding the shift to produce a relatively accurate estimate of target location in Experiment 3 compared to Sheth and Shimojo's experiment.

Frame of Reference. It is interesting to note that although the finger was visible at all times, and thus provided an additional, stable intrinsic cue, participants did not use this information to plan their movements. If the movements were planned in an egocentric representation based on the location of the finger (i.e., a "finger centered" representation), one would expect an accurate representation of target location in all conditions; this was not the case. Although the finger could be seen from where the participant was seated, it was not located near the experimental stimuli, thus could easily be ignored. By requiring participants to fixate on the crosshair, participants' attention may have been directed away from the finger and onto the stimuli presented on the screen.

Instead, participants may have used an eye centered frame of reference during this task. Although the location of a target must ultimately be represented in a hand centered reference frame in order to make an accurate goal directed movement with the hand, it has been suggested that target location is originally stored and maintained using an eye centered frame of reference and is only converted to a hand centered frame of reference prior to movement onset (Henriques, Klier, Smith, Lowy, & Crawford, 1998). When participants re-fixate on the new crosshair location eye movements occur and the stored representation of target location is altered – the brain must remap the location of the target relative to the retina in order to produce an accurate movement (Henriques et al, 1998; Sorrento & Henriques, 2008). A failure to remap (or update) an eye centered representation of target location would result in the target location being in the same place on the retina after the eye movement as it was before. This failure to update would result in participants pointing the full magnitude of the shift. Conversely, if the movement was planned solely on the basis of an updated eye centered representation, the location of the target on the retina would accommodate the shift and participants would be expected to point to the true target location. Because participants were affected by the shift, it is suggested that the eye movements, at least by themselves, cannot explain why participants are slightly biased by the shift in non-target objects.

As mentioned, a hand-centered frame of reference would result in an accurate movement to the target location in all conditions. That is, if the location of the target were calculated based on the distance and direction from the finger the participant would be able to accurately point to the target location given that the finger remained stationary until the response began. However, if an eye-centered frame of reference was used, one would expect to see a similar pattern of results to what we observe except with a much greater magnitude. Specifically, if participants were recalling target location based on the position of the image on their retina, then one would expect participants to point exactly to the location or to the location 2°or 4° left or right of its original location (i.e., to the place where the target would have been relative to the non-target object). However, the pattern of errors observed in Experiment 3 followed neither pattern. Participants in the Large Shift condition generally pointed in the direction of the shift; however, they only shifted approximately 18% of the magnitude of the shift. Thus, it is more likely that participants are pulled by the extrinsic cues, but, being aware of the shift, are able to refrain from making the movement to where the target would be relative the non-target objects' final position.

Although it has been clearly demonstrated that visual information is encoded in an eye-centered frame of reference, there is some evidence to show that neurons in some motor areas can represent visual information in both eye and hand centered frames of reference (Buneo & Andersen 2006; Buneo, Jarvis, Batista, & Andersen, 2002). This additional frame of reference may help to explain why participant error was not equivalent to the size of the shift. Whereas the eyes are required to move in this experiment, the finger is required to remain stable until the movement begins. Therefore, a finger centered frame of reference would provide an accurate representation of target location. If these two frames of reference are able to interact, they may produce an endpoint location between the target's true location and where it would be located relative to the new position of the non-target objects.

Sheth and Shimojo (2004) argue that extrinsic cues dominate and suppress the encoding of an egocentric reference frame because extrinsic cues are more efficient on labour and memory. In most situations, objects in the environment do not change locations over short periods of time; however, movements of the eye, head and limbs do frequently occur. Because of these body movements, an intrinsic representation would need to be constantly updated to remain accurate; every time the eyes move, one would need to recalculate the location of the object as a function of the movement so that an accurate representation can be maintained. This spatial updating is not required using an extrinsic frame of reference as, in many situations, it is quite likely that the world remains stable (Ballard, Hayhoe, Li & Whitehead, 1992). Although these experiments cannot speak to the efficiency of any given reference frame, it is interesting that neither a hand centered frame of reference nor an eye centered frame of reference can fully account for the results of this experiment.

Conclusions

The partial replication of Sheth and Shimojo's (2004) third experiment demonstrates that if non-target objects are noticeably shifted from their initial location participants' estimate of a target's location will be biased by the shift, even when people know a shift occurred. The endpoint location most likely reflects a combination of bottom up and top down processes; the stimuli pull the participant in the direction of the shift and the knowledge of the shift influences the movement so that participants are relatively close to the veridical target location. The knowledge of the shift, regardless of whether or not the participant was explicitly informed, provided participants with the ability to compensate to some degree for the shift. Future studies may manipulate the degree of top-down information to see how participants respond in the absence of this information. As well, future studies could examine this issue using the same procedure; however, participants would be instructed to point to the location where the target would be relative to the non-target objects. This would show whether the participants are able to point accurately to this proposed new target location; if they are able to do this, our results are not simply due to participants being pulled completely by the new non-target object locations.

Experiment 4

Visual structure that is present during the planning phase of a movement can be used to form an allocentric representation of a target location. Experiment 4 seeks to address whether or not visual structure is automatically encoded and maintained in an allocentric representation or whether the type representation (intrinsic or extrinsic) is influenced by top-down processing. As mentioned in Experiment 3, Sheth and Shimojo (2004) examined whether or not participants use information from non-target objects to remember the location of a target. In their second experiment non-target objects were presented along with a target, a delay occurred and then in 50% of the trials the non-target objects reappeared. The removal of non-target objects in 50% of trials was done to determine whether participants would be able to retrieve an accurate intrinsic representation of target location. When non-target objects were re-presented, it is possible for participants to recall target location using either an intrinsic or extrinsic representation; however, when non-target objects were removed, participants were no longer be able to use an extrinsic representation. The authors found that on occasions where the non-target objects had been removed, participants were less accurate when pointing to the remembered target location (Sheth & Shimojo, 2004). It was suggested that the decrease in accuracy is due to a reliance on extrinsic cues and that "only in the absence of visible extrinsic cues do humans fall back more heavily on intrinsic coordinates" (Sheth & Shimojo, 2004, p. 334).

Although individuals may rely on extrinsic cues in certain situations, it is currently unclear whether or not this is an automatic process or a strategy used when extrinsic cues are reliable at least 50% of the time. In the second experiment from Sheth and Shimojo (2004) the non-target objects were equally likely to be re-presented or removed after the delay; however, in Experiment 4 of this thesis the probability of a the landmark being re-presented was manipulated and as such, participants may expect the non-target objects to either be re-presented or removed based on the experimental block. Martens (2004) demonstrated that expectancies are able to affect stimuli fixation and manual responses. It is possible that participants may be able to use different strategies based on their expectations regarding trial type. Experiment 4 of this thesis will examine whether cue stability affects the use of allocentric reference frames. In particular, Experiment 4 examines whether or not unreliable cues will be automatically encoded and maintained in an allocentric representation.

Two experimental conditions were examined as well as a baseline measure to determine if top-down expectations regarding the reliability of non-target objects (also referred to as landmarks in this experiment) can influence whether external cues are incorporated into the representation of target location when planning pointing movements. In one condition, the "Reliable Condition", landmarks were presented to the participant prior to and along with the presentation of a target. A mask then followed and after a delay the landmark was re-presented in the same location in 80% of the trials, and as such, the non-target objects provided reliable extrinsic cues throughout this condition. In the second condition, the "Unreliable Condition", the same task was used however; the non-target objects were re-presented on only 20% of the trials. This created a situation where the landmarks were an unreliable source of allocentric information. Finally, a baseline measure was used where participants were required to point to the remembered target location in the absence of any extrinsic cues.

It is predicted that if extrinsic cues are automatically stored in an allocentric representation, as suggested by Seth and Shimojo (2004), then the pattern of performance will be the same regardless of how reliable the landmarks are in a given block. Under this scenario we would expect to see that any instance when the landmark is removed, participants will have a larger error than any trial when the landmark is stable.

However, if top-down mechanisms are responsible for selecting whether or not an extrinsic representation is utilized, one would expect to see participants' expectations determine whether or not the an allocentric representation is used. Specifically, in the Unreliable Condition, it is predicted that participants will use an intrinsic representation of target location, in which case error will be the same for all trials regardless if the landmark is stable or removed. For every trial in this condition, the non-target object would be more likely to be removed; therefore, one would expect that participants would always ignore the non-target object in this condition. Under this scenario, participants would not use the location of landmarks as a guide to remember the target location; instead, they would be more likely to recall the position of the target using an egocentric representation. An opposite pattern of results would be expected in the Reliable Condition; one would expect movement endpoints to be less accurate in the few trials where the landmarks are removed compared to trials where the landmarks are stable. When landmarks are expected to be reliable it is thought that participants would incorporate the relationship between the target and landmark into an allocentric representation and, as Sheth and Shimojo (2004) proposed, this extrinsic frame of reference may be more efficient in this condition.

Methods

Participants. Twelve participants (6 male, 6 female) with a mean age of 22.25 years participated in Experiment 4. All participants were right handed and received monetary compensation for their participation. Procedures were in accordance with the Wilfrid Laurier University Research Ethics Board and participants provided written and informed consent.

Procedure. Three experimental blocks were presented to participants in a counterbalanced fashion. The "Reliable Condition" consisted of 40 trials wherein 80% of the trials were "Landmark Present" trials, trials where landmarks were re-presented after the delay, and the remaining 20% of trials were "Landmark Removed" trials, trials in which the landmarks were not re-presented after the delay. The "Unreliable Condition" again consisted of 40 trials; however, here 80% of the trials were "Landmark Removed" trials and 20% of trials were "Landmark Present" trials. Participants were informed of the breakdown of trials prior to the onset of each condition. Finally, in a "No Landmark Condition" there were 40 trials in which the target was presented in the absence of any extrinsic cues. Participants completed all trials in a dark room to minimize the availability of other extrinsic cues. Trials were presented in a random order within each block, and a break was given to participants at the end of each block where the lights were turned on.

All participants received 10 practice trials before the experiment to become accustomed to the experimental protocol. The trials were equally likely to be Landmark

Present or Landmark Removed trials and targets were presented randomly at all four target locations. All participants confirmed they were comfortable with the procedure before the experiment began.

The timing of events for the Landmark Present and Landmark Removed trials is illustrated in Figure 15 (A and B respectively). For each trial in the Reliable and Unreliable Conditions, approximately 1000 ms after a verbal warning stimulus, a white outline of a box (115.5 mm x 50 mm) appeared on the display screen for 1000 ms in one of four possible locations (see Figure 14). Following this a target, a small white dot, appeared in the center of the box for 100 ms. A mask, a series of white dots of the same size and colour of the target, then appeared on the screen for 100 ms followed by a 2000 ms delay. In the Landmark Present trials, the landmark then re-appeared for 200 ms whereas in the Landmark Removed trials an additional delay of 200 ms occurred. At this point, an auditory tone was presented, vision was occluded, and participants were to point as quickly and accurately as possible to the remembered target location.

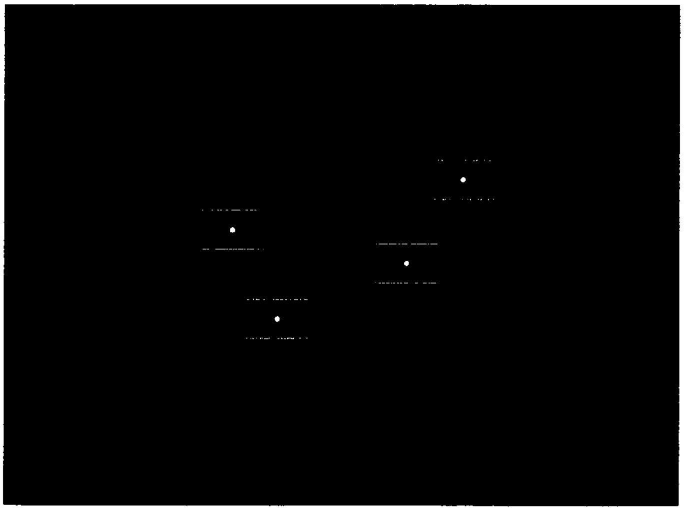
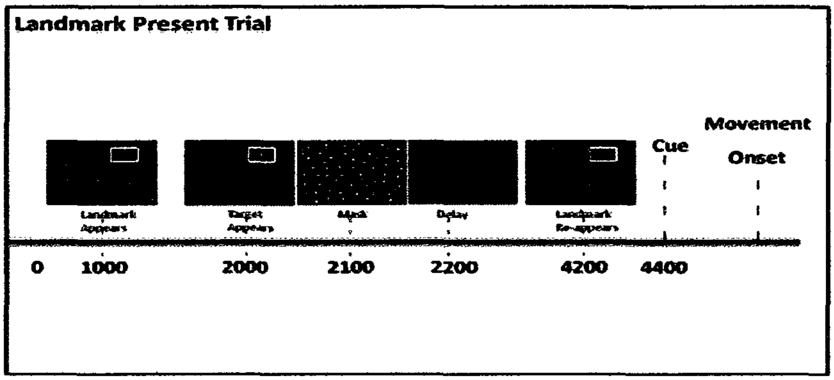


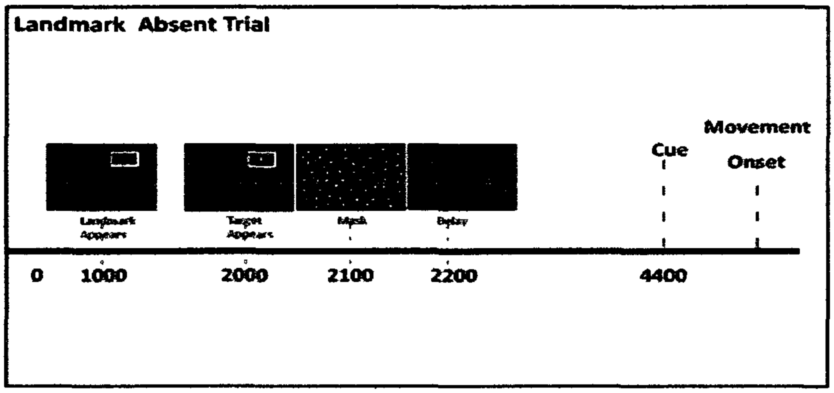
Figure 14. Schematic of target location, targets are shown along with the landmark.

As illustrated in Figure 15C, trials in the "No Landmark" condition began with a verbal warning stimulus, 2000 ms after the warning stimulus, a small white dot appeared in one of four possible locations for 100 ms. A mask then appeared on the screen for 100 ms followed by a 2200 ms delay. At this point, an auditory tone was presented, vision was occluded and participants were to point as quickly and accurately as possible to the remembered target location.

A.



B.



C.

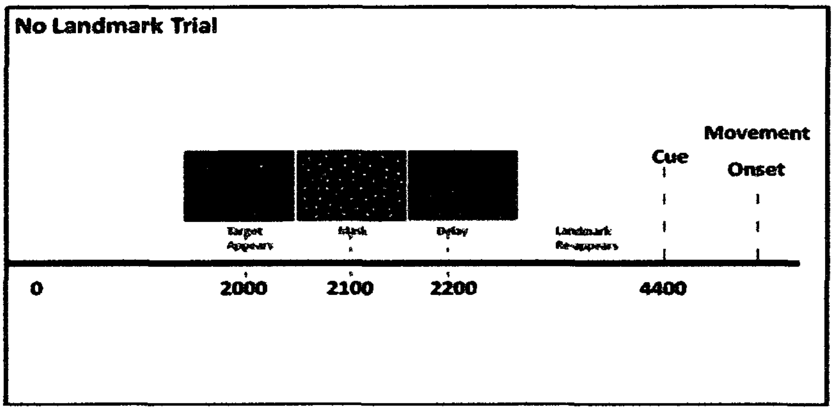


Figure 15. Timeline of events and screen displays for (A) Landmark Present trials, (B) Landmark Removed trials and (C) No Landmark trials.

A similar set-up was used as in Experiment 3. All stimuli, aside from an auditory tone, were presented to participants on a 42 inch touch screen (Winmate Communication Incorporated, San-Chung City, Taiwan) that lay horizontally in front of them. Participants wore liquid crystal goggles (PLATO Visual Occlusion Spectacles, Translucent Technologies, Toronto, ON) during the experiment and all finger movements were recorded by an Optotrak system (Optotrak Cedrus, NDI, Waterloo, ON) through an IRED placed on the tip of the participant's right index finger.

Data Collection and Statistical Analysis. As in the previous experiments, kinematic data was recorded by an OPTOTRAK ™ optoelectronic movement recording system through an IRED placed on the top of the participant's right index finger. Data was recorded in x, y, and z coordinates and was sampled at 200 Hz. RT, MT, error, and variability of error were collected for statistical analysis. Repeated measures ANOVAs were calculated for RT, MT, error and variability of error and pair wise comparisons were made for all significant ANOVA's. Note that Greenhouse-Geiser corrections were used throughout the analysis. Trials were excluded from analysis if the RT was below 200 ms (deemed as an anticipatory response) or above three standard deviations away from the median RT in that block (deemed as missed trials). As well, trials were excluded if the error was greater than three standard deviations from the median value for that participant.

Results

Reaction Time. Figure 16 demonstrates the relationship between RT and each of the conditions in Experiment 4. Data were entered into a one factor repeated measures ANOVA which yielded a significant main effect of condition on RT: F (1.458, 16.042) = 5.537, p= 0.022. That is there was an overall difference in RT amongst the five different conditions: Reliable Condition: 80% Landmark Present, Reliable Condition: 20% Landmark Removed, Unreliable Condition: 20% Landmark Present, Unreliable Condition: 80% Landmark Removed, and No Landmark Condition. Specifically, planned comparisons (uncorrected two tailed t-tests) demonstrated a significant RT difference between trials in the 80% conditions and the 20% conditions (t (23) = -3.119 p= 0.005). The mean RT for 80% Landmark Present and 80% Landmark Removed trials were 807.79 ms and 753.10 ms respectively compared to the mean RT for 20% Landmark Removed and 20% Landmark Present of 917.25 ms and 916.54 ms respectively. In both reliable and unreliable blocks, a planned comparison confirmed a significant difference in RT between the 80% and 20% trials: unreliable condition t (11) = -2.413, p= 0.017; reliable condition t (11) =-1.909, p=0.042.

No overall difference was seen between RT in the reliable and unreliable block (t (23) = 1.312, p = 0.203), between 80% Landmark Present and 80% Landmark Removed (t (11) = 1.507, p = 0.160) or between 20% Landmark Present and 20% Landmark Removed (t (11) = -0.035, p = 0.973).

Planned comparisons also revealed a significant RT difference between the No Box condition and the 80% Landmark Present in the Reliable Condition (t (11) = 1.886, p

= 0.086); 20% Landmark Removed trials in the Reliable Condition (t (11) = 2.863, p = 0.015); and 20% Landmark Removed in the Unreliable Condition (t (11) = 1.231, p = 0.224). However, no difference was seen between the No Box Condition and the 80% Landmark Removed trials in the Unreliable Condition (t (11) = 2.534, p = 0.028).

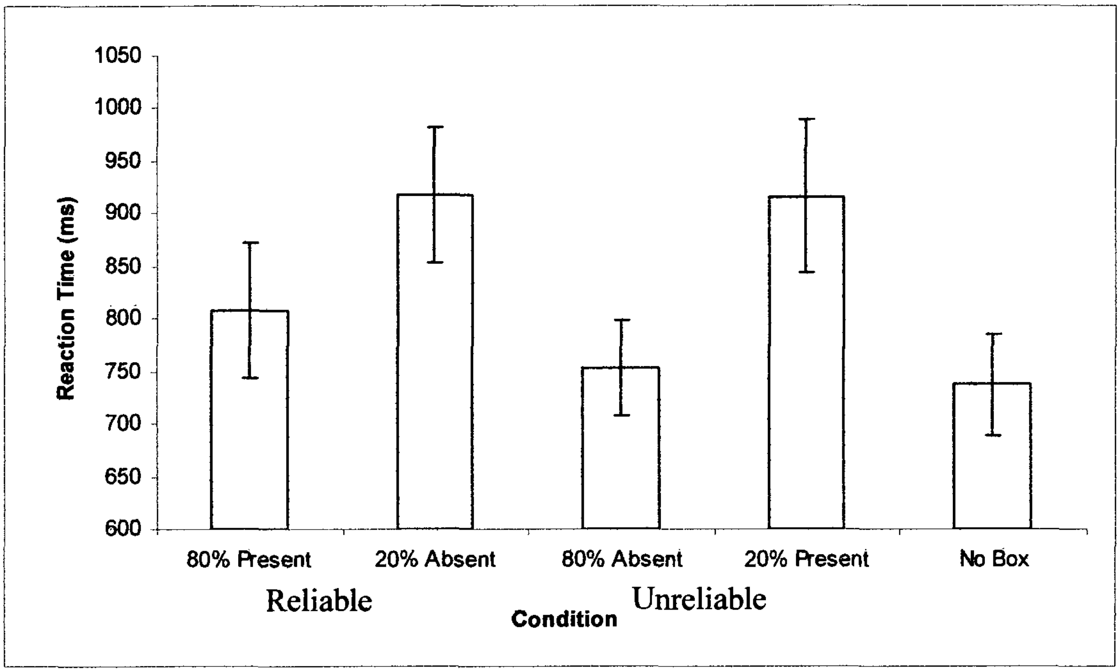


Figure 16. The average RT in ms for the five different conditions in Experiment 4. Error bars represent standard error.

Movement Time. A one factor repeated measures ANOVA revealed no significant difference in the five conditions for MT (F (2.553, 27.860) = 0.968, p = 0.410).

Error. The one factor repeated measures ANOVA revealed a main effect of condition on error (F (2.138, 23.519) = 5.733, p = 0.008) with the average error being 29.81 mm, 39.20 mm and 25.83 mm for trials in the reliable condition, unreliable condition and the no box respectively; Figure 17 demonstrates the relationship between these values. Preplanned comparisons indicated a significant difference in error between the unreliable condition and the reliable condition (t (23) = -3.586 p = 0.002). Within the reliable condition, there was a significant difference in error between Landmark Present and Landmark Removed trials (t (11) = -3.016, p = 0.012) with an average error of 28.02 mm in Landmark Present trials and 31.61 mm in Landmark Removed trials. The difference in error was also approaching significance between Landmark Present and Landmark Removed trials in the unreliable condition (t (11) = 2.179, p = 0.052) with a larger error for landmarks absent trials (40.80 mm compared to 37.61 mm). As well, preplanned comparisons revealed that error in the unreliable condition was significantly different from the no box condition whereas the reliable condition is not (t (11) = 2.989, p = 0.023; t (11) = 0.570, p = 0.580 respectively).

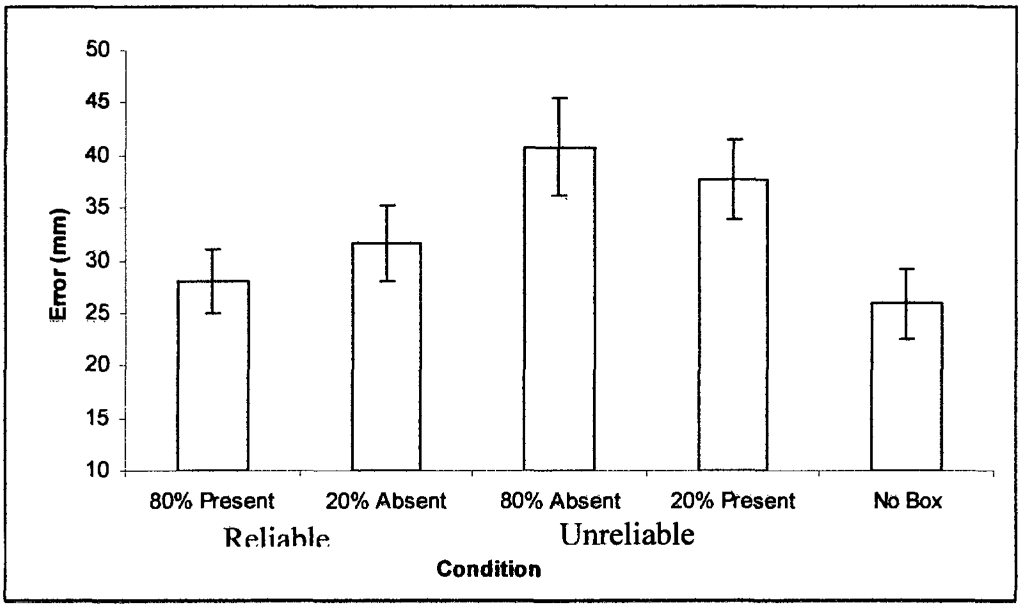


Figure 17. Error measurement for the five conditions in Experiment 1. Error was measured as the average error for all trials in a given condition.

Variability of error. A one factor repeated measures ANOVA found no significant difference in variability of error in the various conditions (F (4, 44) = 0.493, p= 0.741).

Discussion

The aim of Experiment 4 was to explore whether participants automatically incorporate non-target objects into their representation of target location or if participants would be able to ignore these objects when they cannot be reliably used. It was found that participants were slower to respond to oddball trials (those that occurred only 20% of the time in a given block) than to those trials that were more likely to occur. It was also found that participants were more accurate in blocks where landmarks were likely to remain stable. For example, in the reliable condition, the vast majority of trials consisted of a landmark appearing along with the target, a delay and then a re-presentation of the landmark. In these situations, participants would have been able to use the re-presentation of the landmark as a retrieval cue to help recall target location; it was found that participants were quick and most accurate in these trials. However, in this same condition, the landmarks did not reappear after the delay in a few (i.e., 20% of) trials. In these situations, participants were not only slower to respond, but they were also less accurate. Presumably, the decline in performance resulted from participants not being able to use an expected strategy or from a reliance on extrinsic cues.

This experiment sought to address the question of whether top-down mechanisms influence how we use landmarks to help plan our movements. Specifically, it was asked if participants will use landmarks differently if they are expected to be stable or removed. Participants' expectations regarding the reliability of landmarks may affect what visual information is stored in the representation of target location or it may affect how the stored information is utilized. It has been shown, using a visual search task, that expectancies affect the fixation pattern as well as the manual RT of participants; when information is incongruent with expectations participants were slower to respond (Martens, 2004). The results suggest that when participants expect the landmark to be stable, they will incorporate the landmark location into their representation of target location. For example, in the reliable condition for the 80% Landmark Present trials, participants were able to quickly and accurately point to the remembered target location. It may be argued that the re-appearance of the landmark acts as a retrieval cue that helps participants recall target location resulting in a quick and accurate response. It has been demonstrated that the usefulness of any given encoding strategy depends on the conditions that are present during memory retrieval (Tulving & Osler, 1968; Tulving & Thomson, 1973). It is possible that participants encoded target location with respect to the landmark when it is present. Thus, this strategy was beneficial when the landmark was re-presented immediately prior to movement as the presence of the landmark could aid recollection of target location, yet when the landmarks were not re-presented, this encoding strategy had a cost: the magnitude of error increased. It may be possible that in this situation, participants are utilizing a suppressed intrinsic representation. As Sheth and Shimojo (2004) argued, the presence of extrinsic cues suppresses the encoding of an intrinsic frame of reference. This suppressed representation may be recalled when extrinsic cues are not available during the retrieval phase.

The difference in error between Landmark Present and Landmark Removed trials for both Reliable and Unreliable Conditions suggests that target location is stored in an extrinsic frame of reference when non-target objects are present in the visual scene. It has been shown that there is a benefit in performance when objects that are present during the encoding phase are also available during the retrieval phase (Tulving & Thomson, 1973). Thus, when the landmarks were present in the encoding phase and re-appeared prior to movement (i.e., Landmark Present trials), participants were accurate in their estimation of target location. Conversely, when the landmarks were present during the encoding phase, but not during retrieval (i.e., Landmark Removed trials), performance was negatively affected. Even though participants would not have anticipated using the stored representation of the landmark in the Unreliable Condition, they were able to benefit from the re-presentation of the non-target objects, suggesting that participants incorporate the location of non-target objects into an extrinsic frame of reference. Again, the re-presentation of the landmark may have served as a retrieval cue that would allow for an accurate movement to the remembered target location. Because the participants did not expect the landmark to re-appear in the Unreliable Condition, it may have taken additional time to retrieve the stored relationship between the two objects.

The difference in error between the Reliable Condition and Unreliable Condition implies that this phenomenon may be influenced by top down processing. If target location was stored in an extrinsic frame of reference without any effect of top down processing one would not expect a difference in trial type between the two conditions. That is, if landmarks are always incorporated into the representation of target location in the same way, when the landmark is available as a retrieval cue, performance should always be the same. However, performance differed between the two conditions. The decrease in accuracy seen in the Unreliable Condition as a whole compared to the Reliable Condition may have resulted from participants attempting to use an intrinsic frame of reference. Top down information may modulate the strategy utilized; however, extrinsic cues were still incorporated into the representation of target location.

Results from Experiment 2 suggested that when a delay is imposed before the movement begins the presence of non- target objects benefits performance compared to when the target is presented in isolation. Here, we do not see this same effect. Performance on No Box trials was equal to that of trials in the Reliable Condition. Although this result seems contradictory, the nature of the experiments were very different and may have caused this phenomenon to occur. Using a similar task, Sheth and Shimojo (2004) found that participants performed equally when landmarks were always present as to when landmarks were never present. Thus, the findings support the idea that when extrinsic cues are not available, participants will form an accurate representation of target location using an intrinsic frame of reference and that when extrinsic cues are present, they are automatically used to form an extrinsic representation of target location.

It is important to consider that in all conditions, movements were always made after a delay. As previously mentioned, movements made to a remembered target location are thought to be guided by processing in the ventral stream (Goodale & Milner, 1992; Milner & Goodale, 1995). Whereas the dorsal stream computes the location of targets relative to an effector, the ventral stream preserves the relationship among objects (Goodale & Milner, 1992; Milner & Goodale, 1995). The incorporation of non-target objects observed in this experiment may be due to the delay period presented prior to the movement cue. Future studies may consider whether the same effect is seen when movements are made immediately after target offset.

Conclusions

When non-target objects are present in a visual display, target location is automatically represented in an extrinsic frame of reference. As a result, pointing accuracy is improved if the non-target objects are available during the retrieval of target location; however, when the non-target objects are not available during target retrieval performance is negatively affected.

GENERAL DISCUSSION

The goal of this thesis was to broaden our knowledge of how movements are made to a remembered target location when multiple stimuli are present. While many studies have investigated how movements are planned, currently there have been very few studies that have addressed the role of context on movement planning. By looking at different ways in which context can affect movement planning, specifically due to the temporal aspects of the task and the reliability of the non-target objects, we hope to learn how movements are planned when other objects are present in the target scene.

Findings

The results of this thesis illustrate that the temporal aspects of the task can greatly influence how context is used. As Experiment 1 demonstrated, simultaneous presentation of a target and non-target objects can be detrimental to performance, meanwhile performance is improved when non-target objects are presented at least 250 ms in advance of a target. This experiment indicates that competition exists between the various stimuli. The target and non-target objects may compete for attentional processing or, as Tipper and colleagues (1992; Meegan & Tipper, 1998; Meegan & Tipper, 1999) suggest, they may compete for motor output. It is thought that when two or more objects are presented simultaneously, motor programs are created in parallel for each of the objects. For participants to make an accurate movement to the target, they need to inhibit motor programs for non-target objects and activate the motor program for the target.

Experiment 2 also addresses the temporal effects of context; however, it focused on whether movements are initiated immediately after a target is presented or after a delay. This experiment found that when a delay of 2000 ms is present prior to movement participants are faster to respond than when they are required to respond immediately. It is hypothesized that the delay provides additional time for participants to plan their movements, which results in the decreased reaction time observed in Experiment 2.

The temporal aspects of context can clearly influence how the movement is planned, however, this is not the only way in which context can influence movement planning. Experiment 3 shows that participants use the location of non-target objects to help recall target location. When the location of non-target objects shift after the target is encoded and after a delay then participants have greater error in their estimate of target location; specifically, they remember the target to be located in the direction in which the non-target object shifted. In other words, if the non-target objects were shifted left, participants remembered the target to be to the left of its true location. Although top down processing may have prevented participants from producing an endpoint estimate of target location that maps perfectly onto the location where the target would be in relation to the landmarks, participants are pulled by the shift in non-target location. Using a slightly different procedure, Experiment 4 found that regardless of whether one expects non-target objects to be reliable or unreliable, the spatial relationship between the non-target object and the target is encoded and stored in memory. This finding was demonstrated by the increase in error seen in the Unreliable Condition and the improvement of performance in trials within that condition during Landmark Present trials. The results of these two experiments suggest that when present, non-target objects are automatically incorporated in the representation of target location. In other words, the presence of extrinsic cues appears to cause participants to adopt an allocentric frame of reference.

Potential Neurophysiological Mechanisms

This thesis sought to address the behavioural effects of non-target objects on the localization of a target. No neurophysiological measures were used in any of these experiments and the experiments did not seek to find the neurophysiological underpinnings of these phenomenon. However, I offer some speculation as to which underlying neural mechanisms may be most active during the cognitive processes in the varying conditions.

It is believed that depending on the task in question, movement is guided by the dorsal or ventral stream. Visual input is transformed by these two processing streams in very different ways. For instance, the dorsal stream transforms visual input into a representation based on the effector used to perform a particular movement, whereas the ventral stream is able to transform visual input into a perceptual representation that preserves the spatial relationships between objects (Goodale & Milner, 1992; Milner & Goodale, 1995). As well, evidence from visual illusions and patients with damage to their dorsal stream or ventral stream imply that the dorsal stream is involved in real time control over actions whereas the ventral stream is involved in movements made after a delay (Goodale et al, 1994; Dijkerman, Milner, & Carey, 1998; Hu & Goodale, 2000; Westwood, Heath, & Roy 2000; Westwood & Goodale, 2003; Glover, 2003; Carey, Dijkerman, Murphy, Goodale, & Milner, 2006). Further evidence that the dorsal stream is involved in immediate actions and that the ventral stream is recruited when movements are made after a delay comes from an experiment which applied TMS to the anterior intraparietal sulcus (aIPS) in the dorsal stream or to the lateral occipital (LO) cortex in the ventral stream (Rice Cohen, Cross, Tunik, Grafton & Culham, 2009). It was found that TMS applied to LO affected only movements made after a delay whereas TMS applied to the aIPS affected both movements made immediately and after a delay (Rice Cohen et at, 2009).

During all trials in Experiment 1 and trials in the immediate condition in Experiment 2 the target disappeared from view as soon as the movement began, as such it is thought that the dorsal stream would be active in these situations. During these trials, the movement was made immediately after the target had been presented and as such the dorsal stream would be able to guide the movement. However, for trials in the delay condition in Experiment 2 as well as all trials in Experiments 3 and 4 a delay of at least 2000 ms was presented between the disappearance of the target and the onset of the movement cue; in situations where movements are made to a remembered location, it is thought that the ventral stream guides movements (Fischer, 2001; Goodale et al., 1994; Goodale & Milner, 1992). In other words, we believe the dorsal stream would be active during trials when the movement was made immediately after the target was presented, and that the ventral stream would be active in trials in which a delay was present before the participant was able to begin their movement.

Along with the well known motor areas of the brain, areas responsible for attention and response selection are also thought to be involved in the various tasks in our experiments. The role of the frontal cortex in action selection has been well established (Frith, Fridton, Liddle, & Frackowiak, 1991; Goldberg & Segraves, 1987) and it is believed that this area is influential in selecting which motor program is activated. In particular, one possible area involved in inhibiting motor programs for non-target objects is the right inferior frontal gyrus. This region has been shown to be active during response competition during a flanker task, suggesting a role for this area in inhibiting motor programs for irrelevant stimuli (Hazeltine, Poldrack, & Gabrieli, 2000). As well, the right inferior frontal gyrus is most active in the no-go trials of a go/no-go task compared to the go trials and a response selection task, implying that this area may be involved in planning a correct response to the target and inhibiting movement plans to the non-target objects (Kawashima et al, 1996). As such, one would expect this region to be highly active during Experiments 1 and 2, especially during trials with a short SOA.

As well, using an fMRI experiment, Casey and colleagues (2000) explored the neural mechanisms are involved in response competition. In this study participants were presented with a flanker task and were required to respond manually to indicate which direction an arrow pointed in. It was found that the anterior cingulate cortex and dorsolateral prefrontal cortex were most active in the conditions where flankers provided the most interference (Casey et al., 2000). It was suggested that these two areas are involved in detecting or resolving response competition between competing stimuli. As such, it is thought that these areas would be most active in Experiment 1 during trials in which the SOA between non-target and target presentation is the shortest (0 ms or 50 ms); these areas may also be involved in trials with longer SOA's.

In the flanker task used by Casey and colleagues, the anterior cingulate cortex and dorsolateral prefrontal cortex were most active during incompatible trials in a valid condition; a situation where an incompatible trial was presented after a series of compatible trials (Casey et al., 2000). The authors suggest that the involvement of the anterior cingulate cortex and dorsolateral prefrontal cortex during these trials reflects their role in deploying attentional control to events that are behaviourally important rather than highly salient which would suggest that these areas may also be highly active in Experiment 4 where participants are provided with top-down information regarding the stability of the non-target objects. The activity of this area may explain why participants did not produce the same pattern of responses in all Landmark Absent trials. As well, Casey and colleagues (2000) found the caudate nucleus and insula to be active in trials which were incompatible with the other trials in the block, as these areas are thought to be sensitive to changes in the probability of events. It is expected that the caudate nucleus and insula would be active in the 20% of trials that are unexpected in both the Reliable and Unreliable Conditions of Experiment 4.

Additionally, it has been demonstrated that the intraparietel sulcus is active during tasks in which participant's voluntarily direct attention to specific locations and it has been suggested that this area may hold spatial maps of attention (Silver, Ress & Heeger, 2005). Due to spatial nature of our tasks, it is expected that this area would be active during all tasks. Finally, it is also thought that the medial aspect of the posterior parietal cortex would be activated during all experiments as this region is thought to be a human homologue of the parietal reach region in monkeys (Connolly, Anderson, & Goodale, 2003). The nature of our tasks require participants to reach out to the target location, thus this area would presumably be active during our tasks.

Future Studies

Future studies may address whether the effect of SOA on reaction time was due to competition for attentional processing or motor output. Although the current experiments did not aim to address this question, additional studies may be able to distinguish between the two explanations. As well, future studies may look to see how context can affect performance in more complex scenes. In our tasks the scene consisted of one or two non-target objects that were always the same colour of the targets. By presenting a more complex scene to participants we could further investigate which properties of non-target objects are most important in the representation of target location. For instance, an adaptation of Experiment 3 could present multiple non-target objects and systematically vary which objects are shifted. This may show that only the non-target objects closest to the target or perhaps only the largest objects are represented in the allocentric representation of target location. Research has only recently begun to address how context can effect movement planning. As such, there is an abundant opportunity for future research in this field.

CONCLUSIONS

The goal of this thesis was to broaden the understanding of how movements are planned to a target when other objects are present in the environment. It was found that the timing in which the objects are presented, as well as the time at which the movement is made can greatly affect how the movement is planned. It was also found that on some level, participants automatically encode target location in an extrinsic frame of reference. These studies tell us that we cannot ignore the role of context in movement planning; the presence of non-target objects inherently alters the way in which our movements are programmed.

References

Ballard, D. H., Hayhoe, M. M., Li, F., & Whitehead, S. D. (1992). Hand-eye coordination during sequential tasks. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences, 29*, 331–338.

Bridgeman, B., Peery, S. and Anand, S. (1997). Interaction of cognitive and sensorimotor maps of visual space. *Perception and Psychophysics 59*, 456–469.

Buneo, C., A, & Andersen, R., A. (2006). The posterior parietal cortex: sensorimotor interface for the planning and online control of visually guided movements. *Neuropsychologia 44,* 2594–2606.

Buneo, C., A, Jarvis, M., R., Batista, A., P., & Andersen, R., A. (2002) Direct visuomotor transformations for reaching. *Nature 416*, 632–636.

Carey, D.P., Dijkerman, H.C., Murphy, K.J., Goodale, M.A., Milner, A.D. (2006) Pointing to places and spaces in a patient with visual form agnosia. *Neuropsychologia 44,* 1584-1594.

Carrozzo, M., Stratta, F., McIntyre, J., & Lacquaniti, F. (2002). Cognitive allocentric representations of visual space shape pointing errors. *Experimental Brain Research, 147,* 426–436.

Casey, B. J., Thomas, K. M., Welsh, T. M., Badgaiyan, R. D., Eccard, C. H., JenningsJ. R., & Crone, E. A. (2000). Dissociation of response conflict, attentional selection, and expectancy with functional magnetic resonance imaging. *Proceedings of the National Academy of Sciences, 97,* 8728-8733.

Coles, M.G.H., Gratton, G., Bashore, T.R., Eriksen, C.W., & Donchin, E. (1985). A psychophysiological investigation of the continuous flow model of human information processing. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 529-553.

Connolly, J. D., Andersen, R. A., & Goodale, M. A. (2003). FMRI evidence for a 'parietal reach region' in the human brain. *Journal of Experimental Brain Research, 153,* 140–145.

Diedrichsen, J., Werner, S., Schmidt, T. & Trommershauser, J. (2004). Immediate spatial distortions of pointing movements induced by visual landmarks. *Perception and Psychophysics, 66*, 89-103.

Dijkerman, H.C., Milner, A.D., & Carey, D.P. (1998). Grasping spatial relationships: Failure to demonstrate allocentric coding in a patient with visual form agnosia. *Consciousness and Cognition*, 7, 424-437.

Desmurget, M., Jordan, M., Prablanc, C., & Jeannerod, M. (1997). Constrained and unconstrained movements involve different control strategies. *Journal of Neurophysiology, 77*, 1644-1650.

Deubel, H. & Schneider, W. X. (2003). Delayed saccades, but not delayed manual aiming movements, require visual attention shifts. *Annals of New York Academy of Science, 1004*, 289–296.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review, 70*, 80-90.

Duncan-Johnson, C.C., & Koppell, B. S. (1981). The Stroop effect: Brain potentials localize the source of interference. *Science*, *214*, 938-940.

Elliot, D., & Madalena, J., (1987). The influence of premovement visual information on manual aiming. *Quarterly Journal of Experimental Psychology*, 39A, 541–559.

Eriksen, C. W. & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Perception & Psychophysics, 14,* 155-160.

Eriksen, C. W. & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception and Psychophysics, 40,* 225-240.

Fischer, M. H. (2001). How sensitive is hand transport to illusory context effects? *Experimental Brain Research, 136,* 224–230.

Fischer, M. H, & Adam, J. J. (2001). Distractor effects on pointing: the role of spatial layout. *Experimental Brain Research, 136,* 507–513.

Fischer, M.H., Pratt, J., and Adam, J.J. (2007). On the timing of reference frames for action control. *Experimental Brain Research, 183,* 127-132.

Frith, C.D., Fridton, K., Liddle, P.F., & Frackowiak, R.E.S. (1991). Willed action and the prefrontal cortex in man: a study with PET. *Proceedings of the Royal society of London. Series B. Biological sciences, 244,* 241-246.

Glover, S. (2003). Optic ataxia as a deficit specific to the on-line control of actions. *Neuroscience and Biobehavioral Reviews* 27, 447–456.

Goldberg, & Segraves, (1987). Visuospatial and motor attention in the monkey. *Neuropsychologia, 25,* 107-118.

Goodale, M. A., Jakobson, L. S., & Keillor, J.M. (1994). Differences in the visual control of pantomimed and natural grasping movements. *Neuropsychologia, 32,* 1159–1178.

Goodale, M.A., Króliczak, G., & Westwood, D.A. (2005). Dual routes to action: contributions of the dorsal and ventral streams to adaptive behavior. *Progress in Brain Research, 149,* 269-279.

Goodale, M.A. & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neuroscience, 15,* 20-25.

Gorbet, D. J & Sergio, L. E. (2007). Preliminary sex differences in human cortical BOLD fMRI activity during the preparation of increasingly complex visually guided movements. *European Journal of Neuroscience, 25*, 1228–1239.

Gravetter, F. J. & Wallnau, L. B. (2004). Statistics for the behavioural sciences: Sixth Edition. Toronto, Ontartio, Canada: Thomson Wadsworth

Hazeltine, E., Poldrack, R., & Gabrieli, J. D. E. (2000). Neural activation during response competition. *Journal of Cognitive Neuroscience, 12: Supplement 2,* 118-129.

Henriques, D.Y.P., Klier, E.M., Smith, M. A., Lowy, D., & Crawford, J. D. (1998).Gaze-centered remapping of remembered visual space in an open-loop pointing task. *The Journal of Neuroscience, 18,* 1583–1594.

Henry, F.M. & Rogers, D. E. (1960). Increased response latency for complicated movements and a “memory drum” theory of neuromotor reaction. *Research Quarterly, 31,* 448-458.

Houghton, G. & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. Carr (Eds.), *Inhibitory mechanisms in attention, memory and language* (pp. 53-112). Orlando, FL: Academic Press.

Hu, Y. and Goodale, M. A. (2000). Grasping after a delay shifts size-scaling from absolute to relative metrics, *Journal of Cognitive Neuroscience. 12*, 856–868.

Julesz, B. (1975). Experiments in the visual perception of texture. *Scientific American, 232,* 34-43.

Kalaska, J. F. & Crammond, D. J (1992). Cerebral cortical mechanisms of reaching movements. *Science, 255*, 1517-1523.

Kawashima, R., Satoh, K., Itoh, H., Ono, S., Furumoto, S., Gotoh, R., Koyama, M., Yoshioka, S., Takahashi, T., Takahashi, K., Yanagisawa, T., & Fukuda, H. (1996). Functional anatomy of a GO/ NO-GO discrimination and response selection – a PET study in man. *Brain Research, 728*, 79-89.

Lemay, M., Bertram, C. P., & Stelmach, G. *E. (*2004). Pointing to an Allocentric and Egocentric Remembered Target. *Motor Control, 8,* 16-32.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203.

Martens, M. H (2004). Stimuli fixation and manual response as a function of expectancies. *Human Factors, 46,* 410–423.

McIntyre, J., Stratta, F. & Lacquaniti, F. (1998). Short-Term Memory for Reaching to Visual Targets: Psychophysical Evidence for Body-Centered Reference Frames *The Journal of Neuroscience*, *18*, 8423–8435.

Milner, D.A. & Goodale, M.A. (1995). The Visual Brain in Action. Oxford: Oxford Science Publication.

Milner, A.D. & Goodale, M.A. (2008). Two visual systems re-visited. *Neuropsychologia, 46*, 774-785.

Meegan, D.V., & Tipper, S.P. (1998). Reaching into cluttered visual environments: spatial and temporal influences of distracting objects. *The Quarterly Journal of Experimental Psychology, 51A*, 225-249.

Meegan, D.V., & Tipper, S.P. (1999). Visual search and target-directed action. *The Journal of Experimental Psychology: Human Perception and Performance, 25*, 1347-1362.

Murphy, T. D. & Eriksen, C. W. (1987). Temporal changes in the distribution of attention in the visual field in response to precues. *Perception and Psychophysics, 42,* 576-586.

Obhi, S.S & Goodale, M.A. (2005). The effects of landmarks on the performance of delayed and real-time pointing movements. *Experimental Brain Research*, 167, 335-344.

Posner, M. I. (1982). Cumulative Development of Attentional Theory. *American Psychologist, 37*, 168-179.

Rice Cohen, N., Cross, E. S., Tunik, E., Grafton, S. T., & Culham, J. C. (2009). Ventral and dorsal stream contributions to the online control of immediate and delayed grasping: A TMS approach. *Neuropsychologia, 47,* 1553-1562

Schacter, D. L. (1990). Memory. In M. I. Posner (ED.*), Foundations of Cognitive Science*, Cambridge: MIT Press.

Silver, M. A., Ress, D., & Heeger, D. J. (2005). Topographic maps of visual spatial attention in human parietal cortex. *Journal of Neurophysiology, 94*, 1358–1371.

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology, 81*, 174-176.

Sheth, B.R. & Shimojo, S. (2004). Extrinsic cues suppress the encoding on intrinsic cues. *Journal of Cognitive Neuroscience, 16*, 339-350.

Sorrento, G. U. & Henriques, D. Y. P. (2008). Reference frame conversions for repeated arm movements. *Journal of Neurophysiology, 99*, 2968-2984.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology, 37A,* 571-590.

Tipper, S.P., Howard, L.A., & Houghton, G. (1998). Action-based mechanisms of attention. *Philosophical Transactions: Biological Sciences, 353*, 1385-1393.

Tipper, S.P, Lortie, C. & Baylis, G.C. (1992). Selective Reaching: Evidence for action centered attention. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 891-905.

Tulving, E. & Osler, S. (1968). Effectiveness of retrieval cues in memory for words. *Journal of Experimental Psychology, 77,* 593-601.

Tulving, E. & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352-373.

Ungerleider, L.G. & Mishkin, M. (1982). Two cortical visual systems. In D.J. Ingle, M.A. Goodale & R.J.W. Mansfield (Eds). Analysis of Visual Behavior. Cambridge, MA: MIT Press pp.549-586.

Westwood, D. A., Heath, M. and Roy, E. A. (2000). The effect of a pictorial illusion on closed-loop and open-loop prehension. *Experimental Brain Research 134*, 456–463.

Westwood, D.A. & Goodale, M. A. (2003). Perceptual illusion and the real-time control of action. *Spatial Vision, 16*, 243-254.

Whitwell, R., L., Lambert, L. M., Goodale, M. A. (2008). Grasping future events: explicit knowledge of the availability of visual feedback fails to reliably influence prehension. *Experimental Brain Research, 188,* 603-611.

Wise, S. P., di Pellegrinog., G, & Boussaoud, D. (1996). The premotor cortex and nonstandard sensorimotor mapping. *Canadian Journal of Physiology and Pharmacology, 74,* 469–482.