

**IS INTERFERENCE IN GRASPING PRODUCED WHEN COVERT  
ATTENTION IS DIRECTED TO NON-TARGET OBJECTS?**

**by**

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## ABSTRACT

Previous literature has shown that when covert attention is directed to a non-target object while grasping a target fruit, the non-target's size can influence the peak grip aperture for the target fruit (Castiello, 1996). Castiello's study is heavily cited but no replications have even been published. For this reason, the current study first aimed to replicate the interference effect found by Castiello (1996), and then explores the role that binocular vision might play in moderating the effect. Experiment 1 was a strict methodological replication of Castiello's (1996) main experiment. The results revealed a robust effect of the target fruit's size on peak grip aperture, but no effect of the size of the non-target flanking fruit. In Experiment 2, a similar paradigm was used to determine if the effect of the flanking fruit would increase when binocular vision was restricted, based on the idea that actions controlled with binocular vision have privileged access to the dorsal visual pathway which is known to produce metrically precise actions. As in Experiment 1, no evidence was found for an effect of the size of the flanking fruit under binocular or monocular viewing conditions, suggesting that grasping actions are quite robust to interference from concurrently attended non-target objects.

## **LIST OF ABBREVIATIONS USED**

IRED	Infrared Emitting Diode
LGN	Lateral Geniculate Nucleus
V1	Primary Visual Cortex
BSV	Binocular Single Vision
EOG	Electrooculogram
SPSS	Statistical Package for Social Sciences
ANOVA	Analysis of Variance
M	Mean
SE	Standard Error of the Mean



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# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND

Our ability to interact with the world around us is integral to our survival. Motor control processes are key to this; they control our ability to coordinate and execute actions and therefore interact with objects around us. We are able to reach to and grasp objects in order to manipulate them. This action of reaching and grasping is formally referred to as prehension. It has been shown that the act of grasping an object is actually the end result of a motor sequence that begins well prior to object contact. To better understand prehension, it has been sub-divided into two components, the transport component and the manipulation component (Jeannerod, 1984). During the transport component, the elbow and the shoulder are used to move the hand to the location of the object to be grasped. The manipulation component involves use of the distal muscles in the hand to adjust the shape of the hand to conform to the object shape and effectively grasp it. The transport and manipulation component of prehension are not temporally distinct; in fact the fingers of the hand begin to adjust during the transport of the hand.

Normal prehension kinematics have been studied and characterized. From the beginning of the movement the velocity of the hand increases until it reaches a maximum velocity at 50-70% of the movement, after which it decreases until the end of the movement. At the same time the grasp is initiated; the fingers are increasingly separated from movement onset until they reach their peak separation (peak grip aperture) at 60-70% of the total movement. After this point, peak grip aperture is decreased until the fingers enclose the target object (Castiello, 2005; Jeannerod & Prablanc, 1983).

For a prehensile action to be completed accurately, the visual sensory input of one's environment and proprioception of one's current body state must be integrated to activate the correct set of muscles at the correct time (Rosenbaum, 1991). Intrinsic features (true to the object; size, shape, color) and extrinsic features (that relate the object to the viewer; location, orientation) of target objects are analyzed by the visual system. The transport component of prehension is highly related to the extrinsic properties of the target object, whereas the grasp component is highly related to the object's intrinsic properties (Jeannerod, 1984; Jeannerod, 1988). For example, the size of a target object is highly correlated with the peak grip aperture (Jeannerod, 1986). Although peak grip aperture invariably exceeds the actual size of the object, changing the target size will predictably alter peak grip aperture as well as the time to reach peak grip aperture (Jakobson & Goodale, 1991; Jeannerod, 1986; Martenuik, 1990). Since peak hand speed is associated with the initial distance between the hand and the target object, it can be related to the processing of visual information associated with distance or depth. Similarly, because peak grip aperture is associated with the size of the target object, it can be related to the processing of visual information related to the perceived size of the target object (Jackson et al., 1997; Jakobson & Goodale, 1991; Jeannerod, 1986; Melmoth & Grant, 2006; Servos et al., 1992; Servos & Goodale, 1994; Watt & Bradshaw, 2000). All of this shows that vision is important for the accurate execution of prehensile movements; therefore, it is important to further explore the visual system and how it relates to prehension.

Vision not only gives us information about the world around us, it is also able to direct our behaviours. Vision-for-perception and vision-for-action have differing

behavioural and perceptual outputs, and therefore how they process visual information is distinct. These different demands have likely shaped the organization of the visual system into two distinct pathways, the dorsal and ventral streams (Goodale, 2014). The ventral stream functions to perceive object features whereas the dorsal stream uses visual information of object features to direct actions (Goodale & Milner, 1992; Goodale, 2014; Westwood & Goodale, 2011). Within the dorsal stream there are specialized areas that are specifically tuned to achieve accurate movement and prehension. In particular, the lower visual field is emphasized in area V6A (a section of the dorsal stream) (Farotti et al., 2015). This leads to more precise grasping movements (Brown et al., 2005) as well as faster and more accurate pointing movements (Danckert & Goodale, 2001). Additionally, area V6A contains cells that are not actually visually activated but rather are sensitive to arm movement and wrist orientation (Farotti et al., 2015).

The arrangement of the dorsal visual stream is not the only aspect of the visual system that is important to prehension. The ability to perceive depth from stereopsis and ocular vergence angle is also key to accurate prehension. Binocular vision has been divided into three levels, simultaneous perception, fusion and stereopsis. For the purposes of prehension, stereopsis is likely the most important. It is the ability to perceive depth from the horizontally disparate images from each eye (Howard & Rogers, 1996; Rowe, 2012). Stereoacuity refers to one's ability to perceive depth from disparate retinal images. It is typically measured in seconds of arc of retinal disparity, where a smaller stereoacuity value represents the ability to detect smaller differences in depth (von Noorden & Campos, 2002). The ocular vergence angle is the relative alignment between the two eyes when fixating on a target at a particular distance (Howard & Rogers, 1996; Rowe, 2012).

The eyes converge more when an object is moved closer to the face to ensure that the target stays on the fovea of each eye. Vergence information conveys information about target depth relative to the observer, whereas stereopsis conveys relative depth information between two objects (Howard & Rogers, 1996; Neri et al., 2004).

In the absence of binocularity, the visual system relies on different visual cues to determine depth. These cues include linear and aerial perspective, the size of known objects, motion parallax, overlap of objects and texture gradient (von Noorden & Campos, 2002). For details on each of these cues, see section 2.6. Whereas binocular depth cues rely on absolute properties of the target object, perceiving depth from monocular cues relies on a scene-based view of the target object in context with its surroundings. Marotta et al. (1998) tested this idea by having participants grasp a circular target surrounded by other circles, creating the Ebbinghaus Illusion. This illusion causes perceptual misjudgments in the size of the centre circle. Marotta et al. (1998) had participants grasp the central circle under both monocular and binocular conditions, and found that prehensile movements were affected by the illusion only under monocular conditions. Similarly, visual illusions have been shown to affect perceptual judgments but not grasping when binocular vision is used (Aglioti et al., 1995; Bartelt & Darling, 2002; Gentilucci et al., 1996; Haffenden & Goodale, 1998; Haffenden et al., 2001; Hu & Goodale, 2000). Therefore, we can see that both the ventral stream (vision-for-perception) and grasping using monocular vision is affected by visual illusions, but grasping under binocular conditions is unaffected by perceptual illusions.

Although it is clear that vision is important in guiding movements and ensuring accurate prehension, attention is also important in the process. Largely, the visual system

is not capable of fully processing all information in the visual field, and has therefore adopted solutions around this. Firstly, visual information is processed in full detail only at the fovea, and information in the peripheral visual field is more coarsely sampled and processed. Secondly, visual information is selectively processed and visual attention is the method by which certain areas of the visual field are targeted for further information processing (Wolfe, 1994; Desimone & Duncan, 1995). For this reason, attention is important during prehension to direct the visual system to process task relevant information and ignore task irrelevant information. The action of selecting goal-relevant information and ignoring goal irrelevant information is referred to as selection-for-action. If in fact, visual attention is a mechanism for selection-for-action, then the intention to perform an action should result in top-down control that selectively processes visual information that is task relevant (Deubel & Schneider, 1996). To support this view, Bekkering & Neggers (2002) provided evidence that a specific action intention was able to enhance visual processing of action relevant information. They suggest that this is evidence in support of the view that visual attention is a selection-for-action mechanism.

Attention can be sub-divided into overt and covert orienting. During overt attention, the eyes are directed towards the target of attention, whereas during covert attention, cognitive attentional resources are directed to a target location without the eyes being directed there. During prehensile movements, overt attention is biased towards locations on the object that will be grasped (Baldauf & Deubel, 2010; Johansson et al., 2001). Specifically, gaze is directed to the future finger location that is more difficult to make contact with (Brouwer et al., 2009).

Attention is particularly important in cluttered scenes, those with multiple objects that can act as obstacles to the intended movement or as separate potential targets. When obstacles are present, overt attention is maintained on the obstacle while the hand moves around it (Johansson et al., 2001).

The presence of non-target objects has been shown to affect the kinematics of prehension. If the flanker object is an obstacle to the intended movement, the hand will maintain a minimum distance away from the flanker (Tresilian, 1998). In addition, the reach component of prehension has also been shown to deviate towards (Welsh et al., 1999) or away (Tipper et al., 1997) from the flanker. Welsh et al. (1999) suggest that this difference arises from the relevance of the non-target objects. They propose that their non-target objects were not physical barriers to the intended movement whereas those used by Tipper et al. (1997) were intended to be obstacles. In explaining their findings, Welsh et al. (1999) proposed that actions to each object is planned in parallel and parts of the plan for the non-target object “leaks” into the plan for the target objects. Tipper et al. (1997) suggests that their findings arise because competing movement plans are generated and inhibition is required to resolve the competition and the effects of inhibition can be seen in the movement kinematics. The presence of non-target objects has also been shown to affect aspects of prehension other than the trajectory of the reach. Movement time has been shown to increase (Mon-Williams et al., 2001; Saling et al., 1998) and peak grip aperture has been shown to decrease (Jackson et al., 1995; Mon-Williams et al., 2001; Saling et al., 1998; Tresilian, 1998) or remain unchanged (Kritkos et al., 2000). Ultimately, it is unclear at this point how prehension kinematics are affected by non-target objects and the exact role attention plays in directing actions. More research

is needed to determine how action plans for multiple potential objects are processed and the role that attention plays in directing this processing.

Castiello (1996) examined covert attention and its role in prehension. To do this he employed a dual-task paradigm where participants were required to maintain their gaze (overt attention) on a central piece of fruit during a prehension task while simultaneously counting the number of light flashes on a second, flanking piece of fruit (covert attention). Interestingly, he found that participants peak grip aperture for the target fruit was scaled towards the size of the flanker fruit while the grasp for the target was completed with covert attention directed to the flanker. Castiello (1996) proposed that the interference effect he found arose from automatic processing of motor patterns for attended to objects that are not the focus of the intended action. In other words, when attention is directed to an object (even when we have no intention of acting upon it), a motor pattern is created for that object, and that motor plan is able to affect the prehension kinematics for a target object. Similar results were seen in a related study that had participants covertly track a moving flanker while simultaneously grasping a target object (Bonfiglioli & Castiello, 1998). In this study, it was determined that specific features of the flanker object selectively produced interference effects. Specifically, interference effects in the transport component of the grasp were noted when participants had to covertly monitor for the *position* of the flanker. Alternatively, the grasp component showed interference effects when participants had to covertly monitor the *size* of the flanker. This further demonstrates the effect of top-down attentional control on visual information processing and movement planning; attending to a particular aspect of a non-target object produces interference effects specific to the attended aspect of said object.



A recent study by LeBlanc & Westwood (2014) employed a sequential task paradigm to further explore Castiello's (1996) proposal that automatic motor plans are created when objects are attended to. They had participants reach to and grasp a target object followed by either a perceptual or motor task associated with a second object. Participants would either have to verbally report the size of the second object or reach out and grasp it. They hypothesized that because sequential tasks are processed as a whole (Henry & Rogers, 1960; Hesse & Deubel, 2010), that peak grip aperture would be scaled towards the size of the second object. Results indicated that the expected interference effects were only produced when participants attended to the size of the second object for a verbal estimation, but not when planning an action to the second object.

## 1.2 PURPOSE

The purpose of this study was to further explore the role that attention, particularly covert attention, plays in prehensile movements. Previous research demonstrates that movement kinematics can be affected by the presence of non-target objects, which require additional attentional resources, however the findings are not consistent in what effects are produced under different situations. For instance some studies demonstrate that hand trajectories will deviate away from non-target objects (Howard & Tipper, 1997; Tipper et al., 1997) whereas others show hand trajectories deviate towards non-target objects (Welsh et al., 1999). For this reason, a replication of Castiello's (1996) paradigm will be performed to confirm his findings. In particular, the study will focus on the interference effects observed when covert attention was directed to non-target objects that

resulted in the size of the peak grip aperture for the target object being scaled towards the size of the non-target object (Castiello, 1996).

### 1.3 HYPOTHESIS

There are two broad outcomes that could arise from an attempt to replicate Castiello's (1996) paradigm; either replication of the interference effects will be successful or unsuccessful. To reiterate, Castiello found that covertly attending to a non-target object while grasping a target object lead to changes in the peak grip aperture for the target fruit. Specifically, the peak grip aperture for the target fruit was scaled towards the size of the flanker fruit upon which covert attention was directed. Since we are attempting to replicate his study exactly, it is expected that we will find the same pattern of results.

Drawing on Castiello's (1996) findings, LeBlanc & Westwood (2014) expected to find interference effects in a sequential task paradigm in which attention was deployed to two objects, but found evidence of interference only when a perceptual judgment was required of the second object in the sequence. This result was contrary to the idea advanced by Castiello (1996) that competing motor plans (implicit or explicit) interfere with one another. As such, it is possible that Castiello's observations might have been a Type I error and that a replication attempt could fail.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Integral to our everyday functioning is our ability to interact with the world around us. We rely on motor control processes to coordinate and execute actions, ranging from simply picking up a coffee cup to more complex actions like playing the piano. In order to successfully execute an action, the sensory input regarding one's environment and proprioception of one's current body state must be integrated to activate the correct set of muscles to produce the desired action (Rosenbaum, 1991). Attention is also critical in the control of movement by helping to modulate the relevant sensory input to complete the action accurately. A common action performed routinely in our everyday functioning is the act of reaching to and grasping an object; this is also referred to as prehension. During this thesis, prehension will be used to explore the role that attention and vision play in action and will therefore be explored in more detail below.

#### **2.1 PREHENSION**

Prehension has been sub-divided into two components, the transport component and the manipulation component (Jeannerod, 1984). The transport or reach component of prehension involves the use of the shoulder and elbow to move the hand to the location of an object, whereas, the manipulation or grasp component, involves the use of the distal muscles in the hand to interact with a target object. The type of grasp to be adopted for this interaction relies heavily on the properties of the target. The two main types of grasp include the power grip, where the object is grasped between the thumb and all fingers, and the precision grip, where the object is grasped between the thumb and index finger

(Napier, 1960). Additionally, the activity for which the object will be used can affect the type of grasp that is adopted (Marzke, 1994). For example, a fork would be grasped differently depending on whether the individual planned on using it to eat or planned to pass it across the table to someone else.

### **2.1.1 Kinematics of Prehension**

Jeannerod & Prablanc (1983) characterized the overall kinematics of prehension in terms of the hand and finger kinematics. They determined that from the beginning of the movement, the velocity of the hand increases until it reaches a peak at 50-70% of the movement duration. It is at this point that the hand begins to decelerate, producing a bell shaped velocity profile for the transport component of the grasp. In parallel, the grasp component occurs, which is typically characterized in terms of grip aperture (the linear separation between the digits that will be used to grasp the target). Like velocity, grip aperture increases from movement onset until it reaches a peak at approximately 60-70% of movement duration. After this point, grip aperture decreases until the fingers enclose the target object (Castiello, 2005).

Prehension kinematics are often measured using optoelectric tracking systems that employ infrared emitting diodes (IREDs) placed on specific points of interest on the hand. The points typically include the tip of the thumb, the tip of the index finger, and the wrist. The optoelectric system uses multiple infrared sensitive cameras to triangulate the 3-D location in space of each IRED in real time at a high sampling rate (e.g., 200 Hz) (Shumway-Cook & Woollacott, 2001). From the time-series of 3-D positions, prehension kinematics can be calculated for both the transport (based on the wrist marker) and the

grasp component of the action (based on the index finger and thumb markers). Some of the most commonly analyzed parameters include: (i) reaction time – the time from the cue to start the trial and movement onset, (ii) movement time – the time from movement onset to enclosing the target object, (iii) peak hand speed – the maximum wrist velocity, (iv) time to peak hand speed – the time from movement onset to the peak velocity, (v) peak grip aperture – the maximum distance between the thumb and forefinger, and (vi) time to peak grip aperture – the time between movement onset and reaching peak grip aperture.

Kinematic outcomes that encompass both the transport and grasping components include reaction time and movement time. Reaction time is thought to reflect the time necessary to plan and initiate the movement (including visual analysis of the target) whereas movement time reflects the biomechanical constraints of movement execution in addition to the time required to utilize feedback and make adjustments to the action. The transport component of prehension is typically characterized in terms of the peak hand speed and the time to peak hand speed.

Prehension behaviour is guided by the features of the target object. Object properties are analyzed by the visual system, and can be divided into intrinsic (features true to the object; size, shape, color) and extrinsic (features that relate the object to the viewer; location, orientation) properties. The transport component relies on appropriate visual analysis of the extrinsic properties to move the hand to the location of the object (Jeannerod, 1984; Jeannerod, 1988). The magnitude of the peak velocity during the transport component is scaled to the distance between the starting location and the target object, where peak velocity is greater when the target is farther away. For this reason, peak hand speed can be related to the processing of visual information associated with

distance or depth. The time to achieve peak hand speed is thought to separate the time spent in the initial fast phase of the movement (primarily planned in advance of movement onset) and the slow, controlled phase of the movement (primarily related to feedback-based control) (Jackson et al., 1997; Jakobson & Goodale, 1991; Jeannerod, 1986; Melmoth & Grant, 2006; Servos et al., 1992; Servos & Goodale, 1994; Watt & Bradshaw, 2000).

In contrast, the manipulation component of prehension is characterized in terms of peak grip aperture and the time to reach peak grip aperture. The grasp is highly related to the intrinsic properties of an object (Jeannerod, 1984; Jeannerod, 1988). For instance, the size of the peak grip aperture is highly correlated with the size of the target object even though the absolute magnitude of the peak reliably exceeds the actual size of the object (Jakobson & Goodale, 1991; Jeannerod, 1986; Martenuik et al., 1990). Jeannerod (1986) suggests that peak grip aperture always exceeds the target size to incorporate a “safety margin” for the action, thus preventing a collision with the object due to potential errors in size estimation or motor execution. Jakobson & Goodale (1991) noted also that the time taken to reach peak grip aperture was correlated with object size, which makes sense given that the hand must open wider for larger objects. Since peak grip aperture is related to the target object size, it can be used as an index of the processing of visual information related to the size of the target object. Similar to the time to achieve peak hand speed, the time to peak grip aperture can be thought of as a means of separating the initial fast phase of the movement from the slow, controlled phase (Jackson et al., 1997; Jakobson & Goodale, 1991; Jeannerod, 1986; Melmoth & Grant, 2006; Servos et al., 1992; Servos & Goodale, 1994; Watt & Bradshaw, 2000).

Ultimately, appropriate prehensile movements are dependent upon accurate visual information processing and accurate visual perception. Of particular importance is the processing of depth by both monocular and binocular cues. To better understand the role that vision plays in guiding prehensile movements, we will first explore the basics of the visual pathway and how binocular depth cues are then achieved.

## 2.2 VISUAL PATHWAYS

The visual pathway is an array of structures, cells and synapses that processes light from the environment and allows for the perception of vision. Light that is reflected off a target object will be refracted by the cornea and lens of the eye, pass through the aqueous and vitreous and then onto the photoreceptors (rods and cones) at the back of the retina. When the photoreceptors are stimulated by light between 380 and 760nm, they will produce an electrical impulse that is passed through the retina to the bipolar cells then to the ganglion cells. The ganglion cell axons exit the eye as the optic nerve and carry the impulse to the brain (Cassin, 1995; Remington, 2012).

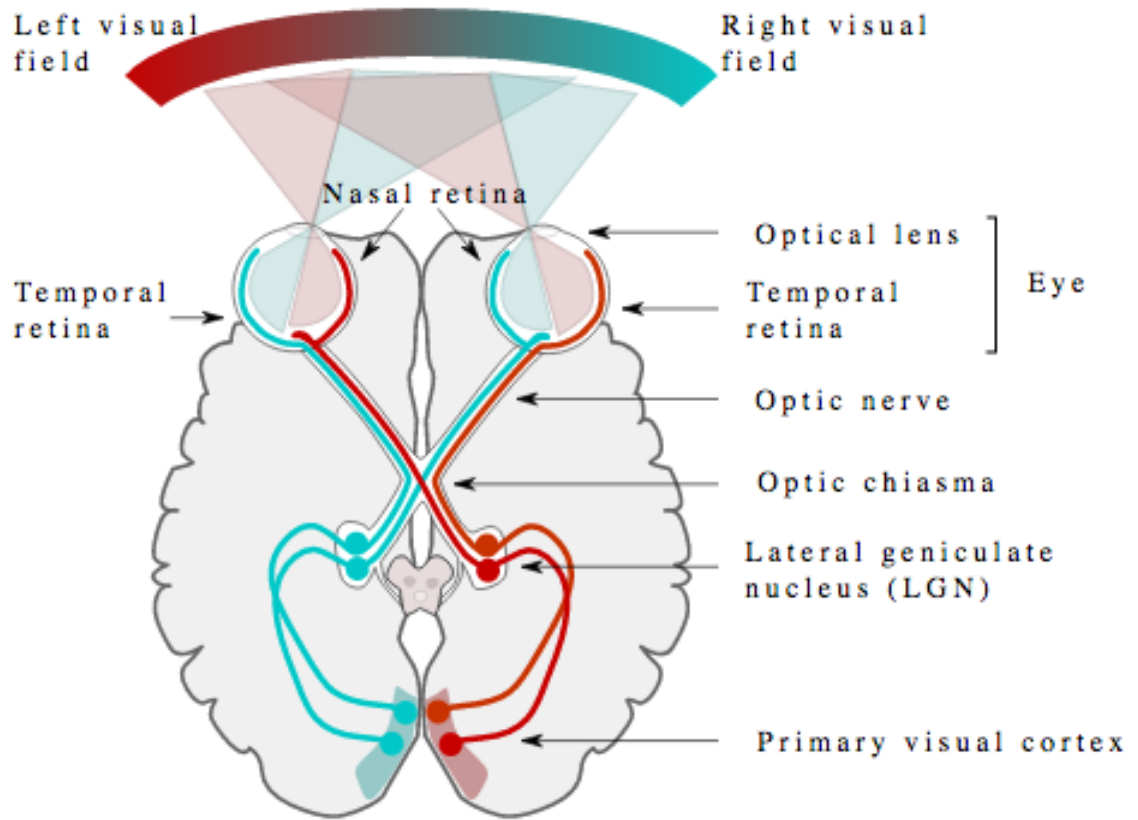
The axons arising from the nasal half of the retina will cross at the optic chiasm to join the uncrossed fibres from the temporal half of the contralateral eye; this process creates two optic tracts that carry visual information from the contralateral visual field. Hemi-decussation at the optic chiasm is important in that it allows information from each eye coming from the same location in space to be directly compared. This process is important in the sensation of depth, or stereopsis (Cassin, 1995).

The two optic tracts travel from the optic chiasm to the midbrain, where the majority of axons synapse in the lateral geniculate nucleus (LGN) of the thalamus

(Cassin, 1995). The LGN is classically thought of as having six layers (Remington, 2012). The bottom two layers are composed of large magnocellular cells; layer 1 receives input from the contralateral eye while layer 2 receives input from the ipsilateral eye. The next four layers are composed of smaller parvocellular cells; layers 3 and 5 receive input from the ipsilateral eye, while layers 4 and 6 receive input from the contralateral eye (Colby, 1988). Between each of these layers there are also koniocellular layers that are made up of the smallest cells in the LGN. Though the majority of ganglion cell axons synapse in the LGN, some also terminate in areas such as the superior colliculus, the pretectal nucleus in the midbrain and the hypothalamus (Remington, 2012).

Axons leaving the LGN form the optic radiations that fan out temporally and inferiorly to terminate in layer IV of the primary visual cortex (V1) of the occipital lobe. Layer IV of V1 also has layers that maintain the separation between the magnocellular and parvocellular projections from the LGN. It is thought that the magnocellular cells mediate movement detection and low-spatial-frequency contrast sensitivity. Parvocellular cells on the other hand are thought to mediate color vision and high-spatial-frequency contrast sensitivity. Area V1 is also highly organized vertically; there are ocular dominance columns maintaining the separation of information from each eye and there are also columns that are specific for stimulus orientation (Remington, 2012; Tovée, 1996) (Figure 2-1).





**Figure 2-1: The Visual Pathway.** Visual information arising from the nasal retina crosses at the optic chiasma to join temporal retinal visual information from the other eye. Together the impulses travel to the lateral geniculate nucleus then to the primary visual cortex. ([https://commons.wikimedia.org/wiki/File:Human\\_visual\\_pathway.svg](https://commons.wikimedia.org/wiki/File:Human_visual_pathway.svg))

The primary visual cortex projects to several areas of the extrastriate cortex, following two broad pathways, called the dorsal and ventral streams. The dorsal stream projects from V1 to the posterior parietal cortex, whereas the ventral stream projects to the inferotemporal cortex (Goodale & Milner, 1992; Ungerleider & Haxby, 1982). Both streams process visual information of object shape and location, however they differ in their output of such information; the output of the ventral stream functions to perceive object features, whereas the dorsal stream uses the object features to direct actions (Goodale & Milner, 1992; Goodale, 2014; Westwood & Goodale, 2011).

The dorsal visual stream can be further divided into at least two distinct but interconnected streams, the dorsomedial and dorsolateral visual streams. Within the dorsomedial visual stream is the medial parieto-occipital cortex, an area that contains the visual area V6 and the visuomotor area V6A (Galletti et al., 2003). Farotti et al (2015) have explored the brain area V6A, and have determined that representation of the lower contralateral visual field is emphasized in this area. This emphasis of the visual field provides psychophysical advantages during hand movements. Specifically, when an object is in the lower visual field, grasping movements are more precise (Brown et al., 2005) and pointing movements are quicker and more accurate (Danckert & Goodale, 2001). They also found that some cells in this area were not visually activated, but instead were activated by the movement of the arm, even when arm movement was completed in the dark. Cells in this area were also shown to be sensitive to the orientation of the wrist during a grasp or sensitive to the type of grip (power versus precision) used. Taking this and all their research on area V6A into account, Farotti et al (2015) suggests that area V6A is well suited to locate targets for prehension and to monitor the accuracy of

prehensile movements. They also suggest that area V6A encodes the visual properties of objects specifically for the purpose of acting upon them.

### 2.3 BINOCULAR SINGLE VISION

A difference exists between binocular vision and binocular single vision (BSV). Binocular vision simply means to have two seeing eyes; this is a benefit in that it increases the field of vision, eliminates the blind spot and provides organisms with a “spare” eye (Howard & Rogers, 1996). On the other hand, BSV occurs when similar retinal images from each eye are perceived as a single image (von Noorden & Campos, 2002). Clinically, BSV has been broken down into three levels to better classify a patient’s binocular status. The lowest form of BSV is referred to as simultaneous perception; this is where a person is able to perceive two dissimilar images at the same time. The second grade of BSV is fusion, which can be sub-divided into sensory and motor fusion. Sensory fusion is where a person can integrate two similar images, one from each eye into a composite image. Motor fusion is the alignment of the eyes so that sensory fusion can be attained and maintained throughout a range of eye movements. The highest form of BSV is stereopsis; this is where a person is able to perceive depth from the horizontally disparate images from each eye (Rowe, 2012).

In order for BSV to occur, certain pre-requisites must be met. The eyes must have overlapping visual fields, there must be retinal correspondence and the images to each eye must be similar in size and shape. Additionally, there needs to be ocular alignment and partial decussation of nasal retinal fibres at the optic chiasm (von Noorden & Campos, 2002).

When light from an object hits the retina, the target object is perceived in a particular location in space. Each area of the retina has a particular directional value, or visual direction. This visual direction is not an absolute value, but instead is relative to the fovea, which holds the principal visual direction. To ensure BSV is achieved and maintained, the oculomotor system must ensure the object is projected to the fovea of each eye simultaneously. To do this, the retina has arbitrarily been given retinomotor values, where the fovea has a retinomotor value of zero and values increase as one moves away from the fovea. When an area other than the fovea is stimulated, the retinomotor value allows for precise ocular rotation to ensure the fovea, or the principle visual direction is pointed towards the target object (von Noorden & Campos, 2002).

When both foveas are pointed towards a target object at a specific distance, an imaginary curve is created that runs through the target object and connects all points in space that also fall on corresponding retinal points. This imaginary line is called the horopter; along the horopter all objects are seen as single and all in the same depth as the target object. Surrounding the horopter is an area known as Panum's fusional space, within this area objects will stimulate disparate retinal points, however, they will still be seen as single. It is the stimulation of retinally horizontally disparate points within Panum's fusional space that gives rise to stereopsis. Objects viewed outside of Panum's fusional space will also stimulate retinally disparate points but instead will give rise to physiologic diplopia (von Noorden & Campos, 2002).

One's ability to perceive disparate retinal images within Panum's fusional space is referred to as stereopsis. Stereoacuity is the measure of stereopsis and is typically measured in seconds of arc of retinal disparity, where a smaller stereoacuity value

represents that the individual is able to appreciate a smaller amount of disparity and perceive it as depth. In other words, an individual with a smaller stereoacuity value is able to detect smaller differences in depth between stimuli (von Noorden & Campos, 2002). Parks (1968) proposed three grades of stereoacuity; peripheral, macular and foveal binocularity. According to Parks, a stereoacuity value of greater than or equal to 400 second of arc is considered peripheral binocularity, stereoacuity between 80 and 200 seconds of arc is macular binocularity and stereoacuity of 60 second of arc or less is considered foveal binocularity (and also considered normal stereoacuity).

### **2.3.1 Assessing Stereopsis**

A patient's level of binocularity can be assessed through a variety of objective and subjective methods. A variety of tests have been designed to assess binocular status ranging from assessing the presence or absence of simultaneous perception to measuring high-grade stereopsis. Unfortunately, many of these tests are subjective and require adequate comprehension and cooperation from the patient. Stereoacuity is used to measure a patient's level of stereopsis, and refers to the smallest lateral disparity that can be detected as the perception of depth (Bohr & Read, 2013).

For the purpose of this thesis we will explore only the Frisby stereotest in detail as it was the only test used in this experiment. The Frisby stereotest consists of three transparent plates with four squares on each. Within each square is an array of blue triangles printed on one side of the plate; in one of the squares there is circular area of the same blue triangles that is printed on the opposite side of the plate. By printing the circular target area on the opposite side of the plate a 3-D image is created. The Frisby

stereotest can measure stereoacuties ranging between 600-20” by using three different plates of different thicknesses and presenting them at varying distances (Frisby, J., 2015).

The Frisby stereotest was chosen over other tests of stereoacuity because it does not require polarized glasses since it presents a true in-depth target. Additionally, the Frisby stereotest has been shown to have a lower false positive rate compared to other stereo tests (Leske & Holmes, 2004), and fewer monocular cues, making it more accurate under monocular conditions (Hahn et al., 2010) (Figure 2-2).



**Figure 2-2: The Frisby Stereoacuity Test.** Within one square on each plate there is a circular area where the pattern is printed on the opposite side of the plate giving rise to depth. Three plates of differing thicknesses are presented at various distances to determine a patient's stereoacuity. (<http://frisbystereotest.co.uk/products/frisby-stereotest-near-assesment/>)

## 2.4 BINOCULAR DEPTH CUES

Although binocular depth information is largely determined from stereopsis (discussed previously) it can also be attained through ocular vergence information. The vergence angle is the relative angular alignment between the two eyes when fixating at a target of a particular distance (Howard & Rogers, 1996). As an object is moved towards the viewer, the eyes converge more to ensure the image remains on the fovea of each eye. This change in vergence conveys information about target depth relative to the observer, whereas stereopsis conveys relative depth between two objects (Howard & Rogers, 1996; Neri et al., 2004). Vergence depth information is useful within reaching distance, but its benefit decreases with increased distances from the observer since the eyes approach optical infinity (Mon-Williams & Dijkerman, 1999).

## 2.5 VISUAL CONTROL OF GRASPING: BINOCULAR VISION

Execution of an appropriate prehensile movement can only occur once the intrinsic properties of an object are processed by the visual system (Jeannerod et al., 1995). As such, grasping actions are dependent upon visual information processing; for this reason it is important to explore the role vision plays in prehension.

Many studies have been completed to assess the role binocularity plays in prehension; it has been demonstrated that binocular cues are important in the planning and execution of prehensile tasks (Marotta et al., 1997; Servos et al., 1992; Servos & Goodale, 1994). Under binocular conditions, participants benefit from both the use of disparate retinal images providing stereoscopic viewing, as well as, ocular vergence information which provides additional depth cues. More recent evidence suggests that



binocular vision is particularly important in the online control of the hand during prehension, aiding the individual in assessing the position of the hand in relation to the target object (Bradshaw et al., 2004; Loftus et al., 2004; Melmoth & Grant, 2006).

### **2.5.1 Acutely Monocular**

Many studies have acutely removed binocularity in normal participants by patching one eye (Loftus et al., 2004; Servos et al., 1992; Servos, 2000; Watt & Bradshaw, 2000) or through the use of liquid crystal goggles (Jackson et al., 1997; Melmoth & Grant, 2006). Although the methodology between different experiments assessing the importance of binocular vision has been varied, there are some consistent findings between studies. After the acute removal of binocular cues, studies have consistently found that movement time is increased and participants spend a longer time in the deceleration phase of the movement (Jackson et al., 1997; Loftus et al., 2004; Melmoth & Grant, 2006; Servos et al., 1992; Servos, 2000). Many studies have also found a decrease in the peak velocity (Loftus et al., 2004; Melmoth & Grant, 2006; Servos et al., 1992; Servos, 2000). Inconsistencies exist in the literature around how peak grip aperture is affected by the acute removal of binocular vision during prehension. Three studies (Loftus et al., 2004; Servos, 2000; Servos et al., 1992) found that peak grip aperture was decreased or remained the same under monocular conditions, whereas Jackson et al. (1997), Melmoth & Grant (2006) and Watt & Bradshaw (2000), all found that peak grip aperture was increased when monocular vision was used. That being said, Jackson et al (1997) only found an increase in peak grip aperture when a flanker object was present, but found no difference in peak grip aperture when targets were presented

alone (single targets were used in the other studies). Some studies also found that the time to reach peak grip aperture was increased under monocular conditions (Melmoth & Grant, 2006; Watt & Bradshaw, 2000).

### **2.5.2 Reduced stereopsis in amblyopic patients**

Amblyopia is a visual condition that literally means “*dullness of vision.*” It is defined as “*a decrease of visual acuity in one eye when caused by abnormal binocular interaction...during visual immaturity, for which no cause can be detected during the physical examination of the eye*” (von Noorden & Campos, 2002). It is known that stereopsis is often degraded in patients with amblyopia (Holopigian et al., 1986; Levi et al., 2015; Webber & Wood, 2005), and therefore patients with amblyopia have often been used in the study of prehensile movements.

When prehensile tasks are executed by amblyopic patients, the final approach to the object is particularly affected (Grant et al., 2007). Participants will spend longer in the final approach of the reach to grasp movement and will also make an increased number of errors during this time (Grant et al., 2007; Grant & Moseley, 2011; Suttle et al., 2011). These studies have been conducted with lone targets. To increase real world validity, Buckley et al (2015) conducted a similar study with amblyopic patients where they included flanker objects. Similarly, they found that amblyopes had a longer overall movement time. They believed this was ultimately a result of their decreased velocity and increased time after contact with the target but before initiating the lift. In addition, they found that peak grip aperture was significantly smaller for amblyopic participants compared to their visually normal participants.

### **2.5.3 Artificially reduced stereopsis**

It has previously been demonstrated that inducing visual blur will degrade stereoacuity (Larson & Bolduc, 1991; Odell et al., 2009). Degrading stereoacuity artificially in this manner has since been used to assess the effect of stereopsis on the performance of fine visuomotor tasks (Melmoth et al., 2007; Melmoth et al., 2009; Niechwiej-Szwedo et al., 2012; Piano & O'Connor, 2013). Inducing blur was accomplished in these studies through the use of optical blur (lenses or contact lenses).

Piano & O'Connor (2013) used a bead-threading task to assess the role of binocularity in a fine visuomotor task. They found that as tasks became more difficult, stereoacuity became a more significant factor in performance. Largely, they found that tasks took longer under conditions of reduced binocularity, and increasing the task difficulty compounded this finding.

When grasping is specifically examined under conditions of reduced stereoacuity, it has been shown that total movement time is increased. That being said, it is increased specifically because participants spend longer in the termination of the reach and not because early landmarks of the action were affected (Melmoth et al., 2007; Melmoth et al., 2009). Under reduced stereopsis viewing there is also a significant increase in the number of grip closure corrections just before and after contact with the target object. Peak grip aperture has been shown to increase compared to grasping under normal stereopsis, and the peak aperture also occurs further from the target object (Melmoth et al., 2007; Melmoth et al., 2009).

Alternatively, Niechwiej-Szwedo et al. (2012) also induced monocular blur and examined the kinematic measures of reaching movements. They concluded that

artificially induced monocular blur had no effect on reaching kinematics, however, reaching kinematics of anisometric amblyopes were affected in their study. The difference could not have come from a difference in the level of monocular blur (since the two populations had the same mean visual acuity in the blurred eye), but is more likely a difference in binocularity. In this study, the stereoacuity of the amblyopic participants ranged from 50-3000'' whereas the participants with artificial monocular blur maintained normal stereoacuity (40'') in 8/12 participants, and the other four participants had stereo acuities ranging between 50-80''. A difference in stereoacuity level is also likely the difference between the null result from this study and the effects found by Melmoth et al. (2007), Melmoth et al. (2009) & Piano & O'Connor, (2013). In these cases stereoacuity was reduced to 400-800'' (Melmoth et al. 2007), to between 200-800'' and ~3000'' (Melmoth et al., 2009) and to 55'', 210'' and >3000'' (Piano & O'Connor, 2013).

Bangerter foils have also been shown to systematically produce monocular blur and therefore decrease stereopsis. Odell et al. (2009) examined a range of seven different bangerter foils to produce monocular blur and examined the resultant visual acuity and stereoacuity looking through each. Bangerter foils may be a better option than optical blur in producing monocular blur for the purpose of kinematic analysis. Optical blur can affect magnification levels, which affect participants' perception of depth. This in itself is enough to affect certain kinematic measures (Melmoth et al., 2007).

#### **2.5.4 Summary of the Role of Binocular Vision**

Ultimately, these studies have a few common findings. Most find that in conditions of reduced binocularity the overall movement time of prehension or fine

visuomotor tasks will be increased. Specifically, participants will spend longer in the final approach to the object. Additionally, in the final approach participants will make more errors and corrections to their movement. The findings in regard to peak grip aperture are not consistent across studies. Many studies find an increase in peak grip aperture under reduced binocularity conditions, but a handful of studies report a decrease in peak grip aperture. The study that used flanking objects also found a decrease in peak grip aperture in participants with reduced stereopsis.

## 2.6 MONOCULAR DEPTH CUES

In addition to the binocular depth cues, stereopsis and vergence, there are also monocular or experiential cues that can relay depth information. Monocular depth cues are scene-based and therefore require one to take in information about the whole scene and compare objects within it. In doing this, depth can be inferred by various methods including, but not limited to, linear and aerial perspective, the size of known objects, motion parallax, overlap of objects and texture gradient. The perception of depth from motion parallax occurs because one perceives nearer objects to move faster than more distant objects. Linear perspective is where objects of a constant size are seen as smaller at a greater distance. Closer objects will be seen as overlapping objects that are further away (overlap of contours), and far away objects are seen with a blueish haze due to the atmosphere (aerial perspective). The size of known objects will also assist in determining size in the absence of binocular vision; if a target object known to be smaller than a second object is actually seen as larger, we judge it to be nearer to the observer (Marotta et al., 1998; von Noorden & Campos, 2002).

## 2.7 VISUAL CONTROL OF GRASPING: MONOCULAR CUES

As discussed previously the dorsal and ventral visual streams differ in their output after processing visual information (Goodale & Milner, 1992; Westwood & Goodale, 2011). The ventral stream uses visual information for perception, whereas the dorsal stream produces actions based on visual information. Since each stream has a different output, their processing of visual information is very different. The former uses scene-based metrics whereas the latter uses absolute metrics to produce action (Goodale, 2014). If in fact monocular depth cues are scene-based in the same way as visual perception, then grasping while using monocular cues could be impacted by visual perceptual illusions.

Many studies have demonstrated that the ventral stream (vision for perception) is influenced by visual illusions whereas the dorsal stream is not susceptible to these illusions. Even in the presence of visual illusions that caused participants to inaccurately perceive the size of a target object, their grasp for the same object always reflected its actual size (Aglioti et al., 1995; Bartelt & Darling, 2002; Gentilucci et al., 1996; Haffenden & Goodale, 1998; Haffenden et al., 2001; Hu & Goodale, 2000). If this interference effect can be seen between the dorsal and ventral streams where the dorsal stream uses absolute metrics to calculate actions and the ventral stream uses relative metrics to calculate perception, then perhaps a similar effect can be seen between actions guided by binocular versus monocular vision, since monocular vision (like vision-for-perception) uses relative metrics compared to binocular vision (like vision-for-action) that uses absolute metrics.

Marotta et al. (1998) tested this idea by having participants grasp a central circular target surrounded by other circular objects (creating the Ebbinghaus Illusion) under both monocular and binocular conditions. In this way they were able to alter the perceived size of the object. They found that participants were only susceptible to the illusion under monocular conditions but not under binocular conditions. Under monocular conditions, where participants were required to process information from the whole scene to determine object size and distance, they found that peak grip aperture was appropriately influenced by the pictorial illusion. Specifically, when the participant would perceive the target as larger, peak grip aperture would be larger and vice versa. Under binocular conditions, where participants were able to use absolute metrics from vergence angle and stereopsis to determine object size and distance, their peak grip aperture was uninfluenced by the pictorial illusion and was consistent with the actual size of the target object.

## 2.8 VISUAL CONTROL OF GRASPING: SUMMARY

Overall, vision is tightly linked to the accurate execution of prehensile movements. In particular, binocularity is important in determining accurate size and depth. This is evident by numerous studies that have eliminated or degraded stereopsis and found that alterations to prehensile kinematics are produced. It is important to note that although vision is important in prehension, the visual system is limited in the amount of information it can process at any given time. To cope with this limitation, attention is important in directing the visual system to process information relevant to the intended action. In the next section, we will further explore the role that attention plays in directing the visual system and how attention influences movement kinematics.

## 2.9 THE ROLE OF ATTENTION IN PREHENSION

The visual system is not capable of fully processing all information in the visual field, and thus has different mechanisms to approach this problem. Firstly, visual information is processed in full detail only at the fovea, and information in the peripheral visual field is more coarsely sampled and processed. Secondly, visual information is processed selectively and visual attention is the method by which certain areas of the visual field are selectively chosen for further information processing. The positioning of attention within the visual field can be exogenous (based on properties of the visual stimuli) or endogenous (based on the user) (Wolfe, 1994; Desimone & Duncan, 1995). For this reason, when an individual plans an action, attention should be critical in directing the visual system to process information relevant to the task and ignore non-relevant information. This action of selecting goal-relevant information and ignoring goal-irrelevant information is referred to as selection-for-action. That being said, do we really ignore non-target stimuli, or could they actually be processed at some level?

### 2.9.1 The Location of Overt Attention

When examining overt attention (i.e., the eyes are directed towards the location of attention) it has been shown that when a prehensile action is planned attentional resources are biased towards locations on the object that will be grasped (Baldauf & Deubel, 2010; Johansson et al., 2001). This is different from when the same object was viewed without the intention of grasping. Specifically, in no-grasping conditions the loci of attention (saccades) were located closer to the centre of gravity compared to in the grasping conditions where the gaze was located closer to the edge of the object. In particular, gaze



landed on one future finger contact location, and did not switch between the two contact locations (thumb and index finger location). The location for the gaze was consistently the location that was more difficult to make contact with (Brouwer et al., 2009).

When non-target obstacles are present, overt attention is maintained on the obstacle as the hand moves around it. To further demonstrate the importance of this, it has been shown that participants are more likely to collide with the obstacle when prevented from fixating on the obstacle location (Johansson et al., 2001). This demonstrates that during prehensile actions, attention is in fact directed to non-target stimuli, at least when it is relevant to the task.

### **2.9.2 Selection-For-action**

As mentioned previously, selection-for-action is the ability to attend to goal-relevant visual information and ignore goal-irrelevant information. Selection-for-action is particularly important in cluttered scenes; those that involve multiple objects one could act upon. Tresilian (1998) found that during grasping movements, people preferred to keep their hand a minimum distance away from non-target objects, “obstacles”. This minimum distance is affected by the speed of the action; specifically, the distance was larger when the movements were completed faster (Tresilian, 1998). In addition, Tipper et al. (1997) have shown that reach trajectories deviate away from non-target objects, as well as purely visual stimuli that doesn’t occupy physical space such as a light (Howard & Tipper, 1997). In contrast, Welsh et al. (1999) demonstrated that hand movements actually deviated *towards* non-target objects. They suggests that this difference may exist because their non-target objects were not physical barriers to the movement, whereas in

many previous studies the non-target objects were intended to be obstacles to movement. Welsh et al. (1999) suggests a deviation towards the non-target object may occur if actions to both objects are planned in parallel and parts of the non-target location “leak” into the movement plan for the target. On the other hand, Tipper et al. (1997) explain the deviation *away* from non-target objects by suggesting that competing movement responses are generated and inhibition is required to resolve the competition. The effect of this inhibition can then be seen in the movement kinematics.

In addition, the presence of non-target objects has also been shown to increase the movement time of the reach (Mon-Williams et al., 2001; Saling et al., 1998) and affect the manipulation component of prehensile movements. Tresilian (1998) found that peak grip aperture was significantly smaller in the presence of distractor objects. The decrease in peak grip aperture was larger the closer the distractor object was to the target object. Similar changes to peak grip aperture have also been reported elsewhere (Jackson et al., 1995; Mon-Williams et al., 2001; Saling et al., 1998). Alternatively, others have found that the presence of distractor objects did not affect peak grip aperture or overall movement time (Castiello, 1996; Kritikos et al., 2000).

It has been suggested that visual attention may in fact be a mechanism for selection-for-action (Deubel & Schneider, 1996). In this view, the intention to perform an action results in top-down control of visual processes that favours the processing of object features relevant to the intended action. In support of this, Bekkering and Neggers (2002) had participants search for and make a saccade to a target object of a specific color and orientation amongst distractor objects. Participants had to either find and point to the target object, or find and grasp the target object. Results indicate that in the grasping

condition fewer saccades were made to objects with the wrong orientation compared to in the pointing condition. In contrast, the number of saccades made to the wrong color was similar in both the pointing and grasping conditions. They suggest this is evidence that a specific action intention can enhance visual processing of action relevant information, and this supports the idea that visual attention is a selection-for-action mechanism.

Overall, these results are unclear in the effects of non-target objects on prehension. Studies showed conflicting effects on reach trajectories and peak grip aperture when prehensile movements were completed in the presence of non-target objects. It is also unclear how and why interference effects are seen in prehension movements when non-target objects are present. Both Welsh et al. (1999) and Tipper et al. (1997) suggest that action plans are produced for both target and non-target objects, however they differ in their explanation of the interference effects produced. As previously mentioned, Tipper et al. (1997) suggests that inhibition of the action plan to the non-target object produces interference effects, whereas Welsh et al. (1999) suggests aspects of the action plan for the non-target object is able to “leak” into the action plan for the target object. Further evidence to explore these possibilities comes from dual task paradigms that examined the role of covert attention.

### **2.9.3 The Location of Covert Attention**

As discussed, selective attention is typically thought of as the act of enhancing the processing of some information while inhibiting others. This would be important when faced with multiple potential objects one could act upon. If one imagines a mountain goat on a cliff, it would be important to be able to accurately produce a motor pattern for its

jump to the next ledge. In fact, it has been proposed that information about irrelevant stimuli (or other possible ledges), including possible motor programs associated with these stimuli, should be separated from the control of an intended action in order to minimize response interference effects (Castiello, 1996). That being said, one could also imagine the scenario where the goat is about to make a jump to the next ledge when it notices a predator near the intended ledge. In this scenario, it would be critical the goat could quickly change its intended motor pattern to successfully execute an action to a different ledge. Considering this angle, it may in fact be important to simultaneously process non-target stimuli on some level. To further explore this idea, studies have examined the role of covert attention in prehension.

In examining the effect of covert attention (i.e., when attention is deployed to a location different from the fovea) on grasping, many studies have employed dual-task paradigms. Castiello (1996) had participants maintain their gaze on a centrally placed fruit while grasping it (motor task). Simultaneously, participants were required to count the number of light flashes on a second, flanker fruit (perceptual task). To ensure that participants were able to maintain covert attention to the flanker fruit during the grasp, Castiello ran a control where participants had to maintain fixation on the central fruit while counting the number of light flashes on the flanker fruit. He found that participants were equally good at counting the flashing lights while grasping the central fruit, as they were when no grasp was required. Interestingly, when participants had to count the light flashes on the flanker fruit while grasping the central fruit, he found that participant's peak grip aperture for the central fruit was scaled towards the size of the flanker fruit, upon which covert attention was placed during the grasp of the central fruit. To ensure

that the kinematic changes seen were not due to counting the flashing lights, he ran another experiment where participants had to grasp the central fruit while counting the number of light flashes on the central fruit itself. In this case he did not find changes to kinematic characteristics that were seen when the flashes were on a separate flanker fruit. For trials where the perceptual task was absent, participants successfully ignored the surrounding flanker objects and no interference effect was seen (Castiello, 1996). Castiello (1996) proposed that the interference seen while grasping results from automatic processing of motor patterns for attended to objects that are not the focus of the intended action.

In a second study that utilized a dual-task paradigm to explore covert attention, participants had to covertly track a moving flanker in the periphery while simultaneously grasping a target piece of fruit. It was determined that specific features of the distractor object selectively affected interference effects. Specifically, interference effects in the transport component of the grasp were noted when participants had to covertly monitor the *position* of the distractor. Alternatively, the manipulation component of the grasp showed interference effects when the flanker was covertly monitored for changes in *size* (Bonfiglioli & Castiello, 1998).

Similar to the proposal made by Castiello (1996), Sandoval & McIntosh (2014) designed an experiment to determine if selecting an object for perception prioritizes it for action. They developed a two-part paradigm; in part 1, participants had to fixate on a central point while covertly monitoring a flanker target prior to movement onset. Then participants had to reach to the central target, which would occasionally jump to either side, requiring a correction to the reach. Participants were very good at correcting the

reach movement in this scenario. In part 2, participants fixated on a central point while covertly monitoring a flanker target *during* the reach movement. Again, participants had to reach to the central target, which occasionally jumped to one side or the other. In this scenario, participants showed a decrease in corrections, specifically to the attended to side. Sandoval & McIntosh propose the decrease in corrections specifically to the attended to side, occurs because the perceptual attention towards that location primed an action towards the target which the participant actively inhibited, resulting in a decrease in the corrections seen to the attended to side.

Recently, LeBlanc & Westwood (2014) employed a sequential task paradigm to examine whether interference seen in grasping, does in fact arise from obligatory processing of motor associations for attended to objects that are not the focus of a target action, as proposed by Castiello (1996). Based on Castiello's findings, it was hypothesized that because sequential tasks are processed as a whole (Henry & Rogers, 1960; Hesse & Deubel, 2010), that the grip aperture for the first object, would scale positively towards the size of the second object. Results indicated that interference effects occurred when attending to the size of the second object for verbal size estimation, but not when planning an action to the second object or when attending to its size for manual size estimation. However, due to limitations of this study, it is unclear whether the interaction seen was a result of a ventral stream task interfering with a pure dorsal stream task (actively processing the first target) or a mixed stream task (grasping the first target from memory).

It has been suggested that selective attention is actually an early mechanism for action selection (Cisek, 2007). Cisek proposes that the dorsal stream divides into sub-

streams where various types of movements are represented; for example, the medial intraparietal area that is concerned with arm movements and the lateral intraparietal area concerned with gaze direction. In addition, he suggests that the dorsal stream represents various potential movements that could be selected based on visual information, and attention is involved in selectively enhancing certain motor patterns and inhibiting others. Though similar, this framework differs from the proposals made by Castiello (1996) and Sandoval & McIntosh (2014) in one major way. Within their proposals, attention to a target is necessary to create the motor pattern associated with acting upon the target object, whereas Cisek (2007) suggests that visual information processing alone produces the motor pattern and attention is required to enhance/inhibit it; which is consistent with the affordance competition hypothesis. This hypothesis broadly states that behaviour is the result of constant competition between potential actions; more specifically actions are evoked by sensory stimuli and selective attention is required to eliminate or suppress additional actions (Cisek, 2007).

Ultimately it is unclear at this time how attention is involved in processing visual information of non-target objects. Is attention required to initiate motor control processes or are motor control processes automatically produced and attention required to select the appropriate motor patterns. As previously mentioned, LeBlanc and Westwood (2014) expected to find peak grip aperture for their first object to scale towards the size of the second object (based on Castiello's (1996) findings). They were surprised when this pattern was not necessarily apparent in their results. To further explore this subject, we decided to first confirm Castiello's findings.

## **CHAPTER 3**

### **EXPERIMENT 1**

#### **3.1 METHODS**

##### **3.1.1 Ethics**

The Dalhousie University Research Ethics Board approved all aspects of this study (Appendix A). Each participant completed informed consent (Appendix B) before partaking in the experimental screening and procedure.

##### **3.1.2 Participants**

A total of sixteen adults (18-45 years of age, mean age 25) were included in this study. In Castiello's (1996) original study, statistically significant results were obtained with a sample of eight participants. For the purpose of replication, we chose to analyze the data after the first eight participants were tested; if replication was not successful we planned to test another eight participants and analyze the total group of sixteen. For this reason, we ended with data from a total of sixteen participants.

The inclusion criteria for this study were in line with that of Castiello's (1996) paper. All participants were right-handed, had normal or corrected-to-normal visual acuity (near visual acuity of 20/25 or better as measured by the Sloan (Good-Lite, Illinois, USA, #725000) near card), were unaware of the purpose of the study and were at least 18 years of age. We added exclusion criteria to ensure the safety of participants and to prevent any confounding factors. Participants with a personal or family history of seizures were excluded as the experimental procedure involved flashing lights that could potentially elicit a seizure in these individuals. Participants with neurologic or movement



abnormalities were excluded as these could affect cognitive and movement functioning; which could lead to abnormal results in grasping kinematics that are unrelated to the research questions. Handedness, the presence of seizure disorders and/or the presence of neurological/motor disorders were determined by self-report (Appendix C). Participant's confidentiality of sensitive information was maintained since they were not required to divulge which exclusion/inclusion criteria they did not meet.

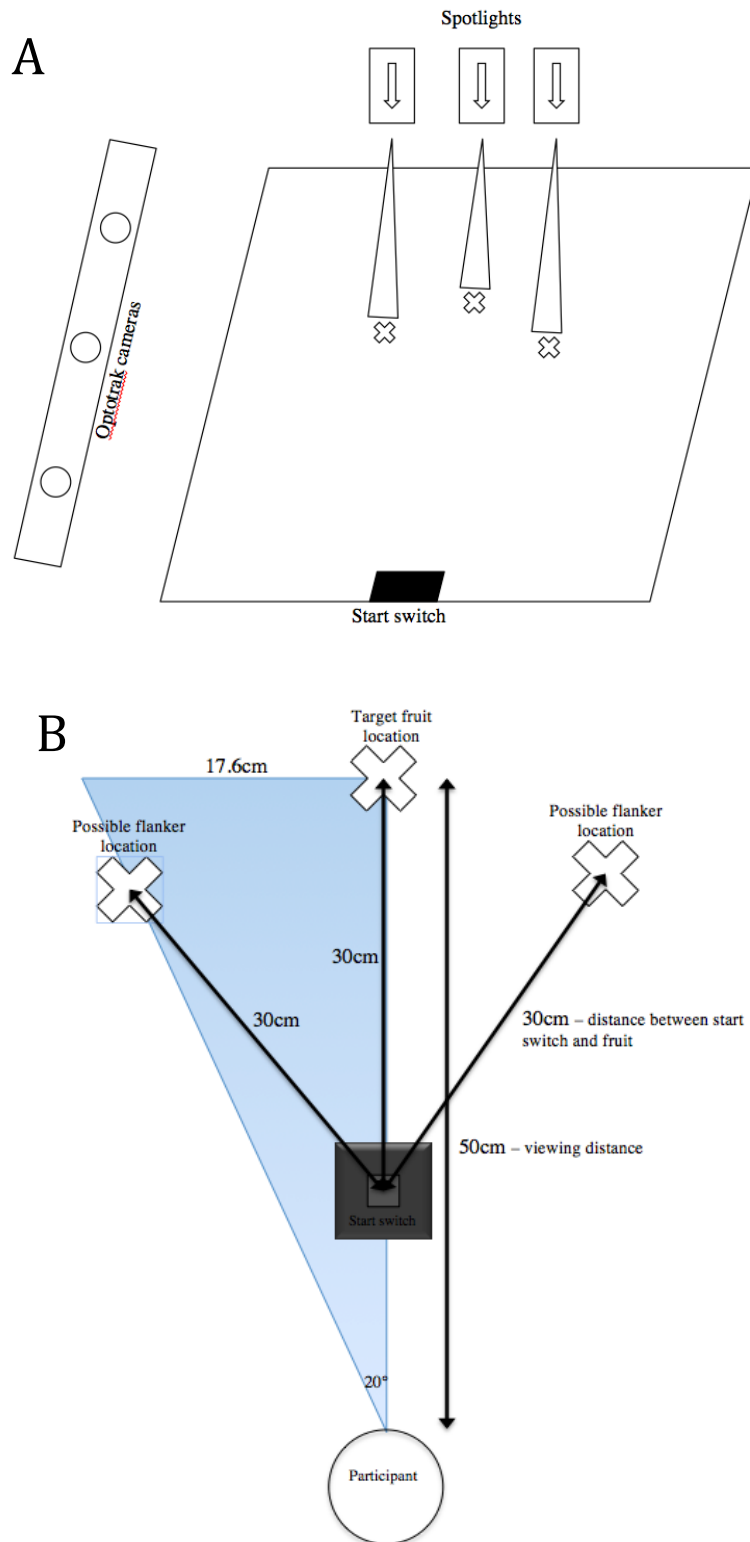
At the completion of all trials, the principal investigator discussed the rationale of the study with participants. Participants were given a debriefing form (Appendix D) and were given an opportunity to ask any questions they may have before leaving the lab.

### **3.1.3 Materials**

#### *3.1.3a Apparatus*

Participants sat in a comfortable and adjustable chair at a table covered in a plain black cloth. A start switch was located at the edge of the table closest to the participant and a wooden block (6 x 8 x 15 cm) was placed under the black cloth so that the centre of the block was 30 cm in front of the start switch. Three potential stimulus locations were marked, each 30 cm from the start switch. The central location was in the middle of the block, and the other two locations were located at a visual angle of 20° to the left and right (calculated assuming a viewing distance of 50 cm). The block elevated the central fruit so that it was less likely that the flanker fruit on the left would block the camera from locating the IREDs during the trial. A lighting apparatus was placed on the back edge of the table so that each of the three potential stimuli locations could be illuminated with a spotlight from above. The central spotlight would produce a constant flood of light; while

the two laterally placed spotlights would flash at 10Hz for 5 seconds as detailed below (Figure 3-1).



**Figure 3-1: Experimental Apparatus.** A) Arrangement of the spotlights, Optotrak 3020™ cameras, start switch and potential target locations. B) Details of target arrangement.

### *3.1.3b Fruit/Stimuli*

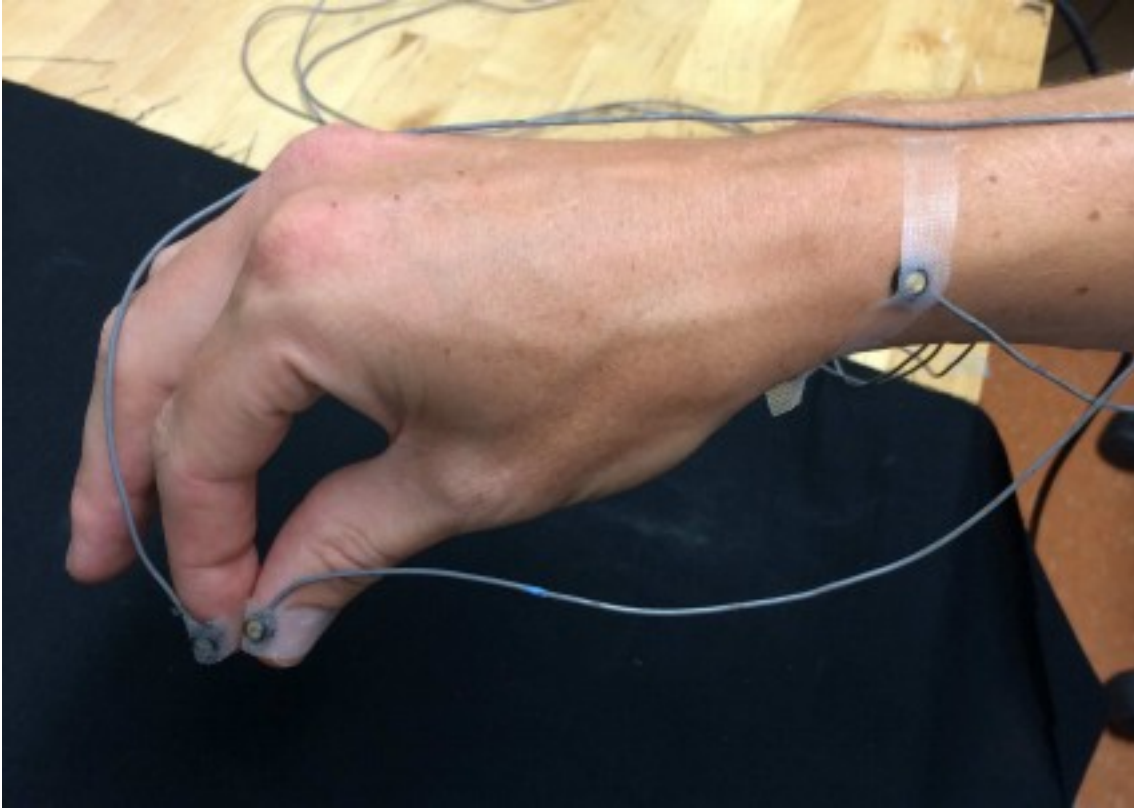
The stimuli for each participant included two pieces of each type of real fruit (apple, banana, cherry/grape & mandarin). One set of each type of fruit (apple, banana, cherry/grape & mandarin) was used as the target fruit and another set of each type of fruit was used for the distractor fruits. This ensured that the target and distractor fruits remained separated to maintain consistency throughout trials. All efforts were made to ensure target fruits and flanker fruits were as similar as possible in size, shape and color. There was a change to the fruit for the second group of eight participants because cherries were no longer in season and could not be obtained locally. Instead of a cherry, a red grape was used in its place for the remainder of the experiment. Appropriate statistical analyses addressed the possibility that this change in fruit influenced the results as noted below.

### *3.1.3c Optotrak 3020<sup>TM</sup>*

Kinematic characteristics of the wrist, index finger and thumb were tracked and recorded using the Optotrak 3020<sup>TM</sup> system (NDI, Waterloo, ON, Canada) (Figure 3-2). This system uses three IREDs (approximately 3mm by 3mm) whose 3-dimensional position in space was tracked at 200Hz by a bank of three infrared detecting cameras. The diodes were attached to the index finger, thumb and wrist of the participants' right hand with medical grade (hypoallergenic and latex free) tape (3M Transpore<sup>TM</sup>) (Figure 3-3).



**Figure 3-2: Optotrak 3020™ Motion Capture System.** The Optotrak 3020™ 3D motion-capture system consisting of three infrared detecting cameras (Bishop & Westwood, 2016).



**Figure 3-3: Placement of Infrared Emitting Diodes.** Positioning of the three IREDs on the wrist, index finger and thumb of the participants right hand (Bishop & Westwood, 2016).

### *3.1.3d Electrooculogram*

Eye movements were recorded with an electrooculogram (EOG) (Tektronix TDS 2012C). This system uses two dermal pad electrodes placed bitemporally, and a third reference electrode placed on the participants' inner forearm of their left arm. The electrodes on the temples record the electrical activity of the eyes and the third electrode records the background electrical activity in the body. The baseline level while looking straight ahead, as well as the response elicited while looking from the target fruit to the flanker fruit was examined for each participant prior to beginning trials. Trials were excluded when an eye movement away from the target fruit was made before the completion of the grasp. This analysis was done in real time and any movement away from the target fruit, as small as a quarter of the distance between the two pieces of fruit, was considered an eye movement and the trial was excluded from analysis.

### *3.1.3e Light Apparatus*

Three spotlights were attached to a stand placed on the back of the table so that they could illuminate each of the potential target locations. The lights were controlled through a control box that allowed the centre light to produce a constant beam of light, and the two lights on the sides would flash at a frequency of 10Hz.

### **3.1.4 Data Collection**

The Optotrak 3020<sup>TM</sup> collected the 3-D position in space of each of the three IREDs during each trial. A customized Python script then used this data to calculate the movement kinematics for each trial. Time at movement onset was defined as the first

sample where speed was greater than 50mm/s for five consecutive samples and time at movement offset was the first sample where speed was less than 50mm/s for five consecutive samples. Movement duration was then calculated as the length of time between these two time points. Peak grip aperture was the largest vector distance between the thumb and finger IREDs that occurred between movement onset and movement offset. Time to peak grip aperture was calculated as the length of time between movement onset and when the peak grip aperture occurred. Peak hand speed was determined as the fastest speed obtained between movement onset and movement offset. The time to peak hand speed was calculated as the length of time between movement onset and the peak hand speed. The kinematic profile graphs of each trial were manually evaluated to ensure the program was extracting the correct values; if an error was found, the correct values were chosen manually.

Reaction time was determined by the Experiment Builder software (SR Research), which recorded the time at which the participant released the start switch. We chose to use this data as a measure of reaction time instead of the data recorded from the Optotrak 3020<sup>TM</sup>, because the release of the start switch button is a more direct measure of movement onset and thus more suitable for defining reaction time than the measured hand kinematics. In addition to this, the data from the Experiment Builder was less subjective, as it simply recorded the time the participant released in start switch.

### **3.1.5 Procedure**

All research was conducted by the principal investigator and took place in the Action Lab (Dalplex, Room 218C), Dalhousie University, Halifax, Nova Scotia, Canada.



Upon arrival in the lab, participants read over and completed the consent form (Appendix B). They then read over the screening form (Appendix C); anyone who answered “yes” to any of the questions was excluded from participation. Those participants who answered “no” to all of the questions then had their near vision assessed by a certified orthoptist with the Sloan (Good-Lite, Illinois, USA, #725000) near card. Those participants without at least 6/7.5 level of visual acuity in each eye were excluded from participation.

Participants were seated at a table with a matte, black surface for all experimental trials. The IREDS of the Optotrak 3020<sup>TM</sup> system were attached to the participant’s right hand with Transpore<sup>TM</sup> medical tape at the following locations; the left lateral edge of the index finger nail, the right lateral edge of the thumb nail, and the radial styloid of the right wrist. Then the EOG electrodes were attached; one to each of the right and left temples, and a third reference electrode was attached to the inner surface of the participants left forearm. Participants were then instructed regarding the grasping task in the following manner:

- 1) Each trial will begin with the right hand on the trigger switch with the thumb and index finger together.
- 2) An auditory tone will then indicate the onset of the trial; after the auditory tone, the central piece of fruit will be illuminated.
- 3) The illumination of the central piece of fruit is the cue to release the start switch and reach out and pick up the central piece of fruit (ensuring to use your thumb and index finger).
- 4) At the release of the start switch, a light will flash on the flanker piece of fruit. You are to count the number of light flashes as you reach out and grasp

the central piece of fruit. For the duration of the trial, you are to maintain your gaze of the central piece of fruit.

- 5) Once the light stops flashing, you will be asked to verbally report the number of light flashes you counted.

Participants performed six trials for each combination of independent variables; this included, central fruit (4 levels: apple, banana, cherry/grape, mandarin), flanker fruit (5 levels: apple, banana, cherry/grape, mandarin, no fruit), and side of flanker fruit (2 levels: left or right; note that for the no-fruit flanker condition half of the trials were considered 'left' and the other half 'right'). This gave a total of 240 (4 x 5 x 2 x 6) trials, which were fully randomized for each participant. Participants were told they could ask for a break at any point throughout the testing, and were also asked if they would like a break after every 40 trials.

Prior to the onset of each trial, participants began with their index finger and thumb pressed together and pressing down the start switch. The beginning of each trial was indicated by an auditory warning signal. At a time of 500, 1,000 or 1,500 ms after the auditory tone the central fruit was highlighted with a stable flood of light. The time delay (500, 1,000 or 1,500 ms) was randomized for each trial. Participants then reached out and grasped the central piece of fruit while simultaneously counting the number of light flashes on the flanker fruit. Participants were instructed to grasp the fruit with the index finger and thumb along the sagittal axis. The release of the start switch triggered the flashing on the flanker fruit. Both lights (the stable flood on the central fruit and the flashing on the flanker fruit) would remain on for 5 sec after the release of the start switch. Upon completion of the flashing, participants were verbally asked by the

examiner to report the number of light flashes. This number was recorded after each trial. There was no additional emphasis to prioritize either of the two tasks (counting versus grasping), and participants were unaware of which task was the main focus of the experiment.

## 3.2 RESULTS

### **3.2.1 Participant Characteristics**

Participant characteristics can be found in Table 3-1. Only two of the sixteen participants were males. The age of participants ranged from 19-45 with an average age of 25.1 years. All participants had at least 6/7.5 vision in each eye; the median visual acuity was 6/6 for each eye.

**Table 3-1: Participant Characteristics - Experiment 1.** Characteristics of participants from Experiment 1

ID	Sex	Age	RE NVA <sup>1</sup>	LE NVA <sup>2</sup>
P101	F	24	6/6	6/6
P102	F	19	6/7.5	6/7.5
P103	M	45	6/7.5	6/7.5
P104	F	25	6/6	6/6
P105	M	24	6/6	6/6
P106	F	25	6/6	6/6
P107	F	42	6/7.5	6/7.5
P109	F	33	6/4.8	6/4.8
P110	F	18	6/7.5	6/6
P111	F	18	6/7.5	6/7.5
P112	F	28	6/6	6/6
P115	F	19	6/4.8	6/6
P116	F	19	6/6	6/6
P117	F	20	6/6	6/7.5
P119	F	21	6/4.8	6/4.8
P120	F	22	6/6	6/7.5

<sup>1</sup> Right eye near visual acuity

<sup>2</sup> Left eye near visual acuity

### 3.2.2 Group Comparisons for the Cherry and Grape Experiments

As explained previously, a substitution in fruits was made halfway through data collection. Initially cherries were used as one of the target fruits, however, they unfortunately went out of season and were no longer available. For this reason, a grape was used to replace the cherry for the remainder of the participants. To ensure the results from the cherry and grape participants could be combined, a between subject factor of experiment type (cherry or grape) was added to a 4 (target; apple, banana, cherry/grape, mandarin) by 5 (flanker; apple, banana, cherry/grape, mandarin, no flanker) repeated measures analysis of variance (ANOVA,  $\alpha = 0.05$ ).

It was found that there was no significant main effect of experiment type (cherry versus grape group) on movement time,  $F(1, 14) = 0.766, p = 0.396$ , peak hand speed,  $F(1, 14) = 0.802, p = 0.386$ , time to peak hand speed,  $F(1, 9) = 0.005, p = 0.946$ , reaction time,  $F(1, 14) = 0.040, p = 0.844$ , or time to peak grip aperture,  $F(1, 13) = 0.862, p = 0.370$ . In addition, no interaction existed between experiment type and any other factor for any of these measures.

When looking at peak grip aperture, however, a significant main effect of experiment type was found,  $F(1, 14) = 8.66, p = 0.011$ , where the overall mean peak grip aperture was larger during the cherry experiment ( $M = 83.7$  mm,  $SE = 3.08$  mm) compared to the grape experiment ( $M = 70.8$  mm,  $SE = 3.08$  mm). This was true not only for trials involving the cherry/grape but for all fruits; it is not entirely clear why this was the case, but there are many possible reasons given that the two groups had different participants, were tested at different times of the year, and used different pieces of fruit. Since the difference between the two groups did not arise from the difference in peak grip

aperture for the cherries and grapes specifically, and since the ‘fruit group’ variable did not interact with any other variable, we were able to justify collapsing the two groups for further analysis.

### **3.2.3 Main Effects/Interactions for Each Dependent Variable**

All statistical measures were completed with the Statistical Package for Social Sciences (SPSS) software. All data were analyzed for outliers based on the distribution for each individual participant. Trials were grouped by participant and target fruit, and then z-scores were calculated trial by trial for each kinematic measure (peak grip aperture, time to peak grip aperture, reaction time, movement time, peak hand speed and time to peak hand speed). Trials that had a z-score of greater than three for any measure were considered outliers and excluded from analysis. Each participant completed 240 trials, giving a total of 3,840 trials for all 16 participants. A total of 149 trials, 3.88% of the data, were deemed outliers and excluded from analysis.

In addition, 12 trials (0.31%) were excluded because participants made an eye movement and 24 trials (0.63%) were excluded because participants made other errors, such as forgetting to count the number of light flashes or moving before their cue. Five trials (0.13%) were excluded because the fruit had been set up incorrectly and another 248 trials (6.46%) were excluded due to technical errors. In all, a total of 438 trials (11.41%) were excluded from further analysis.

First, each dependent measure was analyzed with a 4 (target: apple, banana, cherry/grape, mandarin) by 4 (flanker; apple, banana, cherry/grape, mandarin) by 2 (side; right, left) repeated measures ANOVA ( $\alpha = 0.05$ ) to determine the effect of “side” on

each outcome measure prior to collapsing data across “side” to enable inclusion of “no flanker” trials in a larger analysis. Then, a 4 (target; apple, banana, cherry/grape, mandarin) by 5 (flanker; apple, banana, cherry/grape, mandarin, no flanker) repeated measures ANOVA ( $\alpha = 0.05$ ) was conducted to incorporate the non-flanker data.

The assumption of sphericity was assessed for each outcome with the Mauchly’s Test of Sphericity. When the assumption of sphericity was violated, the lower bound value of significance was checked and reported if it was significant. If it was not significant, but either the Greenhouse-Geisser or the Huynh-Feldt correction was significant, than this value was reported.

### *3.2.3a Peak Grip Aperture*

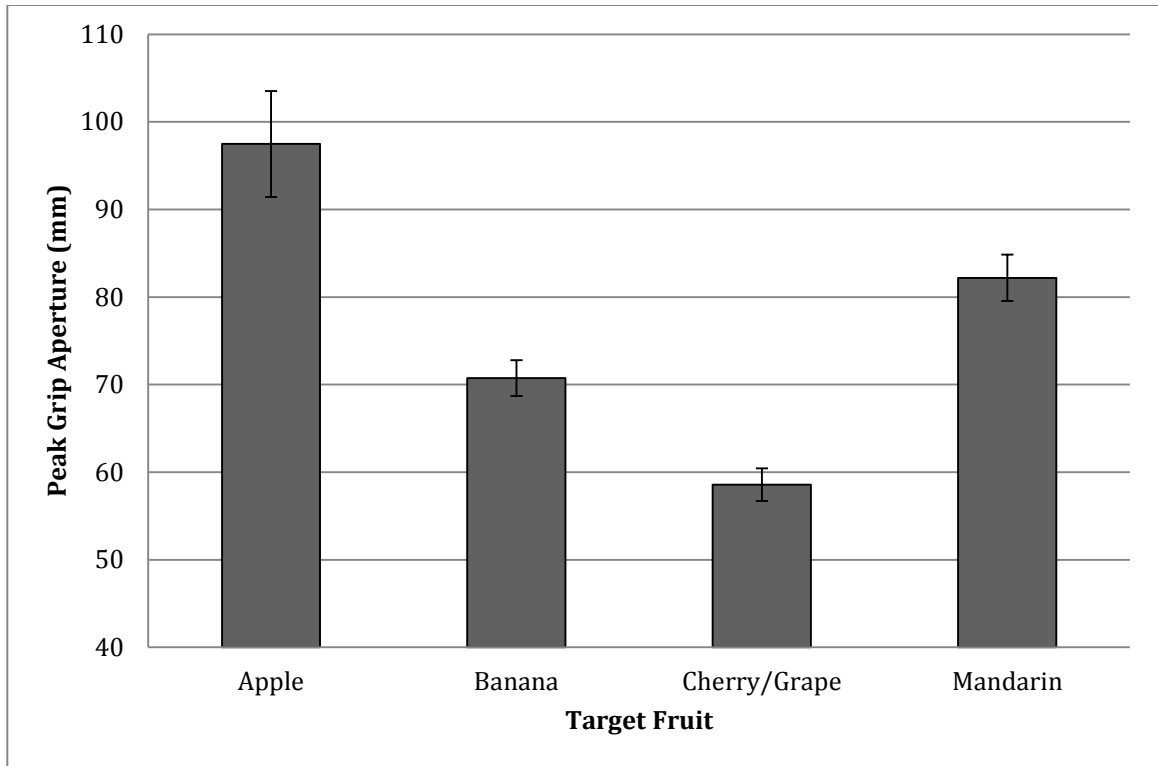
The side of the flanker fruit was not found to have a significant effect on peak grip aperture  $F(1, 12) = 0.686, p = 0.424$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for peak grip aperture across all fruits was 77.2 mm (SE = 2.67 mm).

As expected given the different sizes of the target fruits, there was a significant main effect of target fruit on peak grip aperture,  $F(1, 15) = 36.4, p < 0.001$ , where the peak grip aperture was significantly different for each type of fruit. The apple had the largest peak grip aperture (M = 97.5 mm, SE = 6.05 mm), followed by the mandarin (M = 82.2 mm, SE = 2.65 mm), followed by the banana (M = 70.7 mm, SE = 2.04 mm), and the smallest peak grip aperture was found for the cherry/grape (M = 58.6 mm, SE = 1.86 mm) (Figure 3-4).

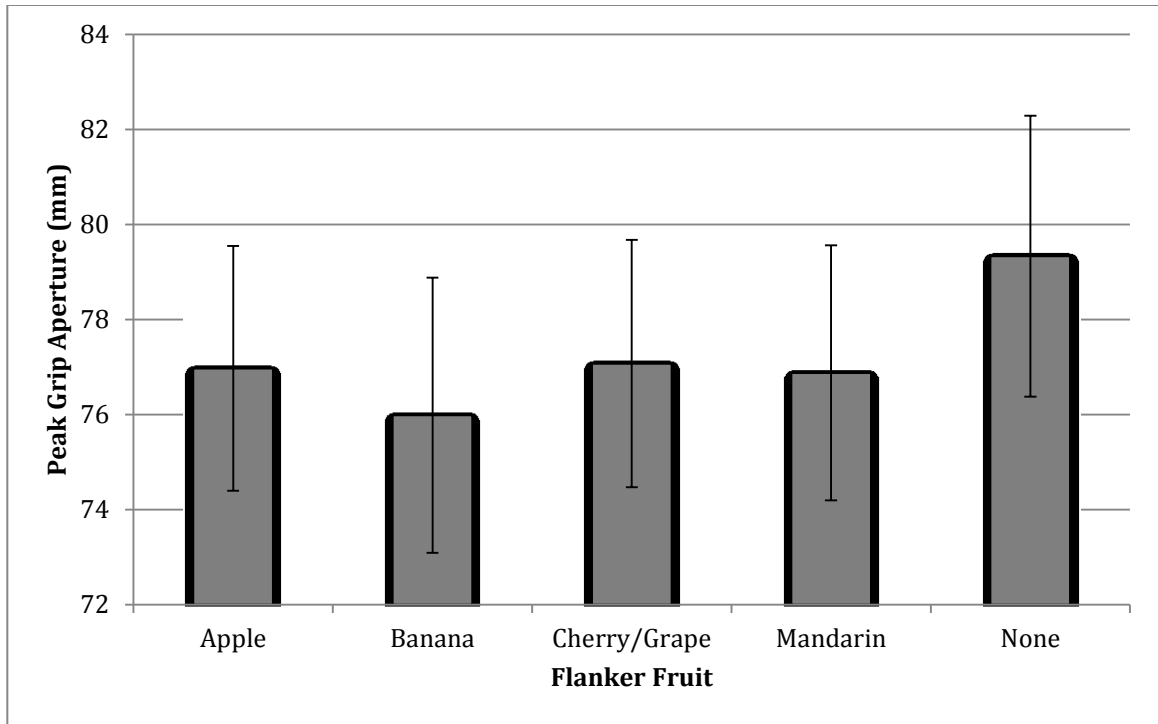
There was a significant main effect of the flanker fruit,  $F(2.4, 36.3) = 3.29, p = 0.040$ . Unfortunately, pairwise comparisons did not reveal a significant difference between any two flanker conditions, likely because these tests were underpowered compared to the omnibus main effect; thus, it cannot be stated with confidence which flankers differ from each other. Nevertheless, a qualitative examination of the data suggests that peak grip aperture was larger for the “no flanker” trials in comparison to all of the other flanker conditions which appeared similar to each other (Figure 3-5).

Contrary to what was found by Castiello (1996), there was no interaction between the type of target fruit and the type of flanker fruit,  $F(1, 15) = 0.899, p = 0.398$ . The size of the flanker fruit did not impact the peak grip aperture for the target fruit (Figure 3-6).

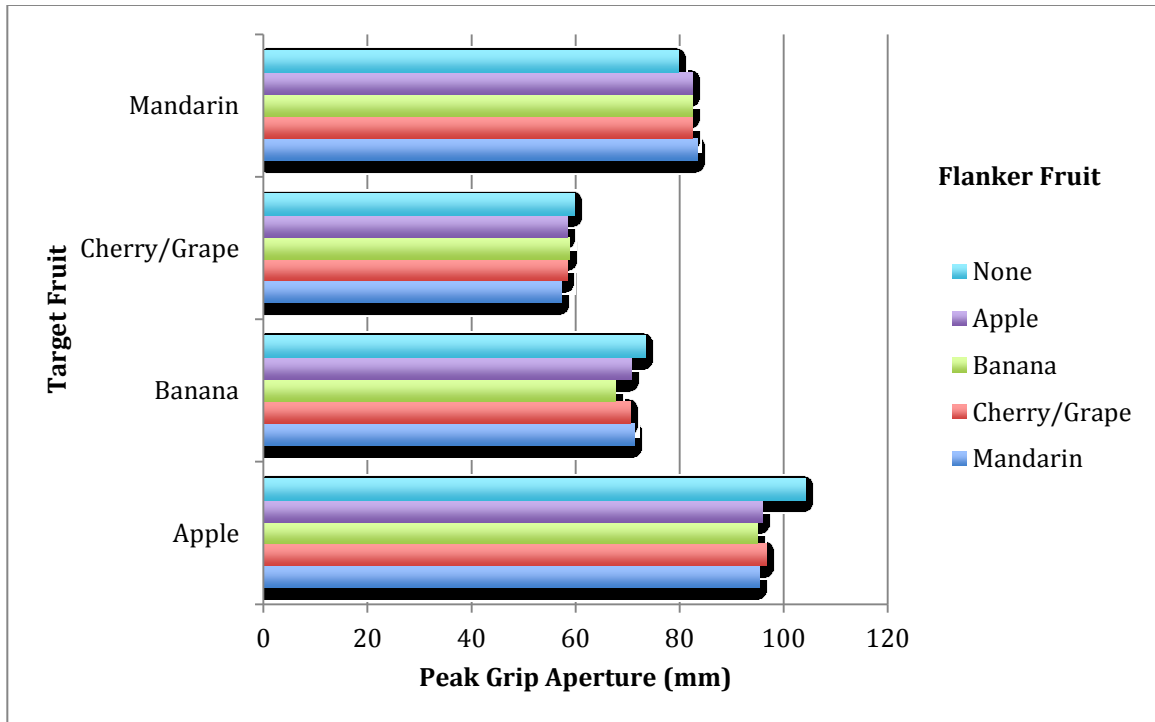




**Figure 3-4: Effect of Target Fruit on Peak Grip Aperture.** The mean peak grip aperture (mm) was significantly different for each target fruit. Error bars represent the standard error of the mean (SEM).



**Figure 3-5: Effect of Flanker Fruit on Peak Grip Aperture.** The mean peak grip aperture (mm) averaged across all target fruits for each type of flanker fruit. A main effect of flanker fruit was found, although pairwise comparisons were underpowered, it appears that peak grip aperture was larger when no flanker fruits were present. Error bars represent SEM.



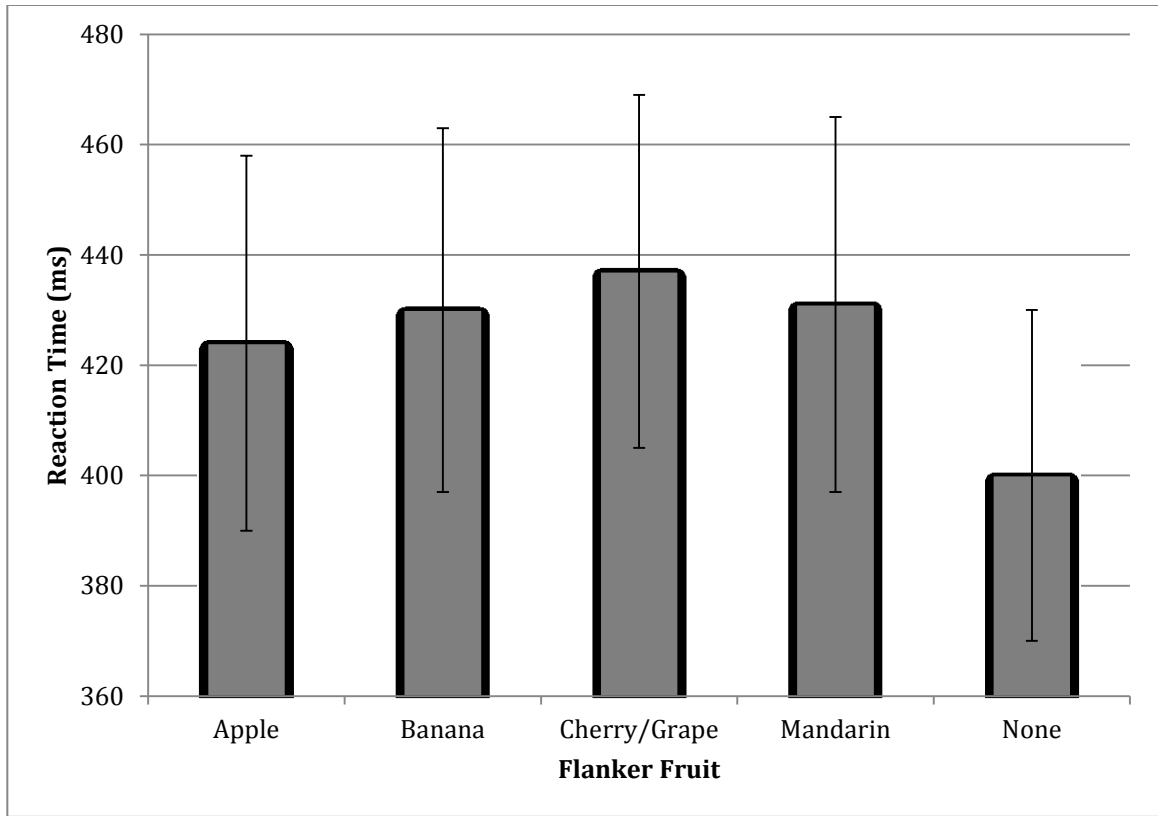
**Figure 3-6: Interaction Between Target and Flanker Fruits.** Mean peak grip aperture (in millimeters) for each target fruit as a function of each flanker fruit. No interaction was found between target fruits and flanker fruits; peak grip aperture for the target fruits were not influenced by the size of the flanker fruit. Error bars represent SEM.

### 3.2.3b Reaction Time

The side of the flanker fruit was not found to have a significant effect on reaction time,  $F(1, 15) = 0.900$ ,  $p = 0.358$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for reaction time was 424 ms (SE = 32.3 ms).

A significant main effect of flanker fruit was found for reaction time,  $F(1, 15) = 4.95$ ,  $p = 0.042$ , where reaction time was faster (M = 400 ms, SE = 30.4 ms) for the no flanker fruit condition compared to when the apple (M = 424 ms, SE = 33.9 ms), banana (M = 430 ms, SE = 32.8 ms), mandarin (M = 431 ms, SE = 34.3 ms) or cherry/grape (M = 437 ms, SE = 32.4 ms) were the flanker fruits (Figure 3-7).

There was no significant main effect of target fruit,  $F(3, 45) = 0.913$ ,  $p = 0.418$  and no interaction found between type of target fruit and type of flanker fruit,  $F(1, 15) = 0.580$ ,  $p = 0.458$ .



**Figure 3-7: Effect of Flanker Fruit on Reaction Time.** Reaction time (ms) averaged across all target fruits as a function of each type of target fruit. Reaction time was significantly faster when no flanker fruits were present compared to when a flanker was present regardless of the type of fruit. Error bars represent SEM.

### 3.2.3c Movement Time

The side of the flanker fruit was not found to have a significant effect on movement time  $F(1, 13) = 2.09, p = 0.172$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for movement time was 697 ms (SE = 36.9 ms).

The results revealed no significant difference in movement time for the different target fruits,  $F(1, 15) = 0.400, p = 0.537$ , or for each type of flanker fruit,  $F(1, 15) = 1.05, p = 0.321$ . In addition, there was no interaction found between the type of target fruit and type of flanker fruit,  $F(1, 15) = 0.866, p = 0.367$ .

### 3.2.3d Peak Hand Speed

The side of the flanker fruit was not found to have a significant effect on peak hand speed,  $F(1, 12) = 0.057, p = 0.815$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for peak hand speed was 788 mm/s (SE = 52.7 mm/s).

No significant difference was found between the peak hand speed for each type of target fruit,  $F(1, 15) = 0.152, p = 0.702$ , or for each type of flanker fruit,  $F(1, 15) = 0.937, p = 0.349$ . No significant interaction was found between the type of target fruit and the type of flanker fruit,  $F(1, 15) = 0.844, p = 0.373$ .

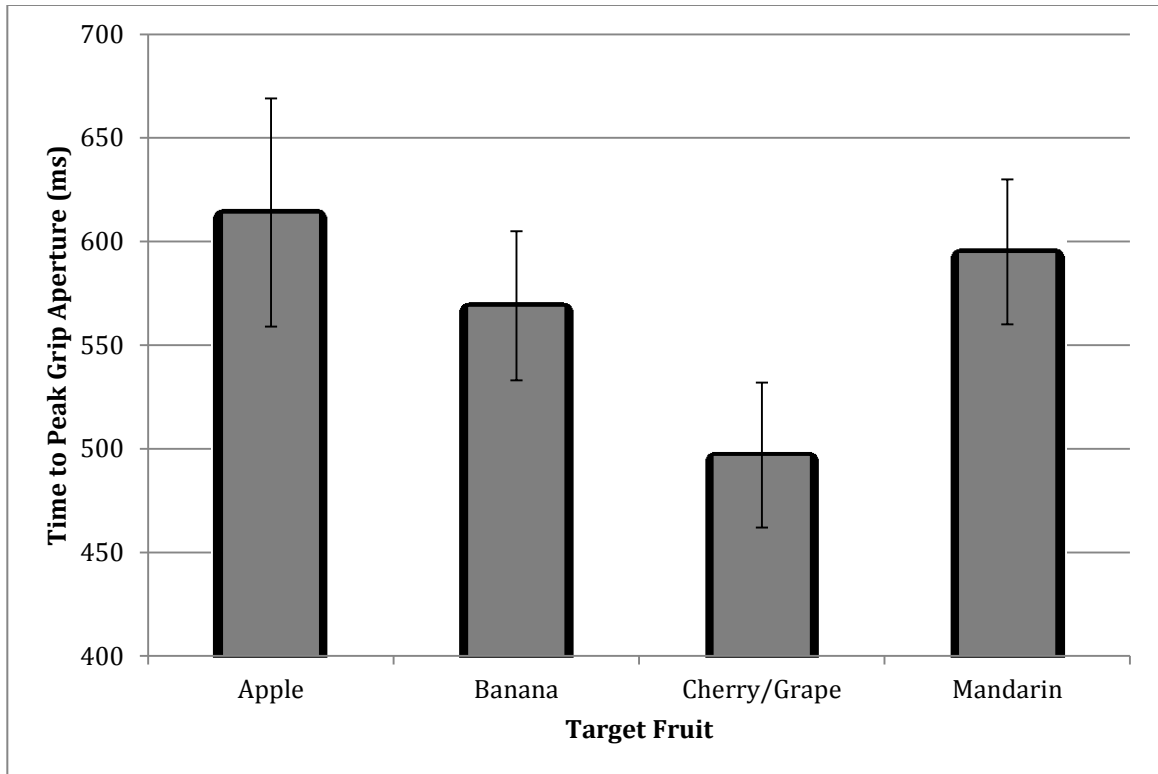
### 3.2.3e Time to Peak Grip Aperture

The side of the flanker fruit was not found to have a significant effect on the time to peak grip aperture,  $F(1, 9) = 0.917, p = 0.363$ , therefore the factor of “side” was

removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for the time it took to reach the peak grip aperture was 569 ms (SE = 36.9 ms).

As expected, a significant main effect on time to peak grip aperture was found for type of target fruit,  $F(1, 14) = 5.54, p = 0.034$ . Host hoc analysis revealed that the time to reach peak grip aperture was significantly shorter when reaching for the cherry/grape (M = 497 ms, SE = 35.5 ms) compared to the banana (M = 569 ms, SE = 36.3 ms), mandarin (M = 595 ms, SE = 35.2 ms) or the apple (M = 613 ms, SE = 55.3 ms) (Figure 3-8).

There was no significant effect of flanker fruit,  $F(4, 56) = 0.641, p = 0.635$  on the time to reach peak grip aperture, nor was there an interaction between the type of target fruit and the type of flanker fruit,  $F(1, 14) = 1.82, p = 0.198$ .



**Figure 3-8: Effect of Target Fruit on Time to Peak Grip Aperture.** The mean time to reach peak grip aperture (mm) was significantly shorter when the target was a cherry/grape compared to all other target fruits. Error bars represent SEM.



### 3.2.3f Time to Peak Hand Speed

The side of the flanker fruit was not found to have a significant effect on the time to peak hand speed,  $F(1, 2) = 11.3, p = 0.078$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for the time it took to reach peak hand speed was 325 ms (SE = 16.3 ms).

Time to peak hand speed was not significantly different for each type of target fruit,  $F(1, 10) = 0.614, p = 0.451$ , or each type of flanker fruit,  $F(4, 40) = 0.734, p = 0.574$ . No significant interaction was found between the type of target and flanker fruits,  $F(12, 120) = 1.27, p = 0.248$ .

## 3.3 DISCUSSION

The goal of this experiment was to replicate the findings of Castiello (1996). He reported that interference effects in prehension were produced when covert attention was directed to a second object beside the target. He had participants reach out and grasp a piece of fruit while simultaneously directing covert attention to a second piece of fruit located nearby. His results showed that the peak grip aperture for the target fruit was scaled towards the size of the non-target fruit upon which covert attention was directed. Castiello (1996) proposed this suggested that motor patterns are automatically processed for attended to objects that are not the focus of an intended action.

In the present experiment, peak grip aperture was scaled accurately to the size of the target object (Jeannerod, 1986), such that the apple had the largest peak grip aperture and the cherry/grape produced the smallest peak grip aperture. Similarly, the time to

reach peak grip aperture also showed predictable results (Jakobson & Goodale, 1991; Jeannerod, 1986; Martenuik, 1990); the time to reach peak grip aperture was shortest for the smallest fruit and longest for the largest fruit. These results confirm that participants were responsive to the properties of the target object and scaled their grasping movements accordingly.

Peak grip aperture was significantly affected by the flanker fruit condition. Although the post hoc analyses were underpowered, the trend shows that peak grip aperture tended to be larger when no flanker fruit was present. This trend is in line with previous literature that has shown that peak grip aperture is smaller when non-target objects are present (Jackson et al., 1995; Mon-Williams et al., 2001; Saling et al., 1998). That being said, Kritikos et al. (2000) found no significant difference in the peak grip aperture for target objects presented alone or in the presence of flankers. Most importantly, the flanker results are different than those reported by Castiello (1996) which indicated a systematic scaling of the peak grip aperture with increasing size of the flanking fruit.

The absence of a flanker also produced differences in reaction time, where participants reacted faster when no flanker fruit was present. The differences in peak grip aperture and reaction time seen for the no flanker condition may not be as simple as the presence or absence of the flanker. The difference between no flanker trials and flanker trials was twofold; not only was there a difference between the presence of the flanker fruit, but participants also were not required to perform the subsidiary task of counting when a flanker was not present. For this reason, one is unable to determine if the difference was due to the presence of the flanker or the requirement to count the light

flashes. That being said, Castiello (1996) performed separate experiments as part of the same study, where he determined that the presence of the flanker fruit alone did not affect movement kinematics for the target fruit. Additionally, the requirement of counting was assessed by having participants count light flashes on the target fruit. In that scenario, there was no difference between movement kinematics between counting trials and non-counting trials.

Contrary to Castiello's (1996) results where he found peak grip aperture for a target was scaled towards the size of a non-target object when covert attention was directed to the non-target, no such interference effect was found as a result of the current study. The type of target fruit as well as the presence of any flanker fruit affected peak grip aperture, but there was no interaction found between target fruit type and flanker fruit type. In other words, the size of the flanker fruit had no impact on the kinematics for the target fruit. Although we attempted to replicate the relevant portions of Castiello's (1996) study as closely as possible, there were some differences between the two studies that could possibly have led to our null result. These differences will be explained further in section 5.1 and 5.2.

In both cases binocular vision was used by participants, however, we wondered if we could produce a similar interference effect to Castiello (1996) if we completed the same task under monocular conditions. It has been shown that prehension guided by binocular vision is not vulnerable to perceptual illusions because it uses absolute metrics of the target. On the other hand, while using monocular vision, participants are reliant on monocular visual cues to determine depth and size, which are scene-based and relative to nearby objects. Marotta et al. (1998) demonstrated that non-target objects, even those

arranged to create a perceptual misjudgment of the target objects' size, had no influence of the peak grip aperture for the target object. On the other hand, when the same task was completed under monocular conditions, where relative metrics between objects were used, non-target objects influenced peak grip aperture for the target. Similar effects have been demonstrated when visual illusions caused participants to perceptually misjudge the size of the target object. Although perceptual misjudgments were made (ventral stream task), peak grip aperture for the target object was accurate (dorsal stream task) (Aglioti et al., 1995; Bartelt & Darling, 2002; Gentilucci et al., 1996; Haffenden & Goodale, 1998; Haffenden et al., 2001; Hu & Goodale, 2000).

## CHAPTER 4

### EXPERIMENT 2

#### 4.1 INTRODUCTION

The goal of this experiment was to determine if directing covert attention to non-target objects would cause interference effects in prehension kinematics for a target object under monocular viewing conditions. As discussed previously, it has been demonstrated that prehensile movements performed under monocular control are susceptible to perceptual illusions whereas interference effects are not found when prehension is guided by binocular control (Marotta et al., 1998). Since size and depth are determined through relative metrics under monocular conditions, we hypothesized that non-target objects might have more of an effect on prehension under monocular control than under binocular conditions where absolute metrics are calculated by disparate retinal images and vergence information. For this reason, we suggest that covertly orienting attention to these non-target objects (as done by Castiello (1996)) under monocular conditions may produce interference effects in prehension similar to those described by Castiello (1996).

We propose here that under binocular conditions, peak grip aperture will be unaffected by the subsidiary task of counting the light flashes on the flanker fruit, as was the case in Experiment 1. Other outcome measures will be affected in accordance with the results of Experiment 1 as follows; 1) peak grip aperture will be scaled towards the size of the target fruit, 2) peak grip aperture may be larger when no flankers are present compared to in the presence of flanker fruits, 3) reaction time will be faster when no flanker fruit is present, 4) the time to reach peak grip aperture will be shorter for smaller

target fruits and 5) movement time, peak hand speed and the time to reach peak hand speed will all be unaffected.

It is hypothesized that movement kinematics will be affected to the greatest extent under monocular conditions since all binocular advantages will be removed. We expect kinematics to be affected to a lesser degree under the reduced stereopsis viewing because participants will still have some binocular advantage but less than in their day to day viewing. Based on the findings of Marotta et al. (1998) and Castiello (1996) discussed above, the main hypothesis is that peak grip aperture will show interference effects similar to those found by Castiello (1996) when trials are completed under monocular or reduced stereopsis viewing conditions. Specifically, peak grip aperture for the target fruit will be scaled towards the size of the flanker fruit when participants are required to perform the subsidiary counting task under monocular and reduced stereopsis visual conditions. Based on the literature reviewed in section 2.5, we also hypothesized that in the monocular condition and reduced stereopsis condition, movement time would be increased, peak hand speed would decrease, time after peak hand speed would increase and time to reach peak grip aperture would increase when compared to the binocular condition.

## 4.2 METHODS

The physical set up for Experiment 2 was identical to Experiment 1. Participants sat at the same table, which was set up in the same manner. The IREDS and EOG electrodes were attached as described in Experiment 1 and participants were given the

same instructions prior to starting the trials. Each trial was arranged in the same fashion as for Experiment 1.

#### **4.2.1 Ethics**

The Dalhousie University Research Ethics Board approved all aspects of this study (Appendix E). Each participant completed informed consent (Appendix F) before partaking in the experimental screening and procedure.

#### **4.2.2 Participants**

A total of eight adults (18-22 years of age, mean age 19.4 years) were included in Experiment 2. The inclusion criteria for Experiment 2 were the same as for Experiment 1, but participants were also required to have normal foveal stereoacuity (at least 55”) as measured by the Frisby 3-plate Stereotest™.

Prior to participation in the study, participants completed the screening form (Appendix G) to ensure they met all inclusion and exclusion criteria. As in Experiment 1, at the completion of the trials participants were debriefed on the rationale for the study, and given an opportunity to ask any questions they had before leaving the lab (Appendix H).

#### **4.2.3 Materials**

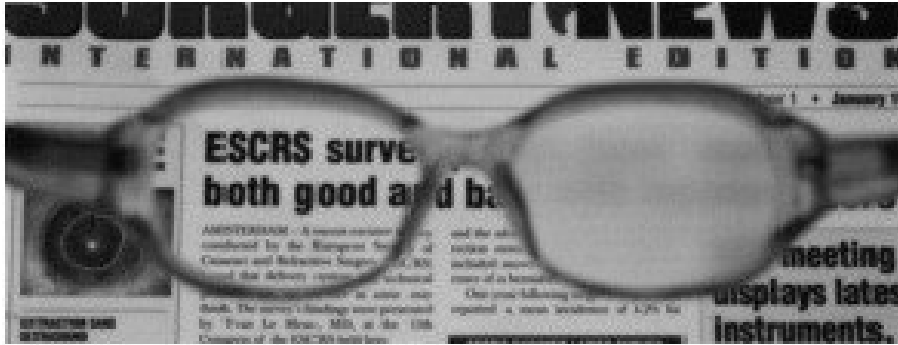
The apparatus was the same as described in Experiment 1. Kinematic characteristics were recorded in the same method as described previously and the same protocol for the EOG was utilized. In contrast to Experiment 1, only the extreme sized

fruits were used for both targets and flankers (apple and red grape) in order to reduce the total number of trials required in the experiment given the increase to three visual conditions. Again, one piece of each fruit was always the target and another was always the flanker fruit.

#### *4.2.3a Creation of Visual Conditions*

Each participant performed trials in three different visual conditions, (i) binocular, (ii) monocular and (iii) reduced stereopsis. In the binocular condition participants completed trials with both eyes opened and with their habitual glasses/contacts if required. In the monocular conditions, participants wore an eye patch (Masteraid ORTOPAD #98494) over their non-dominant eye. These eye patches are latex free and hypoallergenic. Ocular dominance was determined by the hole in the card test. In reduced stereopsis trials, participants wore either their own glasses (if applicable) or a pair of trial frames (Haag-Streit UK, Oculus Universal #4505001) with plano (non-prescription) lenses. A bangerter foil was placed on the lens of the non-dominant eye. The strength of bangerter foil (The Fresnel Prism and Lens Co., #6020, #6010) was determined as the highest strength (most opaque) that still allowed for appreciation of the 600” target on the Frisby 3-plate Stereotest<sup>TM</sup> (Figure 4-1).





**Figure 4-1: Bangerter Foils.** Example of how bangerter foils applied to a lens will create monocular blur. Note: Bangerter foils used in this experiment would have blurred less than shown in the photo. (<http://www.fresnel-prism.com/bangerter-occlusion-foils>)

#### **4.2.4 Data Collection**

Movement kinematics were determined by the same method described in Experiment 1. Previous literature has shown that when participants perform prehensile actions under monocular vision, that they spend more time in the deceleration phase of the movement. For this reason, the time after peak hand speed was also assessed for Experiment 2, as well as the six dependent measures analyzed in Experiment 1. The time after peak hand speed was calculated as the difference in time between the total movement time and the time to reach peak hand speed.

#### **4.2.5 Procedure**

Experiment 2 was completed in the same location and manner as described previously in Experiment 1. Again, upon arrival in the lab, participants read over and completed the consent form (Appendix F). They then read over the screening form (Appendix G); anyone who answered “yes” to any of the questions were excluded from participation. Those participants who answered “no” to all of the questions then had their near vision assessed by a certified orthoptist with the Sloan (Good-Lite, #725000) near card and their stereoacuity assessed with the Frisby 3-plate Stereotest<sup>TM</sup>. Those participants without at least 6/7.5 vision in each eye, or stereoacuity of less than 55” were excluded from participation.

Participants performed six trials for each combination of independent variables; this included, visual condition (binocular, monocular, reduced stereo), central fruit (apple, grape), flanker fruit (apple, grape, no fruit), and side of flanker fruit (left or right) (see Table 4-1). This resulted in a total of 216 (3 x 2 x 3 x 2 x 6) trials. Trials were blocked by

visual condition, where the order of which visual condition was completed first was randomized. Within each block, trials were randomized on the basis of central fruit, flanker fruit and side of flanker fruit. Participants were told they could ask for a break at any point throughout the testing, and were also asked if they would like a break after every 40 trials.

**Table 4-1: Experiment 2 Trials.** The number of trials for each arrangement of independent variables in Experiment 2.

Visual Condition	Central Fruit	Flanker Fruit	Side of Flanker Fruit	Number of Trials
Binocular	Apple	Apple	Left	6
Binocular	Apple	Apple	Right	6
Binocular	Apple	Grape	Left	6
Binocular	Apple	Grape	Right	6
Binocular	Apple	None	-	12
Binocular	Grape	Apple	Left	6
Binocular	Grape	Apple	Right	6
Binocular	Grape	Grape	Left	6
Binocular	Grape	Grape	Right	6
Binocular	Grape	None	-	12
Monocular	Apple	Apple	Left	6
Monocular	Apple	Apple	Right	6
Monocular	Apple	Grape	Left	6
Monocular	Apple	Grape	Right	6
Monocular	Apple	None	-	12
Monocular	Grape	Apple	Left	6
Monocular	Grape	Apple	Right	6
Monocular	Grape	Grape	Left	6
Monocular	Grape	Grape	Right	6
Monocular	Grape	None	-	12
Reduced Stereo	Apple	Apple	Left	6
Reduced Stereo	Apple	Apple	Right	6
Reduced Stereo	Apple	Grape	Left	6
Reduced Stereo	Apple	Grape	Right	6
Reduced Stereo	Apple	None	-	12
Reduced Stereo	Grape	Apple	Left	6
Reduced Stereo	Grape	Apple	Right	6
Reduced Stereo	Grape	Grape	Left	6
Reduced Stereo	Grape	Grape	Right	6
Reduced Stereo	Grape	None	-	12

## 4.3 RESULTS

### 4.3.1 Participant Characteristics

Participant characteristics for each individual participant can be seen in Table 4-2. Eight participants participated in Experiment 2, three females and five males. Participants ranged in age from 18-22, with an average age of 19.4 years. All had at least 6/6 vision in each eye and at least 55" stereoacuity ( $M = 51''$ ) as measured by the Frisby 3-plate Stereotest<sup>TM</sup>. Seven of the participants were right eye dominant. Five participants wore glasses, and therefore we used their own glasses during testing. For the three participants who did not wear glasses, trial frames with plano (non-prescription) lenses were used. The strongest bangerter foil that allowed for appreciation of the 600" target on the Frisby 3-plate Stereotest<sup>TM</sup> was applied over the non-dominant eye of each participant. The 0.2 bangerter foil was used for six participants and the 0.1 was used for the other 2 participants. After the bangerter foil was applied, the resulting stereoacuity measured between 100-600" ( $M = 273''$ ) and the resulting near visual acuity measured through the foil was between 6/24 and 6/38.

**Table 4-2: Participant Characteristics – Experiment 2.** Characteristics of participants from Experiment 2

ID	Sex	Age	D.Eye <sup>1</sup>	Glasses <sup>2</sup>	Initial NVA		Initial Stereo	Foil Used	Foil NVA <sup>3</sup>	Foil Stereo <sup>4</sup>
					RE	LE				
P201	F	18	R	G	6/4.8	6/6	55"	0.2	6/30	170
P202	M	18	R	G	6/4.8	6/4.8	55"	0.1	6/30	170
P203	M	20	R	TF	6/6	6/6	55"	0.1	6/30	600
P204	F	22	R	TF	6/6	6/6	55"	0.2	6/24	100
P205	M	20	R	G	6/4.8	6/6	40"	0.2	6/24	170
P206	F	18	R	G	6/6	6/6	55"	0.2	6/30	170
P207	M	21	R	TF	6/6	6/6	55"	0.2	6/24	600
P208	M	18	L	G	6/6	6/6	40"	0.2	6/38	200

<sup>1</sup> Dominant eye; R = Right, L = Left

<sup>2</sup> The type of glasses worn by the participant during testing; G = the participants own glasses, TF = trial frames with plano lenses

<sup>3</sup> Near visual acuity measured in the non-dominant eye through the bangerter foil

<sup>4</sup> Stereoacuity measured with the bangerter foil applied to the non-dominant eye

### 4.3.2 Main Effects/Interactions for Each Dependent Variable

Similar to Experiment 1, all statistical measures were completed with the SPSS software. Outliers were determined by the same method explained for Experiment 1 (section 4.3). Fifty-seven trials out of a total of 1,728 trials were deemed outliers and excluded from analysis (3.30% of all trials).

In addition, 7 trials (0.41%) were excluded because participants looked towards the flanker fruit, 4 trials (0.23%) were excluded because participants made errors such as moving before the cue, and 29 trials (1.68%) were excluded due to technical errors. In all, a total of 97 trials (5.61%) were excluded from further analysis.

Similar to Experiment 1, each dependent measure was initially analyzed with a 2 (target: apple, grape) by 2 (flanker; apple, grape) by 2 (side; right, left) by 3 (visual condition; binocular, monocular, reduced stereopsis) repeated measures ANOVA ( $\alpha = 0.05$ ) to determine the effect of “side” on each outcome measure prior to collapsing data across “side” to enable inclusion of “no flanker” trials in a larger analysis. Then a 2 (target; apple, grape) by 3 (flanker; apple, grape, no flanker) by 3 (visual condition; binocular, monocular, reduced stereopsis) repeated measures ANOVA ( $\alpha = 0.05$ ) was conducted to incorporate the non-flanker data. Sphericity was assessed by the same method outlined in section 3.2.3.

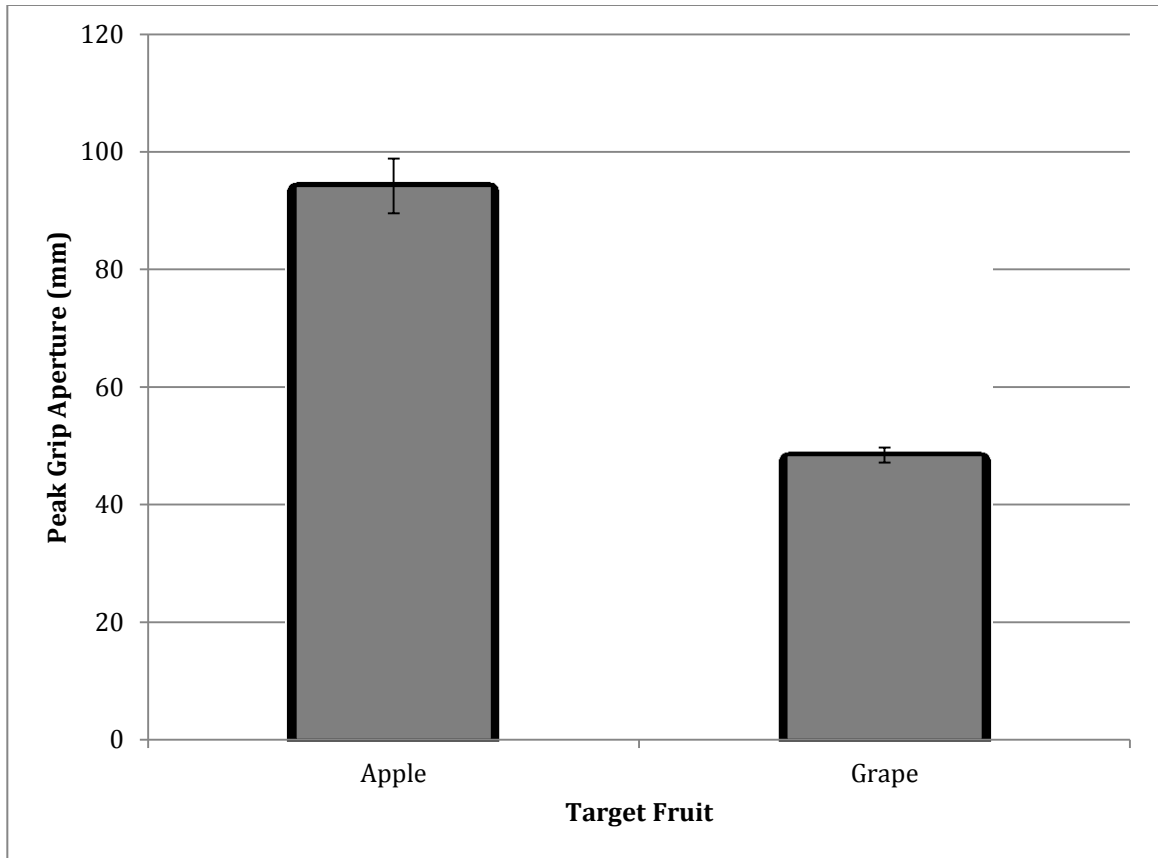
#### 4.3.2a Peak Grip Aperture

Similar to in Experiment 1, the side the flanker fruit was on (left or right), did not have a significant effect on the peak grip aperture,  $F(1, 7) = 5.18, p = 0.057$ . Once again we chose to remove “side” as a factor from further analysis to enable inclusion of the “no

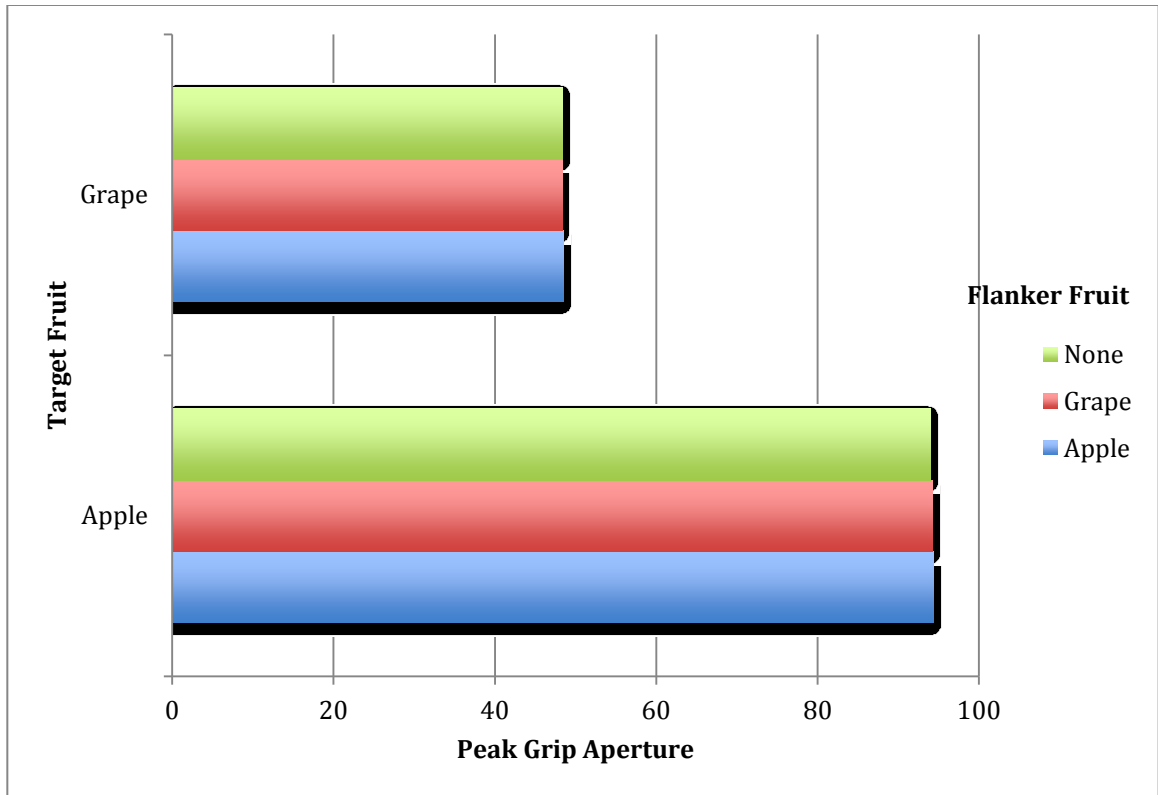
flanker” condition into an omnibus analysis. The grand mean for peak grip aperture was 71.3 mm (SE = 2.81 mm).

As predicted, peak grip aperture was significantly affected by the type of target fruit,  $F(1, 7) = 140, p < 0.001$ . Specifically, peak grip aperture was larger for the apple (M = 94.2 mm, SD = 4.69 mm) compared to the grape (M = 48.4 mm, SD = 1.26 mm) (Figure 4-2). Peak grip aperture was not significantly affected by the visual condition,  $F(2, 14) = 2.22, p = 0.146$ , or by the type or presence of the flanker fruit,  $F(2, 14) = 0.089, p = 0.915$ . No significant interaction between factors was found (Figure 4-3).





**Figure 4-2: Effect of Target Fruit on Peak Grip Aperture.** The mean peak grip aperture for each target fruit was significantly different. Peak grip aperture was scaled to the size of the target fruit, where peak grip aperture for the apple was larger than for the grape. Error bars represent SEM.

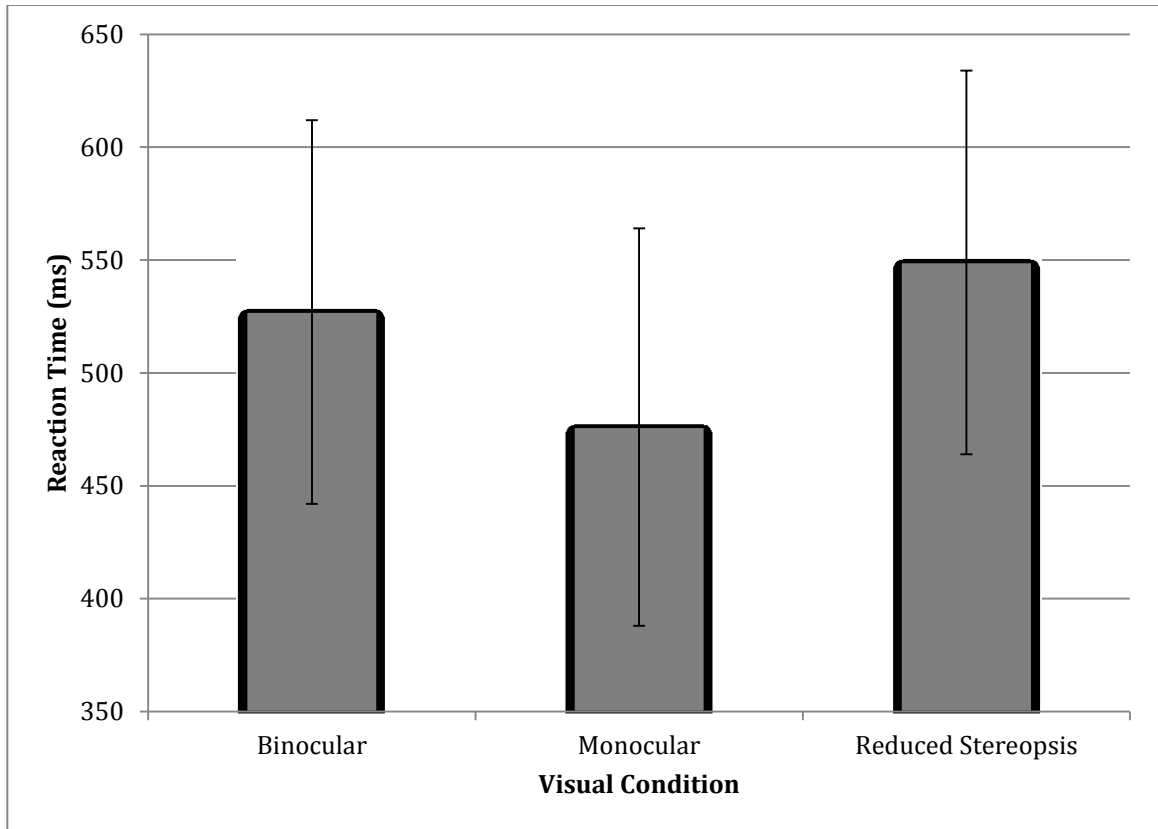


**Figure 4-3: Interaction Between Target and Flanker Fruits.** Mean peak grip aperture (in millimeters) for each target fruit as a function of each flanker fruit. No interaction was found between target fruits and flanker fruits; peak grip aperture for the target fruits were not influenced by the size of the flanker fruit.

#### 4.3.2b Reaction Time

The side on which the flanker fruit was located was not found to have a significant effect on reaction time,  $F(1, 7) = 0.478, p = 0.512$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for reaction time was 517 ms (SE = 85.3 ms).

A main effect of visual condition was found,  $F(1, 7) = 5.64, p = 0.049$ , where reaction time was significantly faster under monocular trials (M = 476 ms, SE = 88.3 ms) than reduced stereopsis (M = 549 ms, SE = 85.3 ms) trials. Reaction time for the binocular trials (M = 527 ms, SE = 85.3 ms) was faster than the reduced stereopsis trials and slower than the monocular trials, but was not significantly different than either (Figure 4-4). Reaction time was not significantly different for the different target fruits,  $F(1, 7) = 0.726, p = 0.422$ , or for different flanker fruits,  $F(2, 14) = 2.50, p = 0.118$ . No significant interaction was found for reaction time.



**Figure 4-4: Effect of Visual Condition on Reaction Time.** Mean reaction time (ms) for prehension under each visual condition. Reaction time was significantly faster in the monocular condition than the binocular condition. Error bars represent SEM.

#### 4.3.2c Movement Time

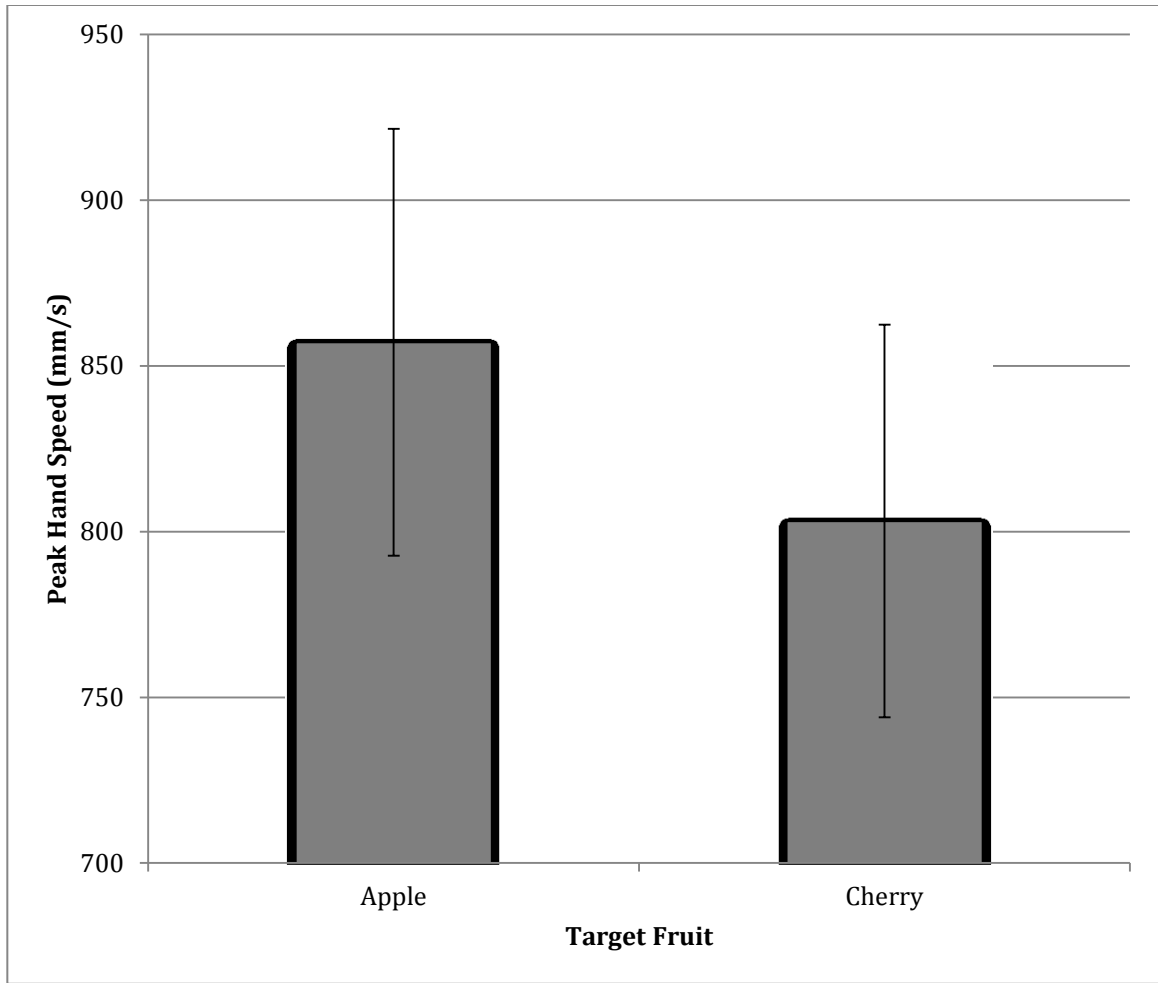
Once again, the side on which the flanker fruits were located did not have a significant effect on movement time,  $F(1, 7) = 0.474, p = 0.513$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for movement time was 707 ms (SE = 66.6 ms).

Movement time was not significantly different under different visual conditions,  $F(2, 14) = 1.78, p = 0.205$ , or when reaching for the different target fruits,  $F(1, 7) = 0.578, p = 0.472$ . In addition, no significant difference in movement time was found for the different flanker fruits,  $F(1, 7) = 1.165, p = 0.316$ . No interaction was found between any factors.

#### 4.3.2d Peak Hand speed

The side of the flanker fruit once again did not have a significant effect on the peak hand speed,  $F(1, 7) = 4.43, p = 0.073$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for peak hand speed was 830 mm/s (SE = 61.6 mm/s).

Peak hand speed was significantly slower,  $F(1, 7) = 24.4, p = 0.002$ , when the target fruit was a grape (M = 803 mm/s, SD = 59.2 mm/s) compared to when it was an apple (M = 857 mm/s, SD = 64.4 mm/s) (Figure 4-5). Peak hand speed was not significantly different under different visual conditions,  $F(2, 14) = 0.931, p = 0.417$ , and was not affected by the flanker fruits,  $F(2, 14) = 0.366, p = 0.700$ . No interaction between factors was found.



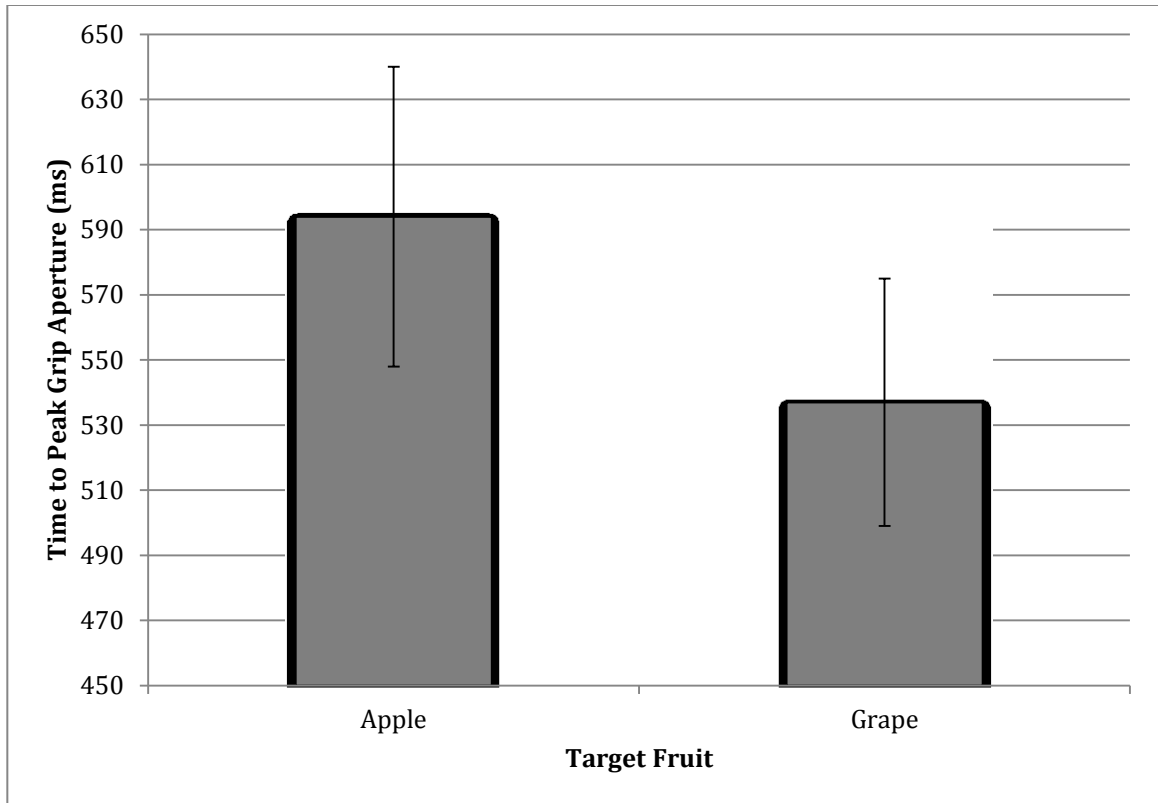
**Figure 4-5: Effect of Target Fruit on Peak Hand Speed.** The mean peak hand speed (mm/s) for each target fruit was significantly different. The peak hand speed was slower for the grape than the apple. Error bars represent SEM.

#### 4.3.2e Time to Peak Grip Aperture

The side of the flanker fruit did not have a significant effect on the time to peak grip aperture,  $F(1, 7) = 1.59, p = 0.247$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for the time to peak grip aperture was 566 ms (SE = 41.4 ms).

Similar to Experiment 1, time to peak grip aperture was significantly affected by the target fruit,  $F(1, 7) = 11.2, p = 0.012$ . It took participants significantly longer to reach their maximum grip aperture when the target fruit was an apple (M = 594 ms, SE = 46.4 ms) compared to when it was a grape (M = 537 ms, SE = 37.8 ms) (Figure 4-6).

The time to peak grip aperture was not significantly different for the different visual conditions,  $F(2, 14) = 0.457, p = 0.642$ , or in the presence of different flanker fruits,  $F(2, 14) = 0.133, p = 0.877$ . No interaction was found between the different factors in their effect on time to peak grip aperture.



**Figure 4-6: Effect of Target Fruit on Time to Peak Grip Aperture.** The mean time to peak grip aperture (ms) for each target fruit was significantly different. It took participants longer to reach their peak grip aperture when the target was an apple than when it was a grape. Error bars represent SEM.



#### *4.3.2f Time to Peak Hand speed*

The side of the flanker fruit, once again, did not have any significant effect on the time to peak hand speed,  $F(1, 7) = 3.92, p = 0.088$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for the time to peak hand speed was 308 ms (SE = 18.4 ms).

Peak hand speed was not significantly affected by the visual condition,  $F(2, 14) = 0.361, p = 0.703$ , the type of target fruit,  $F(1, 7) = 0.017, p = 0.899$ , or by the type of flanker fruit,  $F(1, 7) = 0.296, p = 0.604$ . A significant interaction was found between the type of visual condition and the type of target fruit,  $F(2, 14) = 5.04, p = 0.022$ . A simple effects analysis was conducted that revealed a significant effect of target fruit,  $F(1, 7) = 11.6, p = 0.011$ , within the reduced stereopsis condition only, where the time to reach peak hand speed was significantly shorter when the target fruit was an apple (M = 306 ms, SE = 18.6 ms) than when it was a grape (M = 318 ms, SE = 19.4 ms).

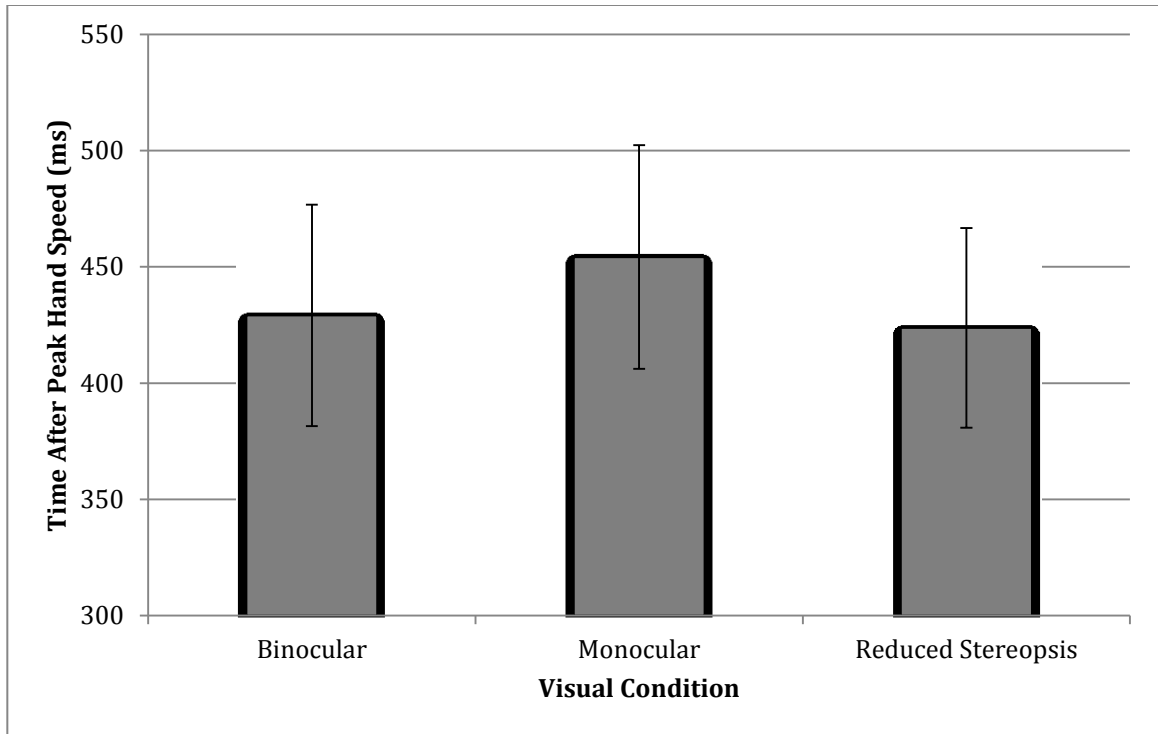
#### *4.3.2g Time After Peak Hand Speed*

The side of the flanker fruit did not have any significant effect on the time after peak hand speed,  $F(1, 7) = 4.08, p = 0.083$ , therefore the factor of “side” was removed from further analysis to enable inclusion of the “no flanker” trials in a larger overall analysis. The grand mean for the time after peak hand speed was 436 ms (SE = 45.8 ms).

The time after peak hand speed was significantly affected by visual condition,  $F(2, 14) = 4.28, p = 0.036$ . Participants spent significantly longer in the time after peak hand speed when trials were completed with monocular vision (M = 454 ms, SE = 48.1

ms) compared to when participants were able to use binocular ( $M = 429$  ms,  $SE = 47.7$  ms) or reduced stereopsis viewing ( $M = 424$  ms,  $SE = 42.9$  ms) (Figure 4-7).

The time after peak hand speed was not significantly affected by the type of target fruit,  $F(1, 7) = 0.956$ ,  $p = 0.361$ , or the type of flanker fruit,  $F(2, 14) = 1.06$ ,  $p = 0.373$ . No interaction was found between the different factors in their effect on time after peak hand speed.



**Figure 4-7: Effect of Visual Condition on Time After Peak Hand Speed.** The mean time after peak hand speed (ms) was significantly longer for the monocular condition than the other two visual conditions. Error bars represent SEM.

#### 4.4 DISCUSSION

The goal of the present experiment was to determine if directing covert attention to non-target objects under monocular viewing conditions or conditions of reduced stereopsis, would lead to an interference effect in peak grip aperture. Specifically, we expected that peak grip aperture for a target fruit would be scaled towards the size of the non-target fruit upon which covert attention was directed.

As expected, peak grip aperture was influenced by the size of the target fruit. Specifically, peak grip aperture was larger for the apple than for the grape. This is consistent with the results from Experiment 1, as well as previous literature showing that peak grip aperture is scaled towards the size of the target object (Jeannerod, 1986). Similarly, target fruit type also had an effect on the time to reach peak grip aperture. The maximum aperture was reached later when the target fruit was an apple than when it was a grape. This makes sense because the aperture was larger for the apple and therefore one would expect it to take longer to reach the larger aperture. This finding is also in line with results from Experiment 1, as well as previous literature (Jakobson & Goodale, 1991; Jeannerod, 1986; Martenuik, 1990). These results confirm that participants were paying attention to the target fruit and adjusting their grasping movements in response to its size.

The peak hand speed reached during the grasp was different for the various target fruits. The peak velocity was slower when the target fruit was a grape than when it was an apple. This is in line with findings from Jakobson & Goodale (1991) who found that peak velocity of the wrist during prehensile actions increased as the size of the target object increased. It is also consistent with Fitts' Law (Fitts, 1954) which predicts a reduction in movement speed when the target is smaller and thus requires increased movement

precision. When Castiello (1996) initially looked at the normal prehensile kinematics for the four types of fruit in his study, he also found supporting results, where peak hand speed was slowest for the cherry and fastest for the apple.

The only two parameters that showed an effect of visual condition were reaction time and time after peak hand speed. Reaction time was quicker when movements were performed under monocular control than when stereopsis was reduced. Movements completed under binocular control had a reaction time between that of the monocular condition and reduced stereopsis condition, but was not found to be statistically different than either group. This pattern was surprising because we expected to find the greatest differences between the binocular condition and the monocular condition since they represent the two extremes of binocularity; one has perfect stereoacuity while the other has no binocular benefit at all. We expected that the reduced stereoacuity condition would fall somewhere in the middle since some level of stereoacuity was still available, just to a lesser extent than the binocular condition.

Previous literature has compared differences in reaction time during prehensile movement completed under binocular and monocular control, and similar to our study found no difference between those two groups (Servos, 2000; Watt & Bradshaw, 2000; Melmoth & Grant, 2006). Additionally, no difference in reaction time was found between prehensile movements executed under binocular and reduced stereopsis viewing conditions (Melmoth et al., 2009). To the best of our knowledge, no literature has examined prehension reaction time while comparing monocular viewing and reduced stereopsis viewing. That being said, perhaps the reduced stereoacuity condition demonstrated the slowest reaction time because participants were able to perform

binocular depth processing, but had to do so with less accurate visual information. This could potentially lead to the slower reaction time in the reduced stereopsis viewing condition. At the same time, perhaps the monocular viewing condition had the fastest reaction time because no processing of binocular depth information was required.

The time after peak hand speed was also affected by the type of visual condition. Participants spent longer in the deceleration phase of the movement in the monocular condition compared to the binocular or reduced stereopsis condition. This is consistent with previous literature (Bradshaw et al., 2004; Melmoth & Grant, 2006).

Contrary to our predictions, the act of directing covert attention towards a flanker fruit had no effect on the peak grip aperture for the target fruit, regardless of the visual condition. We predicted that peak grip aperture for the target fruit would be scaled towards the size of the flanker fruit when prehension was conducted under monocular or reduced stereopsis viewing conditions. It is possible that an effect was not found because the targets used were always placed in the same location in space and were also familiar objects. It has been shown that familiar objects aid prehension in the absence of binocular visual information (Marotta & Goodale, 2001). Instead of relying on visual information processing to determine the depth and size of the target, it is very possible that participants used the remembered size and location of the objects when planning their movements.

Contrary to the findings of Experiment 1, there was no main effect of flanker fruit on peak grip aperture. To recall, in Experiment 1 there was a main effect of flanker fruit on peak grip aperture, however the post hoc analysis was underpowered to determine where the difference lay. That being said, by examining the data, it appeared there was a

trend where peak grip aperture was larger when no flanker fruit was present. In general the literature has been divided on this outcome; some studies have shown that peak grip aperture will be smaller in the presence of a flanking object (Jackson et al., 1995; Mon-Williams et al., 2001; Saling et al., 1998; Tresilian, 1998), as was the trend in Experiment 1, whereas others report no difference in peak grip aperture (Kritkos et al., 2000), similar to Experiment 2.

## **CHAPTER 5**

### **CONCLUSION**

The current study aimed to replicate prehensile interference effects produced by covertly attending to a non-target object (Castiello, 1996). As previously discussed, Castiello (1996) had participants maintain fixation on a target fruit while reaching out and grasping it. Simultaneously, his participants were to count the number of light flashes on a nearby non-target piece of fruit. The action of counting the light flashes was used to covertly direct attention away from the target and towards a non-target object. He found that when covert attention was directed to the flanker object, peak grip aperture for the target fruit was scaled towards the size of the flanker fruit.

We chose to replicate this study after conflicting results were obtained in another study in our lab. LeBlanc & Westwood (2014) had developed a sequential task paradigm based on Castiello's (1996) interference effects, where they proposed that peak grip aperture for the first object in the sequence would be scaled towards the size of the second object since sequential tasks are processed as a whole (Henry & Rogers, 1960; Hesse & Deubel, 2010). They only found a similar interference effect when size for the second object was verbally reported, but not when participants were required to grasp the second object.

#### **5.1 SUMMARY OF RESULTS**

The results of this study were unable to replicate the interference effects found by Castiello (1996) where peak grip aperture for the target fruit was scaled towards the size of the flanker fruit. Although we attempted to maintain features of Castiello's (1996)



study that were relevant to the interference effects of interest, there were still some differences between his study and the current one. During the original study, the flashing of the lights on the flanker fruit began at four different time points; 1) before movement onset, 2) at movement onset, 3) after the hand passed a photoelectric cell 10 cm into the movement, and 4) after the hand passed a photoelectric cell 20 cm into the movement. The interference effect of interest was not affected by the spotlighting onset; therefore we only used one onset time, at movement onset. Since Castiello (1996) did not find a difference in peak grip aperture between the different spotlight onset conditions, this likely did not account for the difference between the two results.

One of the biggest differences between the two studies was that we standardized the type of grasp used, whereas Castiello (1996) allowed participants to use a different type of grip for each target fruit. For example, in his study participants grasped the cherry with a precision grip and the apple with a whole-hand grip. In our study, participants grasped each type of target fruit with a precision grip. This was done in an attempt to more easily compare the peak grip aperture for the different fruits without a compounding factor of a different type of grasp type (with associated differences in grasping kinematics). Since participants used the same type of grasp for all targets in our study, perhaps this made it less likely that the motor pattern for the flanker fruit (same type of grasp) would interfere with the prehension of the target fruit.

Although we were unable to reproduce Castiello's interference effects, there are aspects of our resulting kinematics that are consistent with previous results. Previous literature demonstrated that movement time was increased (Mon-Williams et al., 2001; Saling et al., 1998) and peak grip aperture is decreased (Jackson et al., 1995; Mon-

Williams et al., 2001; Saling et al., 1998; Tresilian, 1998) in the presence of non-target objects. Although pairwise comparisons were underpowered, our results also demonstrate a trend that peak grip aperture in the presence of flanker objects is smaller than for lone targets. Consistent with previous literature, peak grip aperture was scaled to the size of the target fruit (Jakobson & Goodale, 1991; Jeannerod, 1986; Martenuik et al., 1990) and the time to reach peak grip aperture was longer for larger fruits (Jakobson & Goodale, 1991).

Contrary to previous literature, the current study showed no difference in movement time between trials with lone target fruits and those with flanker objects. That being said, in our study there were two differences between lone target trials and those with flankers; 1) the presence of the flanker, and 2) the requirement to count the number of light flashes on the flanker object. For this reason it is difficult to compare the current study to previous studies where the subsidiary task of counting was not present.

After it was determined that covertly attending to a non-target stimulus had no effect on the peak grip aperture for a target, it was considered that perhaps binocular vision allowed participants to accurately determine the size of the target and to disregard non-target objects. Previous literature demonstrates that prehensile movements conducted under binocular vision rely on the absolute metrics of the target object and are not susceptible to visual illusions (Marotta et al., 1998). Similarly, when movements are completed under monocular control, size and depth information is determined through relative metrics therefore non-target objects in the scene become important in determining size and depth (Aglioti et al., 1995; Bartelt & Darling, 2002; Gentilucci et al., 1996; Haffenden & Goodale, 1998; Haffenden et al., 2001; Hu & Goodale, 2000). Therefore,

we conducted a study similar to Experiment 1, but where we created three different visual conditions; binocular, monocular and reduced stereopsis. It was predicted that under monocular and reduced stereopsis conditions, non-target objects would have a greater effect on the prehension of the target object. Specifically, we would see a similar interference effect as found by Castiello (1996) where peak grip aperture for the target fruit was scaled towards the size of the non-target fruit upon which covert attention was directed.

Similar to Experiment 1, peak grip aperture was scaled to the size of the target fruit, where larger apertures were used for the apple compared to the grape. Additionally, the time to reach peak grip aperture was longer for the apple than for the grape. Previous literature has shown that peak hand speed achieved during prehension is slower for smaller targets compared to larger ones (Jakobson & Goodale, 1991; Castiello, 1996); this was also confirmed in Experiment 2, where peak hand speed was slower for the grape than the apple.

It is difficult to explain why reaction time was fastest for movements completed under monocular control and why the slowest reaction time was found for movements completed under reduced stereopsis viewing. Previous literature has typically compared the difference between binocular vision and either of these two groups, and has not directly looked at the differences in prehension while executed under monocular and reduced stereopsis viewing. That being said Melmoth et al. (2009), examined prehension in normal and stereo deficient participants under binocular, monocular and reduced stereopsis viewing conditions. Although their main focus was to examine differences between the normal and stereo-deficient participants, they did find a similar pattern of

results in their normal cohort. Movement onset was slowest for the reduced stereopsis viewing and fastest under monocular vision. As described previously, this pattern of results could arise if binocular depth information processing with less accurate visual information (as in the reduced stereopsis condition) takes more time than under monocular control when no binocular depth information processing is required.

Previous literature demonstrates consistent kinematic effects on prehension when completed monocularly or with reduced stereopsis compared to when executed with binocular vision. Based on previous literature we expected to find an increase in movement time and a decrease in peak hand speed when movements were performed without normal binocular visual cues. Additionally, previous literature has shown changes to peak grip aperture and the time to reach peak grip aperture when prehension is executed with only monocular visual cues. In the current study, none of the previously determined effects were produced. Possible explanations will be discussed in section 5.2. Consistent with previous literature, our results did reveal a significant increase in the time spent in the deceleration phase of the movement when prehension was completed under monocular control compared to when binocular vision was used (Bradshaw et al., 2004; Melmoth & Grant, 2006).

## 5.2 MAIN FINDINGS & LIMITATIONS

Overall it was found that participants were responsive to target characteristics and adapted their grasp as predicted. Specifically, participants consistently scaled their peak grip aperture to the size of the target object, and the time to reach peak grip aperture was shorter for smaller targets. Reaction time was also found to be faster when targets were

presented without flanker fruits and also for trials completed with monocular vision compared to with reduced stereopsis viewing. As well, participants spent longer in the deceleration phase of the movement when trials were completed with monocular vision compared to binocular or with reduced stereopsis and, the peak velocity of the hand was slower for smaller targets than for larger ones in Experiment 2.

We were unable to reproduce the interference effect found by Castiello (1996) under normal binocular viewing or when binocular vision was removed or degraded. Although significant effort was used to ensure the relevant aspects of Castiello's (1996) study were maintained, there were in fact some differences between it and the present study that could have led to the differing results. The main differences have been discussed previously, but include the type of grasp used for the different fruits and the onset of the spotlighting. Castiello used four time points to initiate the onset of the spotlighting whereas we decided to only use one. That being said, although he did find differences in kinematics between the different spotlighting onset groups, the specific interaction effect we wished to replicate was not affected by the spotlight onset time.

Another major difference between the two studies was the type of grasp used. Castiello (1996) allowed participants to use different grasp types for the different types of fruit, whereas we had participants use a precision grip for all types of fruit. It is possible the difference in grip types and not just the direction of covert attention to the non-target fruit alone lead to the resulting interference effect. In fact, Sartori et al. (2014) found a similar pattern of inference effects and attributed their findings to a difference in grasp type. They examined the prehensile movements of monkeys in their natural environment and determined that peak grip aperture for targets was in fact influenced by the presence

of incongruent non-target objects that were within arm's reach. Specifically, they found that peak grip aperture for a small target would be larger when a large non-target object was also within reach and vice versa for large objects surrounded by a small non-target object. Unlike in Castiello's (1996) study, the monkeys were not required to direct covert attention to the non-targets in order to produce this effect, their presence within arm's reach was enough to produce the interference effect. Non-target objects that were outside of the monkeys reach did not produce any interference effects. As their study occurred in the monkey's natural environment, the monkeys used a precision grip for the small targets and a power grip for the large targets. As suggested here, Sartori et al. (2014) also suggests that the interference effects could result when the target and non-target objects require different motor patterns to achieve the grasp. Based on their findings, it is possible that directing covert attention to the non-target object is not required to produce interference effects but rather differing potential motor patterns alone are able to interact with each other. Unfortunately, the differences between our study and Castiello's (1996) study make it difficult to say for certain if his results are reproducible or not.

That being said, one could consider that Castiello's (1996) results were the result of a type I error, and in actuality no interference effect is present as shown by the results of the current study. In this case, peak grip aperture for a target fruit is not affected by the presence of nearby non-target objects, even when attention is directed towards them. In fact, illusion studies (Aglioti et al., 1995; Bartelt & Darling, 2002; Gentilucci et al., 1996; Haffenden & Goodale, 1998; Haffenden et al., 2001; Hu & Goodale, 2000) support this idea; such studies have demonstrated that under binocular viewing conditions prehension movements are unaffected by nearby targets, even when they create visual illusions

disrupting the perceived size of the target. If we return to the mountain goat on the ledge, it is particularly important for him that potential motor patterns that are not involved in the intended action, do not interfere in the motor pattern to jump to the next ledge. It could in fact be very harmful to the goat if such interference existed.

It is important to continue research in this area as it has many implications including improved rehabilitation of patients with impaired motor performance, potentially including patients after an accident, stroke or those with Parkinson's disease. Additionally, this line of research is important in areas such as distracted driving, which is becoming an increasingly important topic as deaths associated with distracted driving continue in rise in many areas.

In response to Experiment 2 in particular, the largely null effect of visual condition could arise from the fact that a limited number of targets were used, they were always placed at the same distance from the start switch and they were familiar objects. It has previously been demonstrated that familiar objects aid prehension in the absence of binocular visual information (Marotta & Goodale, 2001). Since only two possible targets were used throughout the study and they were always placed at the same location, participants could have quickly and easily learned the size of the two targets, after which they would not be reliant on visual information, but could instead simply reach from memory.

Visual condition did produce changes to reaction time in Experiment 2. Specifically, participants were faster to react when trials were executed under monocular vision compared to when reduced stereopsis was used. When participants executed trials with binocular vision, their reaction time was found to be midway between the monocular

condition and the reduced stereopsis condition, but was not significantly different than either group. It is possible that this pattern of results indicates that visual information processing of depth occurs before movement onset and that determining depth from degraded binocular visual information takes more time than when normal binocularity is in place or when no binocular calculations of depth need to be calculated (as in monocular viewing). In support of this idea, Grant & Conway (2015) found that movement onset time was delay for amblyopic patients with reduced stereoacuity compared to stereo-normal participants.

Although the current study did not find a significant increase in movement time for trials completed with monocular vision, a significant increase in the length of the deceleration phase was produced for monocular trials. It is possible that the current study did not show a difference in overall movement time for trials completed with monocular vision, because although the time spent in the deceleration phase of the movement was increased, the reaction time for these trials was decreased. These changes, when combined together would cancel each other out, causing the overall movement time to be unchanged.

### 5.3 FUTURE DIRECTIONS

There are a few ways one could circumvent the limitations of the current study. One way to examine the differences between the current study and Castiello's (1996) would be to replicate his study exactly, including adding the 4 spotlighting onset time points, as well as allowing participants to adopt different grasps for the different fruits. This would ensure that the results of his study are reproducible. On the other hand, Sartori



et al. (2014) did find similar interference effects when simply looking at different types of grasps, without the presence of a subsidiary counting task to direct covert attention to the non-target object. When taking this into account, the four spotlighting onsets and the presence of the subsidiary task alone are likely not as important as the type of grasp used. Therefore, future research could look at prehension for targets and flanker objects that require different types of grasps, such as picking up your morning cup of orange juice when it is next to a grapefruit.

The only effects the different visual conditions had on movement kinematics was that reaction time was significantly faster when executed under monocular vision compared to when executed with reduced stereopsis and participants spent longer in the deceleration phase of the movement during monocular trials, despite previous literature showing consistent changes, particularly of increased movement time. It is very likely that during this study participants were able to rely on their remembered size and location of target fruits since the targets were familiar objects, only two targets were used and they were always in the same location. For these reasons, future studies looking at how non-target objects influence prehension, and/or how attention influences the execution of movements, could look at the difference between familiar and novel objects. For example, a similar paradigm as the ones used here could be employed that used either both familiar and novel objects, or could only use novel objects. It would also be important to change the location of the targets from trial to trial. This would ensure that participants rely on visual information processing of the objects in front of them and not on their memory for the object.

#### 5.4 PRACTICAL IMPLICATIONS FOR ORTHOPTIC PATIENTS

Despite the fact that we know common visual disorders such as amblyopia or strabismus affect binocularity and depth perception, and that depth perception is important in the execution of accurate movement, relatively little is known about how these disorders affect motor patterns. Practicing orthoptists can attest that parents of children with one of these visual disorders will often mention their child is clumsy, and adult patients with these disorders will sometimes complain of difficulty performing certain actions, like walking up or down stairs. To begin addressing these concerns, researchers have begun looking into how movement parameters are affected by not just the acute loss of binocular vision, but also how movement is affected in populations with visual disorders that affect binocularity. Understanding the importance of binocular vision in everyday life is important when deciding on treatment protocols and for determining the timing of surgery in young patients.

Although research has begun into exploring how movement is affected by decreased binocular function, current clinical techniques are targeted to assess the perceptual differences caused by these disorders and not how movement is affected. In the future, examining the movement kinematics of patients with binocular visual disorders may provide a better understanding of how the disorder affects their daily lives.

If indeed, the null results in Experiment 2, arise from some type of learning effect, where participants are able to use familiar size to produce accurate prehension in the absence of binocular visual information, then this could be good news for the orthoptic patient. It indicates, that at least for common actions on familiar objects that there is

minimal effect of reduced or absent stereoacuity, and these patients should be able to adapt to their loss effectively.

## 5.5 CONCLUSION

The previously demonstrated interference effect, where directing covert attention to a non-target object produced altered peak grip aperture for the target fruit, was not reproduced here. Specifically, Castiello (1996) found that the act of directing covert attention to a non-target object, during the grasp of a target object, resulted in alterations to the peak grip aperture where it was scaled towards the size of the attended to, non-target object. Although effort was made to ensure relevant features of Castiello's study were replicated here, the same interference pattern was not found, despite consistencies in other kinematic measures.

When examining the effect of binocular vision on prehensile kinematics while directing covert attention away from the target object, null effects were found. Previous literature examining prehension guided by binocular, monocular and reduced stereopsis viewing conditions determined that consistent kinematic changes to prehension are produced. The majority of these expected results were not found in the current study. One reason to explain this difference may be the fact that the target objects in this study were familiar objects of a familiar size, and previous literature has demonstrated that familiar objects are able to assist in accurate prehension even under scenarios where binocular cues are removed. Further studies would be required to determine the role of attention in patients with reduced binocularity, and these studies should ensure the use of targets of unknown size.

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APPENDIX A



**Health Sciences Research Ethics Board  
Letter of Approval**

March 04, 2015

Ms Mallory Coughlin  
Science\Clinical Vision Science

Dear Mallory,

**REB #:** 2015-3476

**Project Title:** Interference in Grasping is Produced When Covert Attention is Directed to a Second Target

**Effective Date:** March 04, 2015

**Expiry Date:** March 04, 2016

The Health Sciences Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,



Dr. Brenda Beagan, Chair

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Post REB Approval: On-going Responsibilities of Researchers

After receiving ethical approval for the conduct of research involving humans, there are several ongoing responsibilities that researchers must meet to remain in compliance with University and Tri-Council policies.

1. Additional Research Ethics approval

Prior to conducting any research, researchers must ensure that all required research ethics approvals are secured (in addition to this one). This includes, but is not limited to, securing

appropriate research ethics approvals from: other institutions with whom the PI is affiliated; the research institutions of research team members; the institution at which participants may be recruited or from which data may be collected; organizations or groups (e.g. school boards, Aboriginal communities, correctional services, long-term care facilities, service agencies and community groups) and from any other responsible review body or bodies at the research site.

## 2. Reporting adverse events

Any significant adverse events experienced by research participants must be reported **in writing** to Research Ethics **within 24 hours** of their occurrence. Examples of what might be considered “significant” include: an emotional breakdown of a participant during an interview, a negative physical reaction by a participant (e.g. fainting, nausea, unexpected pain, allergic reaction), report by a participant of some sort of negative repercussion from their participation (e.g. reaction of spouse or employer) or complaint by a participant with respect to their participation. The above list is indicative but not all-inclusive. The written report must include details of the adverse event and actions taken by the researcher in response to the incident.

## 3. Seeking approval for protocol / consent form changes

Prior to implementing any changes to your research plan, whether to the protocol or consent form, researchers must submit them to the Research Ethics Board for review and approval. This is done by completing a Request for Ethics Approval of Amendment to an Approved Project form (available on the website) and submitting three copies of the form and any documents related to the change. Please note that no reviews are conducted in August.

## 4. Submitting annual reports

Ethics approvals are valid for up to 12 months. Prior to the end of the project’s approval deadline, the researcher must complete an Annual Report (available on the website) and return it to Research Ethics for review and approval before the approval end date in order to prevent a lapse of ethics approval for the research. Researchers should note that no research involving humans may be conducted in the absence of a valid ethical approval and that allowing REB approval to lapse is a violation of University policy, inconsistent with the TCPS (article 6.14) and may result in suspension of research and research funding, as required by the funding agency.

## 5. Submitting final reports

When the researcher is confident that no further data collection or analysis will be required, a Final Report (available on the website) must be submitted to Research Ethics. This often happens at the time when a manuscript is submitted for publication or a thesis is submitted for defence. After review and approval of the Final Report, the Research Ethics file will be closed.

## 6. Retaining records in a secure manner

Researchers must ensure that both during and after the research project, data is securely retained and/or disposed of in such a manner as to comply with confidentiality provisions specified in the protocol and consent forms. This may involve destruction of the data, or continued arrangements for secure storage. Casual storage of old data is not acceptable.

It is the Principal Investigator’s responsibility to keep a copy of the REB approval letters. This can be important to demonstrate that research was undertaken with Board approval, which can be a requirement to publish (and is required by the Faculty of Graduate Studies if you are using this research for your thesis).

Please note that the University will securely store your REB project file for 5 years after the study closure date at which point the file records may be permanently destroyed.

#### 7. Current contact information and university affiliation

The Principal Investigator must inform the Research Ethics office of any changes to contact information for the PI (and supervisor, if appropriate), especially the electronic mail address, for the duration of the REB approval. The PI must inform Research Ethics if there is a termination or interruption of his or her affiliation with Dalhousie University.

#### 8. Legal Counsel

The Principal Investigator agrees to comply with all legislative and regulatory requirements that apply to the project. The Principal Investigator agrees to notify the University Legal Counsel office in the event that he or she receives a notice of non-compliance, complaint or other proceeding relating to such requirements.

#### 9. Supervision of students

Faculty must ensure that students conducting research under their supervision are aware of their responsibilities as described above, and have adequate support to conduct their research in a safe and ethical manner.

**APPENDIX B**  
Word of Mouth Participants



**CONSENT FORM**

**Title of Study:** Interference in grasping is produced when covert attention is directed to a second target.

<b>Principal Investigator &amp; Contact Person:</b> Mallory Coughlin M.Sc. Clinical Vision Science candidate Faculty of Health Professions Dalhousie University Email: Mallory.Coughlin@dal.ca	<b>Study Supervisor:</b> Dr. David Westwood Faculty School of Health and Human Performance and Department of Psychology Dalhousie University Telephone: (902) 494-1164 Email: David.Westwood@dal.ca
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**Introduction:**

We invite you to take part in a research study being conducted by Mallory Coughlin who is M.Sc. student in Clinical Vision Science at Dalhousie University. Dr. David Westwood, a Faculty member in the School of Health and Human Performance and department of Psychology, will supervise the study. Your participation in this study is voluntary and you may withdraw from the study at any time. The study is described below. This description includes information about the risks, inconveniences, or discomforts that you might experience during participation in the study. Participating in the study might not benefit you, but we may learn things that could benefit others.

Participation in this study is voluntary and if you have any questions about this study, please do not hesitate to contact Mallory Coughlin, the Principal Investigator.

**Purpose of the Study:**

The purpose of the study is to confirm the findings of a highly cited paper for which future work will be based to better understand the link between movement and attention. The exact purpose of the study will be explained after you have participated in the study.

**Participants in this Study:**

You are eligible to participate in the study if you are a right-handed adult (18 years of age or older), with normal or corrected-to-normal visual acuity and no personal or family history of seizures/epilepsy or any other neurological illness.

**Investigator Conducting the Study:**

The experimental session will be administered by Mallory Coughlin who is a M.Sc. student in Clinical Vision Science in the Faculty of Health Professions, under the supervision of Dr. David Westwood, Professor in the School of Health and Human Performance & Dept. of Psychology, Dalhousie University.

**What you will be asked to do:**

You will be asked to volunteer for a one-time visit of approximately 120 minutes. The study will take place in the Dalplex, room 218C. During your visit you will be asked to sit at a comfortable, adjustable chair in front of a table and complete a consent form, screening form and short vision check. You will then be asked to complete a total of 240 trials of a reaching task. Each trial will consist of picking up a piece of fruit while simultaneously counting the number of light flashes on a second piece of fruit. During the experiment, infrared-emitting diodes (IREDS) will be fixed to the index finger, thumb and wrist of your right hand; these will measure your movement while you pick up the fruit. In addition, you will also have electrodes on either side of your right eye; this will record if and when your eye makes a movement.

**Possible Benefits, Risks and Discomforts:**

The risks of this study are minimal and will include mainly mental fatigue. For the duration of the study you will be sitting, which could lead to some physical discomfort. To minimize this discomfort, there are breaks built into the trials, and you are encouraged to take any additional breaks that you may require. You may not benefit personally from participation in this study, however the information gained will help to better understand how movements and attention are connected.

**Compensation / Expense Reimbursement**

You will receive no compensation or reimbursement for participating in this study.

**Confidentiality & Anonymity**

After completing the informed consent signature page, you will be assigned a unique participant number that will be linked to your data. Your identity will not be revealed when the experimental data is reported. All data from the study will be kept in Dr. Westwood's secure faculty office for 5 years following the publication of the study results. After 5 years, all electronic and physical data will be destroyed. Dr. David Westwood and Mallory Coughlin are the only people who will have access to your data, and you are able to withdraw your data at any point during or after your participation in the study.

**Questions and Contact Information:**

Please keep this letter for your personal records. If you have questions about this study either now, or after you have participated, please contact the principal investigator, Mallory Coughlin  
Email: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

If you know of anyone else who may be interested in participating, please feel free to discuss this project with them and ask them to contact Mallory Coughlin directly for further information.

**Concerns about Your Participation:**

The office of Human Research Ethics Administration at Dalhousie University has reviewed this study; however, the final decision to participate is yours. If you have any difficulties with or wish to express your concern about any aspect of your participation in this study, you can contact Dalhousie University Research Ethics at [ethics@dal.ca](mailto:ethics@dal.ca)

## INFORMED CONSENT SIGNATURE PAGE

**Title of Study:** Interference in grasping is produced when covert attention is directed to a second target.

I have read the information consent letter and meet the requirements for participation as outlined on the screening form for this study. I agree to participate in this study being conducted by Mallory Coughlin, a M.Sc. student in Clinical Vision Science at Dalhousie University. I have had the opportunity to ask any additional questions understand that I may withdraw my consent at anytime and without penalty, by contacting the principal investigator

I understand that this study has received ethics review though the office of Human Research Ethics Administration at Dalhousie University. If I have any concerns or comments as a result of my participation in this study I may contact [ethics@dal.ca](mailto:ethics@dal.ca).

I agree to participate in this study.

Participant Name (please print)	Participant Signature	Date:
Researcher Name (please print)	Researcher Signature	Date:

**Participant Code:** \_\_\_\_\_

**Participant Date of Birth:** \_\_\_\_\_

**Participant sex:** \_\_\_\_\_



Psychology Subject Pool Participants



**CONSENT FORM**

**Title of Study:** Interference in grasping is produced when covert attention is directed to a second target.

<b>Principal Investigator &amp; Contact Person:</b> Mallory Coughlin M.Sc. Clinical Vision Science candidate Faculty of Health Professions Dalhousie University Email: Mallory.Coughlin@dal.ca	<b>Study Supervisor:</b> Dr. David Westwood Faculty School of Health and Human Performance and Department of Psychology Dalhousie University Telephone: (902) 494-1164 Email: David.Westwood@dal.ca
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**Introduction:**

We invite you to take part in a research study being conducted by Mallory Coughlin who is M.Sc. student in Clinical Vision Science at Dalhousie University. Dr. David Westwood, a Faculty member in the School of Health and Human Performance and department of Psychology, will supervise the study. Your participation in this study is voluntary and you may withdraw from the study at any time. The study is described below. This description includes information about the risks, inconveniences, or discomforts that you might experience during participation in the study. Participating in the study might not benefit you, but we may learn things that could benefit others.

Participation in this study is voluntary and if you have any questions about this study, please do not hesitate to contact Mallory Coughlin, the Principal Investigator.

**Purpose of the Study:**

The purpose of the study is to confirm the findings of a highly cited paper for which future work will be based to better understand the link between movement and attention. The exact purpose of the study will be explained after you have participated in the study.

**Participants in this Study:**

You are eligible to participate in the study if you are a right-handed adult (18 years of age or older), with normal or corrected-to-normal visual acuity and no personal or family history of seizures/epilepsy or any other neurological illness.

**Investigator Conducting the Study:**

The experimental session will be administered by Mallory Coughlin who is a M.Sc. student in Clinical Vision Science in the Faculty of Health Professions, under the supervision of Dr. David Westwood, Professor in the School of Health and Human Performance & Dept. of Psychology, Dalhousie University.

**What you will be asked to do:**

You will be asked to volunteer for a one-time visit of approximately 120 minutes. The study will take place in the Dalplex, room 218C. During your visit you will be asked to sit at a comfortable, adjustable chair in front of a table and complete a consent form, screening form and short vision check. You will then be asked to complete a total of 240 trials of a reaching task. Each trial will consist of picking up a piece of fruit while simultaneously counting the number of light flashes on a second piece of fruit. During the experiment, infrared emitting diodes (IREDs) will be fixed to the index finger, thumb and wrist of your right hand; these will measure your movement while you pick up the fruit. In addition, you will also have electrodes on either side of your right eye; this will record if and when your eye makes a movement.

**Possible Benefits, Risks and Discomforts:**

The risks of this study are minimal and will include mainly mental fatigue. For the duration of the study you will be sitting, which could lead to some physical discomfort. To minimize this discomfort, there are breaks built into the trials, and you are encouraged to take any additional breaks that you may require. You may not benefit personally from participation in this study, however the information gained will help to better understand how movements and attention are connected.

**Compensation / Expense Reimbursement**

You will obtain 2 course credit points for your participation in this study that is expected to take approximately 2 hours.

**Confidentiality & Anonymity**

After completing the informed consent signature page, you will be assigned a unique participant number that will be linked to your data. Your identity will not be revealed when the experimental data is reported. All data from the study will be kept in Dr. Westwood's secure faculty office for 5 years following the publication of the study results. After 5 years, all electronic and physical data will be destroyed. Dr. David Westwood and Mallory Coughlin are the only people who will have access to your data, and you are able to withdraw your data at any point during or after your participation in the study.

**Questions and Contact Information:**

Please keep this letter for your personal records. If you have questions about this study either now, or after you have participated, please contact the principal investigator, Mallory Coughlin  
Email: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

If you know of anyone else who may be interested in participating, please feel free to discuss this project with them and ask them to contact Mallory Coughlin directly for further information.

**Concerns about Your Participation:**

The office of Human Research Ethics Administration at Dalhousie University has reviewed this study; however, the final decision to participate is yours. If you have any difficulties with or wish to express your concern about any aspect of your participation in this study, you can contact Dalhousie University Research Ethics at [ethics@dal.ca](mailto:ethics@dal.ca)

# SIGNATURE PAGE



**Study Title:** Interference in grasping is produced when covert attention is directed to a second target.

**Name of Principal Investigator:** Mallory Coughlin

**Research Supervisor:** Dr. David Westwood

**Telephone:** (902) 225-6150

**Email:** Mallory.Coughlin@dal.ca

### Psychology Department Subject Pool Policy

Individuals with specific ethical concerns should contact either the Research Supervisor or a member of the Human Research Participants & Ethics Committee of the Department of Psychology, Tel: 494.1580, email [psych.ethics@dal.ca](mailto:psych.ethics@dal.ca).

Please sign below to confirm that you have had your questions answered to your satisfaction, that you are aware that all records are entirely confidential and that you may discontinue participation at any point in the study.

**If you anticipate receiving educational credit points for assisting in this research, you may choose to do so as either a Research Participant or as an Observer.**

**If you choose to be a Research Participant, the researcher will keep your data and use it in the research project.**

**If you choose to be an Observer, the researcher will destroy any data that you may have provided, after you complete the study.**

**Please check one box below to indicate whether you choose to be a Research Participant or an Observer.**

**Research Participant  
(Use my data)**

**Observer  
(Destroy my data)**

Participant's Signature:

Date:

Principal Investigator's Signature:

Date:

## APPENDIX C



**Title of Study:** Interference in grasping is produced when covert attention is directed to a second target.

### PARTICIPANT SCREENING FORM

If the answer to any of these questions is “YES”, you are not eligible to participate in this study. It is not necessary to disclose which of the questions or conditions applies to you.

- Please inform the investigator you are unable to participate.
- If you have any questions regarding the question or any of the conditions listed below, please ask the investigator.

- 1. Have you ever had a seizure or been diagnosed with epilepsy/epilepsy syndrome?**
- 2. Has anyone in your family (parents, siblings, aunts/uncles, grandparents) ever had a seizure or been diagnosed with epilepsy/epilepsy syndrome?**

Possible examples may include (but are not limited to):

- Hypothalamic Hamartoma
- Infantile Spasms/West’s Syndrome
- Juvenile Myoclonic Epilepsy
- Progressive Myoclonic Epilepsies
- Dravet Syndrome
- Reflex Epilepsies

- 3. Have you ever been diagnosed with any neurological disease/illness that has affected your ability to perform co-ordinated eye movements, visual and cognitive processing skills, head and neck movements while seated, or upper limb fine motor skills?**

Possible examples may include (but are not limited to):

- Acquired Brain Injury as a result of: Trauma, Cerebral palsy, Encephalitis, Hydrocephalus, Meningitis, Stroke, Tumour, etc.
- Developmental Coordinator Disorder
- Movement Challenges such as: athetosis, chorea, dystonia, spasticity, rigidity, etc.
- Peripheral neuropathy
- Vestibular disorder
- Progressive conditions such as: Amyotrophic Lateral Sclerosis (ALS), Huntington’s, Multiple sclerosis, Parkinson’s disease, etc.

- 4. Are you left-handed?**

In addition to answering these questions, your near visual acuity will be assessed by a certified orthoptist, to ensure that it is normal or corrected to normal.

## APPENDIX D



### SUBJECT DEBRIEFING FORM

**Title of Study:** Interference in grasping is produced when covert attention is directed to a second target.

**Principal Investigator:**

Mallory Coughlin

E-mail: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

Thank you for your participation in this research study. The study is being conducted so that we can learn more about how attention can influence movements in healthy individuals.

This study is a replication of a past study conducted by Castiello in 1996. In his original study, participants would have completed trials very similar to the ones that you just completed. He also had participants reach and grasp a piece of fruit (while maintaining their gaze on the fruit); at the same time, his participants were to count the number of light flashes on a second piece of fruit. The main kinematic outcome where he found an effect was peak grip aperture, which is the maximum distance achieved between the thumb and index finger during the grasp of the central fruit. His study revealed that participants' peak grip aperture for the central fruit was scaled towards the size of the second fruit when they were required to count the number of light flashes on the second piece of fruit. He hypothesized that this occurred because attention allowed the motor pattern for each fruit to be processed, even though there was no intention to act on the second piece of fruit. Castiello's (1996) finding has been highly cited in work relating vision, attention and prehension (grasping); though to our knowledge has not been replicated to date.

Research is unclear regarding how the visual system, attention and movements are connected. Research by Castiello (1996) and Sandoval & McIntosh (2014) suggest that motor patterns are automatically produced when an object is attended to. On the other hand, Cisek (2007) suggests that visual information processing alone is enough to produce motor patterns, and that attention is required to enhance or inhibit them. From this it is clear that further research is required to decipher the mechanisms at work and the link between the visual system, attention and how movements are produced. Before extending the findings from these studies to try to answer these questions, we feel it is important to first replicate the findings to ensure a strong basis of knowledge to work from. Knowledge from this line of work could potentially be applied to those with ADAH or to better understand distracted driving.

If you have any questions or comments about this experiment, please feel free to communicate them with us. Thank you again for your participation!

Mallory Coughlin  
Dalhousie University

References:

Castiello, U. (1996). Grasping a fruit: Selection for action. *Journal of Experimental Psychology: Human Perception and Performance*, 22, 582-603.

Cisek, P. (2007). Cortical mechanisms of action selection: The affordance competition hypothesis. *Philosophical Transactions of the Royal Society B*, 362, 1585-1599.

Sandoval Simila, S., & McIntosh, R.D. Look where you're going! Perceptual attention constrains the online guidance of action. *Vision Research* (2014), [Http://dx.doi.org/10.1016/j.visres.2014.06.002](http://dx.doi.org/10.1016/j.visres.2014.06.002)

APPENDIX E



**Health Sciences Research Ethics Board  
Letter of Approval**

February 11, 2016

Ms Mallory Coughlin  
Science\Clinical Vision Science

Dear Mallory,

**REB #:** 2016-3757

**Project Title:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

**Effective Date:** February 11, 2016

**Expiry Date:** February 11, 2017

The Health Sciences Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,



Dr. Brenda Beagan, Chair

**APPENDIX F**  
Word of Mouth Participants



**CONSENT FORM**

**Title of Study:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

<b>Principal Investigator &amp; Contact Person:</b> Mallory Coughlin M.Sc. Clinical Vision Science candidate Faculty of Health Professions Dalhousie University Email: Mallory.Coughlin@dal.ca	<b>Study Supervisor:</b> Dr. David Westwood Faculty School of Health and Human Performance and Department of Psychology Dalhousie University Telephone: (902) 494-1164 Email: David.Westwood@dal.ca
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**Introduction:**

We invite you to take part in a research study being conducted by Mallory Coughlin who is M.Sc. student in Clinical Vision Science at Dalhousie University. Dr. David Westwood, a Faculty member in the School of Health and Human Performance and department of Psychology, will supervise the study. Your participation in this study is voluntary and you may withdraw from the study at any time. The study is described below. This description includes information about the risks, inconveniences, or discomforts that you might experience during participation in the study. Participating in the study might not benefit you, but we may learn things that could benefit others.

Participation in this study is voluntary and if you have any questions about this study, please do not hesitate to contact Mallory Coughlin, the Principal Investigator.

**Purpose of the Study:**

The purpose of the study is to investigate the effects of reducing depth perception on grasping movements, and the role that attention plays under these circumstances. The exact purpose of the study will be explained after you have participated in the study.

**Participants in this Study:**

You are eligible to participate in the study if you are a right-handed adult (18 years of age or older), with normal or corrected-to-normal visual acuity, stereoacuity (depth perception) and no personal or family history of seizures/epilepsy or any other neurological illness.

**Investigator Conducting the Study:**

The experimental session will be administered by Mallory Coughlin who is a M.Sc. student in Clinical Vision Science in the Faculty of Health Professions, under the supervision of Dr. David Westwood, Professor in the School of Health and Human Performance & Dept. of Psychology, Dalhousie University.



**What you will be asked to do:**

You will be asked to volunteer for a one-time visit of approximately 90 minutes. The study will take place in the Dalplex, room 218C. During your visit you will be asked to sit at a comfortable, adjustable chair in front of a table and complete a consent form, screening form and short vision check. You will then be asked to complete a total of 216 trials of a reaching task. Each trial will consist of picking up a piece of fruit while simultaneously counting the number of light flashes on a second piece of fruit. The vision of your non-dominant eye will be occluded on some trials with a patch, and will be blurred on other trials with a bangerter foil. During the experiment, infrared-emitting diodes (IREDS) will be fixed to the index finger, thumb and wrist of your right hand; these will measure your movement while you pick up the fruit. In addition, you will also have electrodes on either side of your right eye; this will record if and when your eye makes a movement.

**Possible Benefits, Risks and Discomforts:**

The risks of this study are minimal and will include mainly mental fatigue. For the duration of the study you will be sitting, which could lead to some physical discomfort. To minimize this discomfort, there are breaks built into the trials, and you are encouraged to take any additional breaks that you may require. You may not benefit personally from participation in this study, however the information gained will help to better understand how movements and attention are connected.

**Compensation / Expense Reimbursement**

You will receive no compensation or reimbursement for participating in this study.

**Confidentiality & Anonymity**

After completing the informed consent signature page, you will be assigned a unique participant number that will be linked to your data. Your identity will not be revealed when the experimental data is reported. All data from the study will be kept in Dr. Westwood's secure faculty office for 5 years following the publication of the study results. After 5 years, all electronic and physical data will be destroyed. Dr. David Westwood and Mallory Coughlin are the only people who will have access to your data, and you are able to withdraw your data during or after your participation in the study but not after any reports of the results have been published.

**Questions and Contact Information:**

Please keep this letter for your personal records. If you have questions about this study either now, or after you have participated, please contact the principal investigator, Mallory Coughlin Email: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

If you know of anyone else who may be interested in participating, please feel free to discuss this project with him or her and have them contact Mallory Coughlin directly for further information.

**Concerns about Your Participation:**

The office of Human Research Ethics Administration at Dalhousie University has reviewed this study; however, the final decision to participate is yours. If you have any difficulties with or wish to express your concern about any aspect of your participation in this study, you can contact Dalhousie University Research Ethics at [ethics@dal.ca](mailto:ethics@dal.ca).

**INFORMED CONSENT SIGNATURE PAGE**

**Title of Study:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

I have read the information consent letter and meet the requirements for participation as outlined on the screening form for this study. I agree to participate in this study being conducted by Mallory Coughlin, a M.Sc. student in Clinical Vision Science at Dalhousie University. I have had the opportunity to ask any additional questions understand that I may withdraw my consent at anytime and without penalty, by contacting the principal investigator

I understand that this study has received ethics review though the office of Human Research Ethics Administration at Dalhousie University. If I have any concerns or comments as a result of my participation in this study I may contact ethics@dal.ca.

I agree to participate in this study.

Participant Name (please print)	Participant Signature	Date:
Researcher Name (please print)	Researcher Signature	Date:

**Participant Code:** \_\_\_\_\_

**Participant Date of Birth:** \_\_\_\_\_

**Participant sex:** \_\_\_\_\_

**CONSENT FORM**

**Title of Study:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

<b>Principal Investigator &amp; Contact Person:</b> Mallory Coughlin M.Sc. Clinical Vision Science candidate Faculty of Health Professions Dalhousie University Email: Mallory.Coughlin@dal.ca	<b>Study Supervisor:</b> Dr. David Westwood Faculty School of Health and Human Performance and Department of Psychology Dalhousie University Telephone: (902) 494-1164 Email: David.Westwood@dal.ca
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**Introduction:**

We invite you to take part in a research study being conducted by Mallory Coughlin who is M.Sc. student in Clinical Vision Science at Dalhousie University. Dr. David Westwood, a Faculty member in the School of Health and Human Performance and department of Psychology, will supervise the study. Your participation in this study is voluntary and you may withdraw from the study at any time. The study is described below. This description includes information about the risks, inconveniences, or discomforts that you might experience during participation in the study. Participating in the study might not benefit you, but we may learn things that could benefit others.

Participation in this study is voluntary and if you have any questions about this study, please do not hesitate to contact Mallory Coughlin, the Principal Investigator.

**Purpose of the Study:**

The purpose of the study is to investigate the effects of reducing depth perception on grasping movements, and the role that attention plays under these circumstances. The exact purpose of the study will be explained after you have participated in the study.

**Participants in this Study:**

You are eligible to participate in the study if you are a right-handed adult (18 years of age or older), with normal or corrected-to-normal visual acuity, stereoacuity (depth perception) and no personal or family history of seizures/epilepsy or any other neurological illness.

**Investigator Conducting the Study:**

The experimental session will be administered by Mallory Coughlin who is a M.Sc. student in Clinical Vision Science in the Faculty of Health Professions, under the supervision of Dr. David Westwood, Professor in the School of Health and Human Performance & Dept. of Psychology, Dalhousie University.

**What you will be asked to do:**

You will be asked to volunteer for a one-time visit of approximately 90 minutes. The study will take place in the Dalplex, room 218C. During your visit you will be asked to sit at a comfortable, adjustable chair in front of a table and complete a consent form, screening form and short vision check. You will then be asked to complete a total of 216 trials of a reaching task. Each trial will consist of picking up a piece of fruit while simultaneously counting the number of light flashes on a second piece of fruit. The vision of your non-dominant eye will be occluded on some trials with a patch, and will be blurred on other trials with a bangerter foil. During the experiment, infrared-emitting diodes (IREDS) will be fixed to the index finger, thumb and wrist of your right hand; these will measure your movement while you pick up the fruit. In addition, you will also have electrodes on either side of your right eye; this will record if and when your eye makes a movement.

**Possible Benefits, Risks and Discomforts:**

The risks of this study are minimal and will include mainly mental fatigue. For the duration of the study you will be sitting, which could lead to some physical discomfort. To minimize this discomfort, there are breaks built into the trials, and you are encouraged to take any additional breaks that you may require. You may not benefit personally from participation in this study, however the information gained will help to better understand how movements and attention are connected.

**Compensation / Expense Reimbursement**

You will obtain 1.5 course credit points for your participation in this study that is expected to take approximately 1.5 hours.

**Confidentiality & Anonymity**

After completing the informed consent signature page, you will be assigned a unique participant number that will be linked to your data. Your identity will not be revealed when the experimental data is reported. All data from the study will be kept in Dr. Westwood's secure faculty office for 5 years following the publication of the study results. After 5 years, all electronic and physical data will be destroyed. Dr. David Westwood and Mallory Coughlin are the only people who will have access to your data, and you are able to withdraw your data during or after your participation in the study but not after any reports of the results have been published.

**Questions and Contact Information:**

Please keep this letter for your personal records. If you have questions about this study either now, or after you have participated, please contact the principal investigator, Mallory Coughlin Email: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

If you know of anyone else who may be interested in participating, please feel free to discuss this project with them and ask them to contact Mallory Coughlin directly for further information.

**Concerns about Your Participation:**

The office of Human Research Ethics Administration at Dalhousie University has reviewed this study; however, the final decision to participate is yours. If you have any difficulties with or wish to express your concern about any aspect of your participation in this study, you can contact Dalhousie University Research Ethics at [ethics@dal.ca](mailto:ethics@dal.ca)

## SIGNATURE PAGE



**Study Title:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

**Name of Principal Investigator:** Mallory Coughlin

**Research Supervisor:** Dr. David Westwood

**Telephone:** (902) 225-6150

**Email:** Mallory.Coughlin@dal.ca

### **Psychology Department Subject Pool Policy**

Individuals with specific ethical concerns should contact either the Research Supervisor or a member of the Human Research Participants & Ethics Committee of the Department of Psychology, Tel: 494.1580, email psych.ethics@dal.ca.

Please sign below to confirm that you have had your questions answered to your satisfaction, that you are aware that all records are entirely confidential and that you may discontinue participation at any point in the study.

**If you anticipate receiving educational credit points for assisting in this research, you may choose to do so as either a Research Participant or as an Observer.**

**If you choose to be a Research Participant, the researcher will keep your data and use it in the research project.**

**If you choose to be an Observer, the researcher will destroy any data that you may have provided, after you complete the study.**

**Please check one box below to indicate whether you choose to be a Research Participant or an Observer.**

**Research Participant**  
(Use my data)

**Observer**  
(Destroy my data)

Participant's Signature:

Date:

Principal Investigator's Signature:

Date:

**Participant Code:** \_\_\_\_\_

**Participant Date of Birth:** \_\_\_\_\_

**Participant sex:** \_\_\_\_\_

APPENDIX G



**Title of Study:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

**PARTICIPANT SCREENING FORM**

If the answer to any of these questions is “YES”, you are not eligible to participate in this study.

It is not necessary to disclose which of the questions or conditions applies to you.

- Please inform the investigator you are unable to participate.
- If you have any questions regarding the question or any of the conditions listed below, please ask the investigator.

- 5. Have you ever had a seizure or been diagnosed with epilepsy/epilepsy syndrome?**
- 6. Does anyone in your family (parents, siblings, aunts/uncles, grandparents) have a known history of having a seizure or been diagnosed with epilepsy/epilepsy syndrome?**
- 7. Have you ever been diagnosed with any neurological disease/illness that has affected your ability to perform co-ordinated eye movements, visual and cognitive processing skills, head and neck movements while seated, or upper limb fine motor skills?**
- 8. Are you left-handed?**

In addition to answering these questions, your near visual acuity and stereoacuity will be assessed by a certified orthoptist, to ensure that it is normal or corrected to normal.

Visual Acuity:

OD	
OS	

Stereoacuity:

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## APPENDIX H



### SUBJECT DEBRIEFING FORM

**Title of Study:** Is interference in grasping produced when covert attention is directed to a non-target object under monocular or reduced stereopsis viewing conditions?

**Principal Investigator:**

Mallory Coughlin

E-mail: [Mallory.Coughlin@dal.ca](mailto:Mallory.Coughlin@dal.ca)

Thank you for your participation in this research study. The study is being conducted so that we can learn more about how attention can influence movements in individuals when stereopsis is reduced or removed.

In 1996 Castiello performed a study where participants completed trials very similar to the ones you have just completed. He also had participants reach and grasp a piece of fruit (while maintaining their gaze on the fruit); at the same time, his participants were to count the number of light flashes on a second piece of fruit. The major difference was that participants in his study did not have their vision manipulated as you did. His study revealed that participants' peak grip aperture for the central fruit was scaled towards the size of the second fruit when they were required to count the number of light flashes on the second piece of fruit. Recently, we have attempted to replicate his findings; however we were unsuccessful in reproducing the effect he found. We now feel it is plausible that a similar effect may be found when stereopsis (depth perception) is removed or degraded. It has previously been shown that grasping movements are affected when performed monocularly (Jackson et al., 1997; Bradshaw et al., 2004; Piano & O'Connor, 2013). In addition, it has been demonstrated that under monocular viewing conditions participants use the whole scene to determine size and depth information (Marotta et al., 1998). For this reason, we feel it reasonable to predict that non-target objects will influence grasping kinematics under monocular conditions more than binocular conditions, and that when attention is directed towards non-target objects, this effect will be amplified. Knowledge from this line of work could potentially be applied to those with ADHD, or visual abnormalities such as amblyopia or strabismus.

If you have any questions or comments about this experiment, please feel free to communicate them with us. Thank you again for your participation!

Mallory Coughlin  
Dalhousie University

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- Jackson, S. R., Jones, C. A., Newport, R., & Pritchard, C. (1997). A kinematic analysis of goal-directed prehension movements executed under binocular, monocular, and memory-guided viewing conditions. *Visual Cognition, 4*(2), 113-142.
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