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The Effect of Dividing Attention on the Maintenance of Object Representations

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THE EFFECT OF DIVIDING ATTENTION ON THE MAINTENANCE OF
OBJECT REPRESENTATIONS

by

Jillian C. Mayer

B.S., University of Illinois - Champaign/Urbana, 2007

A Thesis

Submitted in Partial Fulfillment of the Requirements for the
Master of Arts

Department of Psychology
in the Graduate School
Southern Illinois University Carbondale
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THESIS APPROVAL

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A Thesis Submitted in Partial
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for the Degree of
Master of Arts
in the field of Psychology

Approved by:

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AN ABSTRACT OF THE THESIS OF

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TITLE: THE EFFECT OF DIVIDING ATTENTION ON THE MAINTENANCE OF OBJECT REPRESENTATIONS

MAJOR PROFESSOR: Dr. Matthew Schlesinger

Numerous theories have been developed in explanation of object perception, such as Feature Integration Theory, which posits that an object is perceived after two stages: a pre-attentive stage and a focused attention stage. It is during the focused attention stage that a representation of the perceived object is formed. Theories such as object file theory account for the maintenance of these object representations following their creation. Evidence for object file theory has been provided by studies of the object specific preview benefit. This thesis seeks to examine the effect that dividing attention has on the maintenance of object representations via the object specific preview benefit. Using the tenets of object file theory and the cortical field hypothesis for dual task interference, it is hypothesized that by presenting participants with two simultaneous tasks which make use of overlapping cortical areas the object representation initially formed will be lost resulting in the loss of the object specific preview benefit. Whereas presenting participants with two simultaneous tasks which are associated with spatially separate, or non-overlapping, cortical regions will not result in the loss of the object specific preview benefit.

DEDICATION

I dedicate this research project to the memory of my father.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION

Imagine it is your first and only night in New York City. Your plane landed several hours ago for a conference. A review of the schedule reveals that you won't have much time for exploring the sights of the city later. Thus, you decide to head out and hit the sidewalks despite the late hour as it appears that there won't be much time for it later. As you walk down Broadway something captures your attention, out of the corner of your eye. Could it be that old friend from high school you haven't seen in years? Before you get the chance to look more closely; the person moves behind another. You are extremely curious so you begin to focus on the area where your potential friend disappeared. You move your eyes to where you think you'll see him emerge from the crowd and sure enough you recognize your friend as he comes back into view. You quickly call out his name and approach him in order to catch up with an old acquaintance.

There are numerous difficulties apparent in the previous sidewalk scene. Several of these are of central relevance to this thesis. Firstly, the movement of your friend makes the process of perceiving and recognizing your friend markedly different from a similar situation where movement is removed; for example, recognizing his face in a high school yearbook. Similarly, the presence of occlusion in the situation makes the perceptual and recognition processes even more difficult. Specifically, the existence of occluding surfaces such as other people, signs, and lampposts necessitates the movement of your eyes to watch for the emergence of your friend in a new area. Finally, the need for you to

attend to your surroundings and focus on the relevant areas of space plays a role in the successful recognition of your friend. If your attention had been directed elsewhere, such as on a map of the city, you might never have noticed your friend to begin with.

The various components of the recognition task outlined before can be broken down into different psychological mechanisms which have been studied in the laboratory. The following literature review presents a summary of the relevant experimental findings which offer explanation for the various phenomena present in the sidewalk scenario just introduced. It first reviews several of the prevalent theories in the field of object perception as well as introduces a working definition of “object” using Feature Integration Theory, one of the prevalent theories of object perception. A summary and analysis of Feature Integration Theory as well as Object File Theory are presented. The findings concerning the object specific preview benefit, which has been used as evidence for both theories, is presented. Finally, the role that attentional factors play in object representation maintenance is explored by analyzing relevant empirical findings, including neuropsychological research.

Following the discussion of the role of attention in object representation formation and maintenance in the literature review, the idea of differential dual task interference based on secondary task type will be introduced. In this discussion, the results of a pilot study will be presented. Finally, the present study which was designed with the primary aim of examining the effects of

secondary task type on dual task performance and the maintenance of object representations will be introduced.

CHAPTER 2

LITERATURE REVIEW

A selection of psychological research has focused on the ability of human beings to perceive objects. Today research is still being undertaken in an effort to offer a more complete explanation for the mechanisms underlying accurate object perception. Numerous theories of object perception have been introduced and evolved as the study of object perception has progressed. Four types of theories will be introduced and briefly summarized in this work: Pandemonium Theory, Template-Based Theory, Recognition-by-Components Theory, and Feature Integration Theory.

Before discussing the prevalent theories of object perception it is necessary to introduce several definitions of common terminology and highlight some distinctions found within the object perception literature. These discriminations are useful in establishing exactly what object perception theories are attempting to explain and how they attempt to do it. Perhaps the first definition necessary is that of an object.

Numerous definitions of what an object is have been proposed. Many researchers do not explicitly specify what is meant by the term “object” in their publications. Indeed, this question is often answered implicitly by the stimuli used in the experimental design or theoretical implications. For example, in research on Feature Integration Theory, it is posited that objects are defined by separate colors, orientations, and directions of movement which are bound together during

the focused attention stage of Feature Integration Theory, which will be discussed in greater detail at a later point in this thesis (Treisman, 2006).

However, several psychologists have worked to provide a more clear and precise definition of objects and object perception. Xu (1999), for example, posits that object perception is the automatic parsing of the visual field into regions which appear to belong to discrete objects. The process of object individuation, or the mechanism by which the regions are separated into discrete objects, involves the integration of three types of information: spatiotemporal, object property, and object kind.

According to Xu (1999), the integration of these three distinct categories of information enables humans to perceive distinct objects in their visual fields. The first class mentioned, spatiotemporal information, organizes the visual field in such a way that objects are those spatial areas which move on spatiotemporally continuous paths as well as regions that move as wholes.

The second type of information necessary is object property information. This category of information is used to distinguish regions of the visual field as objects according to their features, such as color, shape, size, and texture. Similarly, the third type of categorization, object kind simply refers to the information available which indicates the specific class to which an object belongs.

For this thesis, the term “object” from this point forward will be operationally defined as a group of bundled features (visual characteristics such as size, color, and shape) which share certain properties. There are multiple

properties which may be shared. One property of immediate concern, which was introduced previously, is spatiotemporality. In review, spatiotemporality refers to the continuity of a group of bundled features in space and time. For example, a group of objects moving together through time and space would share this property. This is illustrated in the viewing of a plane as a single object, instead of seeing the wing as separate from the cabin. It is because the wings and cabin are moving together across the sky at the same time that the plane is seen as a single object, not a collection of parts. Alternatively, if two objects follow the same path but do so at different times, the objects are not seen as sharing the property of spatiotemporality. In other words, objects must share both properties of space and time in order to be spatiotemporally congruent. There are additional properties, such as non-visual properties (e.g., sound) which will not be discussed as they are not directly relevant to the proposed study.

An additional distinction which is directly relevant to the current discussion is that between object recognition and object identification. Object recognition and object identification are both components of object perception. However, each of these terms has its own distinct meaning. Object recognition has been defined as the process of experiencing something previously encountered (Mandler, 1980); for example, recognizing your friend's face in the introductory sketch. In order for recognition to occur an object must have been viewed before. Alternatively, object identification is the process which involves taking recognition one step further. Object identification involves naming an object, classifying it into a category, knowing its relationship to other concepts and objects, and other

similar processes (Mandler, 1980). An example of object identification from the introduction is the experience of knowing your friend's name.

The terms bottom-up and top-down processing are also used in characterizing the psychological processing underlying object perception theories. Bottom-up processing, also referred to as data-driven processing, refers to mechanisms which occur with the perception of sensory stimuli. These mechanisms operate according to a fixed set of rules. In visual data-driven processing, distinctive features such as contours, edges, and color changes are extracted (Cohen, 1958). Thus, in this type of process the sensory information drives the processing. For example, while walking the sidewalks of New York, you notice a bright red car driving past because the salient object [the car] stood out from the surrounding visual field due to its properties, not due to your knowledge of cars.

However, your ability to seek out your friend from the crowd due to your understanding of occluding surfaces is explained by another type of processing. Top-down processing is conceptually driven or based upon a person's knowledge. Thus, higher level conceptual procedures guide the perceptual processing. Examples of these higher level processes include memories of past experiences, such as the ability to recognize an animal after it has been encountered previously (Goldstein, 2008). Referring back to the previous example, top-down processing allows you to perceive your friend in the right location because of previous experiences you may have had with visual

searches. For example, you know where you need to look because you have knowledge of your friend's height.

By returning to the concept of bottom-up processing, an additional distinction can be made. This is the difference between local features and global aspects. Local features are those elements which are viewed on the small scale. They are those features which are adjacent or share a limited region of space. Local features can be thought of as belonging to a neighborhood. They are the details which compose an object such as the arch of your friend's brow. Global aspects, however, can be thought of as a map in its entirety. They give the entire object or form its' shape such as recognizing your friend's face as a face and being able to read the No Parking Sign, as opposed to seeing each individual letter as standing entirely on its own, not as part of a word.

The final component of object perception which requires definition is context, which was introduced previously with top-down processing. Context is simply the set of circumstances which surround a specific object. As mentioned earlier, the context of a particular instance of perception can influence the way in which an object is perceived. Palmer (1975) eloquently demonstrated the role context plays in object perception in a study which asked participants to identify objects which were presented after either an appropriate or inappropriate context. For example, two participants might see a kitchen scene. Next the participants are each shown different objects. For example, the first participant sees a loaf of bread while the second participant sees a mailbox. Palmer (1975) found that objects were identified with greater speed following presentation of the

appropriate setting [the bread following the kitchen] than in the inappropriate setting [the mailbox following the kitchen]. Thus, it appears that what is seen immediately before the presentation of an object, the context, has an effect on the subsequent recognition and identification. In essence, the context of a situation plays a role in determining object recognition or identification. If the context does not match the object presented, recognition and identification take additional time.

As mentioned previously, many types of theories have been offered in an attempt to explain the processes underlying object perception. One of the first widely recognized theories was Selfridge's (1959) Pandemonium Theory.

Pandemonium (Data-Driven) Theory

Data-driven theories emphasize the role of bottom-up processing in feature extraction, such that it is the object's features which guide perception. Selfridge (1959) was one of the first to propose a theory of this type with his Pandemonium Theory. This specific theory posits that perception of sensory stimuli results from groups of demons, or various stages of analysis which "shout" their results, see Figure 1. For example, in the first stage of analysis, Selfridge held that an image demon passes on the retinal image to a group of feature demons which shout when the feature they are responsible for detecting is present, see Figure 1. Subsequent analysis is performed by cognitive demons, which analyze specific patterns of feature demon activation, and decision demons, which "listen" to the chaos of the shouting demons and select the pattern which best explains the demon activation.

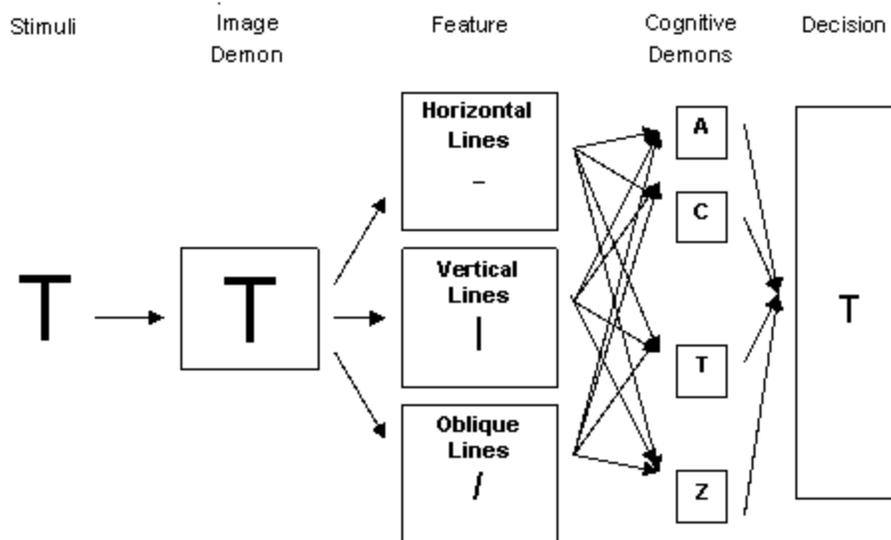


Figure 1. Schematic for the Pandemonium Theory of object perception. The image demon receives the sensory input. The feature demons decode specific features. The cognitive demons integrate the activation of the feature demons. The decision demons integrate the activation of the cognitive demons and reach a decision regarding the identity of the stimulus.

This process can be equated to real world phenomenon in order to aid in its understanding. Picture the chaos present on the trading floor at the New York Stock Exchange. The traders [feature demons] are present and shouting what they are instructed to by their brokerage [image demons]. There are post display units which watch the action [cognitive demons] and report what is occurring to brokers who decide what to do [decision demons].

Evidence for this type of theory has been found in studies of object identification. For example, Keren & Baggen (1981) were able to use Pandemonium theory to explicate the errors that people make when trying to identify letters, such as a greater likelihood of misidentifying letters that share

common features such as “C” and “S” as compared to letters which share no or very few features in common such as “T” and “X”. Similarly, Sanocki (1987) used a theory of this type to explain the between-letter confusions that occur when details of letters such as size and font type are manipulated.

Bottom-up explanations of object perception are able to account for many aspects of object perception. However, some researchers shied away from focusing on specific features, as the Feature demons do in the aforementioned Pandemonium system. This led to the development of model-based theories of object perception, which counter the data-driven emphasis of pandemonium theories with an emphasis on top-down processing.

Model (Template-Based) Theory

Model based theories of object perception refrain from using features exclusively as the data driving object identification. Rather, this type of theory relies on detailed conceptual information regarding objects. This detailed conceptual information is referred to as a model or template. Thus, the structure of an object is obtained through higher level processing of the features.

According to the template matching or model based theory of object perception, an object is only able to be identified when it matches a template or model stored in memory. As evident in Figure 2, model-based theories allow for some but not all shifts in object features. Orientation is one shift not permitted by this theory of object perception. Thus, for each extreme change in orientation or features a new template would be necessary. This would require an astronomical number of templates in order to successfully identify all of the objects in the

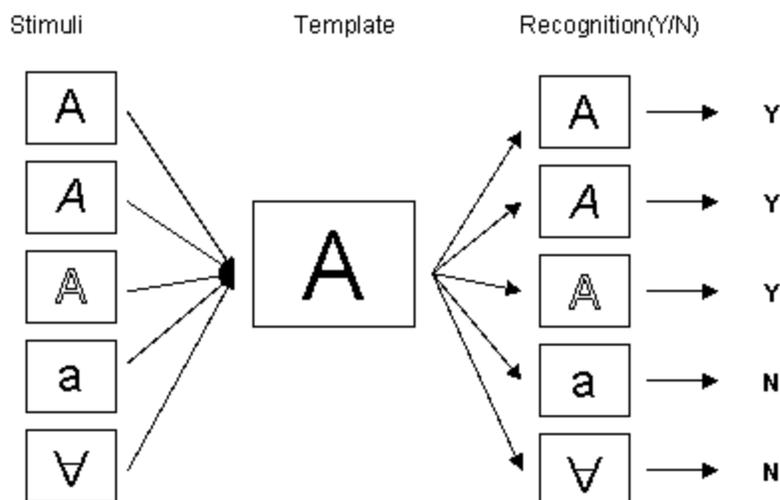


Figure 2. Schematic for the recognition of the letter “A” using a template-matching theory of identification. The incoming stimuli are compared to a model. When the stimuli matches the model, recognition occurs.

visual world (Coven, Ward, & Enns, 1999). While evidence is provided for this type of theory in that it is able to explain some aspects of letter recognition, it has been criticized for its simplistic nature. Despite their inability to account for real world perception, model based theories have been useful in that they have paved the way for creating artificially intelligent machines able to pick up specific objects (Coven, Ward, & Enns, 1999).

Recognition-by-Components Theory

An additional object perception theory was introduced by Irving Biederman in 1987 which emphasized the importance of object features in perception, in the Recognition-by-Components (RBC) theory. This theory emphasizes the importance of three-dimensional features in object perception, as opposed to

two-dimensional features such as lines and curves. Specifically, the theory posits that object perception is the result of the recognition of primitive three-dimensional components, which Biederman termed geons, such as cubes and spheres, see Figure 3.

One important property of geons is their ability to be recognized from different angles which is known as view invariance. While the property of view invariance can also be prescribed to the template-matching theories, the RBC theory is able to account for object perception without relying on an astronomical number of templates. In formulating his theory, Biederman (1987) calculated that a relatively small set of geons [36] could result in the generation of an ample number of objects to account for successful object perception. Evidence was provided for this theory in a series of experiments that measured the time it took to identify objects accurately. In this work, Biederman (1987) found that rapid identification of objects was possible only when important aspects of each component geon were visible to the participants.

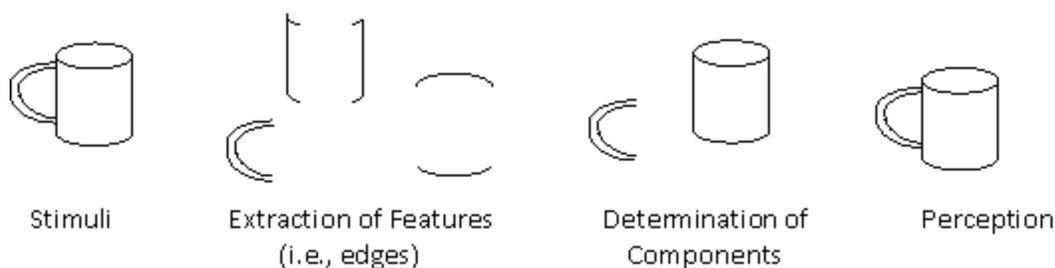


Figure 3. Simplified schematic of objection perception inspired by the RBC theory posited by Biederman (1987). In this theory of object perception, features are first extracted. Following this initial extraction, the components or geons which make up the object are determined. An analysis of the arrangement of these geons leads to perception of the object.

Feature Integration Theory

Like Biederman's RBC theory, Treisman's Feature Integration Theory (FIT) accounts for object perception by relying on feature analysis. The features analyzed according to FIT, however, are two dimensional as opposed to three dimensional. Examples of two dimensional features are lines, curves, and colors. According to FIT, object perception is the result of analysis of the features present with bottom-up followed by top-down processing (Treisman, 1998a, 1998b).

Treisman (1998a) posits that this process of perceiving objects due to feature analysis is composed of two stages, the pre-attentive stage and the focused attention stage, see Figure 4. During the pre-attentive stage the features of an object are analyzed. This is a data-driven stage whereby the sensory stimuli determine the processing. Following this stage, is more context-driven

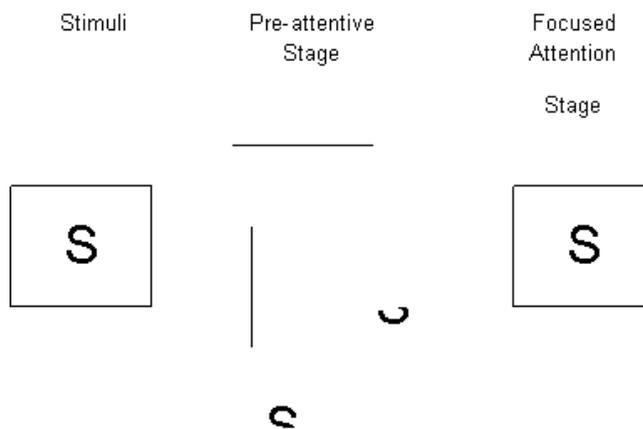


Figure 4. Schematic of object perception according to Feature Integration Theory. When visual stimuli are first encountered the features are extracted during the pre-attentive stage of perception. During this stage the features are free-floating and are not bound together to form the object in its entirety. During the subsequent focused attention stage, the features are organized into a perceivable object.

processing. During the focused attention stage, the features are combined to form a coherent object which is able to be perceived. Thus, it is not until attention has been focused that an object is fully perceived (Treisman, 1986).

The study of illusory conjunctions provides support for the processes posited for each stage in recognition by FIT. An illusory conjunction is a recombination of object features. Treisman and Schmidt (1982) studied this phenomenon by presenting a display that contained two black numbers flanked by four objects to participants for a short period of time. A mask followed the short presentation in order to eliminate any remaining perceptual traces that persist after the stimulus has been removed. Following the mask, participants were asked to report the black numbers as well as the objects at each of the four locations. When reporting the objects, participants demonstrated illusory conjunctions. For example, if two of the objects were a blue square and a red circle, an illusory conjunction which might be reported is a blue circle. The existence of these illusory conjunctions is taken as evidence that early in the perceptual process, the pre-attentive stage, features exist independently of one another.

Treisman (1986, 1998a, 1998b, & 2006) posits that following the pre-attentive stage is the focused attention stage. What happens after this stage of object perception? Specifically after attention is focused upon an object and perception has occurred, is there another process which occurs? The work of Treisman and others suggests that once an object is perceived another process

occurs, the formation of an object file (Kahneman & Treisman, 1984, Treisman, 1992, & Kahneman, Treisman, & Gibbs, 1992).

Object File Theory of Object Representations

According to object file theory, object perception is the process of creating and utilizing temporary perceptual representations of real world objects. These temporary representations are referred to as object files (Kahneman & Treisman, 1984). Thus, once a group of features is perceived as an object, according to Object File Theory, an internal representation for that object is created.

Research concerning object files has been undertaken in the past twenty plus years in order to elucidate the characteristics of object files. One of the principle methods for investigating object file theory is the study of the object specific preview benefit.

The Object Specific Preview Benefit

The object specific preview benefit is the phenomenon whereby a “preview” of characteristics of a specific object speeds recognition of these attributes at a later time. The facilitation is regarded as evidence that an object representation persists despite “gaps” in visual input, in the form of an object file. The facilitation has been found to be due to two processes: perceptual priming and object representation formation/maintenance (Henderson & Anes, 1994).

The first process, priming, involves a speeded reaction in response to stimuli exposed to previously. These speeded reactions are not due to perceptual specificity, the specific information relating to a specific episode of time. For example, the details for presentation such as the time and place of the initial

appearance. Priming has been found to be evident in experimental settings via non-specific preview benefits, which are speeded response times regardless of spatial or spatiotemporal continuity. In the laboratory, the nonspecific preview benefit would present itself as a decreased response time to a target that was seen previously in a different location or at a different time.

Unlike priming, which prepares an individual to provide a later response, object representations provide a temporary, episode-dependent reference for comparison. Thus, even though attention may no longer be focused on an object, information gleaned during the focused attention stage, according to FIT and object file theory, is still available as long as the object representation persists. The object specific preview benefit (OSPB) is simply the experimental phenomenon whereby an object is identified more quickly if it is the same as the object presented initially. Previous research has shown that experimental participants are quicker to make a same rather than different judgment in object recognition tasks (Egeth & Blecker, 1971). The object specific preview benefit coincides with this finding as it is when the object representation is the same as the previously presented stimuli that object specific preview benefits are present. In other words, participants can speedily recognize an object as being the same but it takes more time to recognize that it is a different object as it necessitates the creation of a new object representation.

Initially, the object specific preview benefit was studied using the object reviewing paradigm introduced by Kahneman and Treisman (1984), see Figure 5. In this paradigm, participants initially view a preview display with two boxes,

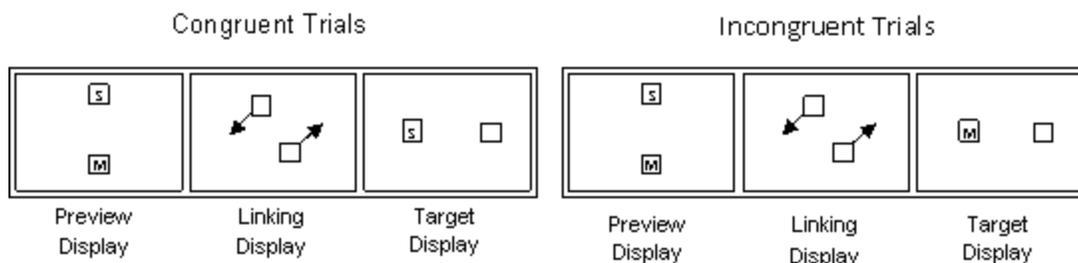


Figure 5. Schematic of object reviewing paradigm.

each of which encases a single target [letter]. Following the preview is the linking display where the targets disappear and the boxes move. During the final stage, the target display, a target appears in one of the boxes (either the same or different than the original target) and participants are asked to say the target present in the box. Object file theory correctly predicts that participants respond more quickly when the target is the same as it was originally, or in the preview display. This is because it matches the object file functioning at that time.

Specifically, because the target [or object feature] at test matches the target, the letter, that was originally bound to the object representation created during the focused attention stage, participants are able to more quickly identify the object as the same. If a new letter is present, the old file must be disregarded causing a delay in response time due to the necessity of the creation of a new object file with the new target bound to the object to account for the new object present.

Kahneman, Treisman, and Gibbs (1992) explored the effects of various changes in displays on object-specific priming using a response time study of the object reviewing paradigm. In particular, the study of object specific preview

benefits was undertaken with the manipulation of display time, ISI time, surface features, number of targets, and motion. Several themes emerged from the results of the experimental series. Specifically, object specific preview benefits were found to occur when the two objects are perceived as being “the same,” which occurred when: 1) a shared location is present between the initial and final target, 2) a shared relative location within a pattern in motion, and 3) the appearance within the moving frame is successive.

The three experimental situations described above all rely on the spatiotemporal continuity between the two object appearances. In the first situation, both objects are presented in the same space. Essentially, the object does not move. Thus, the initial location is the same as the final location.

In the second situation there is a shared relative location within a pattern of motion, which is not visible to the participant. Specifically, the movement pattern between the two objects results in the final location, i.e., the invisible movement “makes sense” in that the movement from beginning to end is logical. A specific motion path is perceived, although not actually present, with the object beginning in the initial location and seeming to move invisibly to the final location.

Finally, in the third situation the movement and location are successive such that the object moves to a location which is suggested by the movement pattern, i.e., the movement is continuous. In this situation, the motion path is visible whereby the participants see the movement of the object from the initial location to the ending location.

These findings suggest that object files are maintained when spatiotemporal continuity is present. Additionally, Kahneman et al. (1984) found that maximal performance also occurs when there are fewer objects. For example, participants perform better when the number of objects is less; for example, 3 objects instead of 5. This suggests that only a specific number of object files can be maintained at any given time.

As the research of Kahneman et al. (1984 & 1992) indicated the importance of spatiotemporal continuity, additional experiments were undertaken to see what other properties of objects, if any, are necessary for the maintenance of object representations, as evident by the presence of OSPBs. One line of research has looked at the importance of surface features.

Kahneman et al. (1992) posited that object specific preview benefits are independent of surface feature congruence, after finding that changing a surface feature of an object, such as color, does not eliminate the object specific preview benefit.

Subsequent work has sought to further elucidate object representation formation and maintenance by using the object reviewing paradigm or a modified version of it. For example, Mitroff and Alvarez (2007) used the object reviewing paradigm to study what features are important for object file persistence. Specifically, this series of experiments studied the effect of manipulating the size, shape, color, location in time and space, and the shape of an enclosed feature on the object specific preview benefit. Using the moving display from the object reviewing paradigm, the authors were able to demonstrate that it is

spatiotemporal information used to track object files over time, not surface features such as color and shape. These results were found by modifying Kahneman and Treisman's object reviewing paradigm by manipulating the surface and spatiotemporal features of the objects. Specifically, during the ISI of the object reviewing paradigm, changes to the object occurred without the participants' awareness. The response time to identify the target was recorded following these manipulations. The authors found that object specific preview benefits were eliminated when the spatiotemporal features were manipulated. However, surface feature changes had little or no effect on the object specific preview benefit. These findings suggest that surface features are not encoded as strongly, if at all, into the object representation created after an object is perceived.

An additional question concerning object file representation concerns how long they persist in memory in the absence of the object. Noles, Scholl, and Mitroff (2005) attempted to answer this question by studying the decay of object file representations over time using a modified object reviewing paradigm. The modified object reviewing paradigm uses a forced match/no match decision task instead of verbal report of the letter used in the standard object reviewing paradigm. The authors were successfully able to replicate the central findings from Kahneman et al. (1992) as well as test the duration of object files using three types of motion. These experiments provide evidence that object file representations last for up to 8 seconds.

Previous studies of the object specific preview benefit relied on the disappearance of objects. In 2006, Kawachi and Gyoba introduced an additional means of studying the object specific preview benefit which makes use of occlusion, or the movement of an object behind an occluding surface. This modified paradigm allows for further analysis of object representation maintenance, in that it makes it possible to study the effect of modifying spatial as compared to temporal components. In other words, the tunnel effect paradigm allows experimenters to manipulate the spatial path allowing for spatial discontinuity without changing the temporal path. Similarly, by using a tunnel effect paradigm, objects no longer must disappear “into thin air” only to reappear at a later time. Instead they can move in and out of occlusion which potentially makes studies of the object specific preview benefit more relatable to the world outside of the laboratory as most objects do not “pop” in and out of existence but rather move into and out of view.

The Tunnel Effect and the Object Specific Preview Benefit

While there are numerous examples in nature of how object perception and occlusion interact on a daily basis, many illustrations of the interplay between the two have occurred in the laboratory. Indeed, experimental work from nearly fifty years ago clearly illustrates this interplay with the study of the tunnel effect (Burke, 1952).

The tunnel effect is created when an object moves behind an occluding surface (i.e., the tunnel) and then emerges from the other side of the occluder. When the object reappears at the correct time and location, observers perceive

the movement as continuous behind the tunnel. The movement is seen as belonging to a single object. Thus, the tunnel effect is the perception of the continuous movement of an object despite a lack of visible path of motion (Burke, 1952). Interestingly, the perception of continuity of motion still occurs even after changes in the surface features of the object, such as a color change from green to red during occlusion (Burke, 1952).

While an interesting phenomenon, conclusions drawn from the tunnel effect may also be limited by the use of verbal reports, which have several inherent flaws including the lack of quantitative data as well as the tendency of verbal reports to be influenced by higher-level biases, such as the beliefs and expectations of the participants (Flombaum, Kundey, Santos, & Scholl, 2004).

Recent work has attempted to address this concern. In the first demonstration of the tunnel effect in non-humans, Flombaum, Kundey, Santos, and Scholl employed a new non-verbal means for measuring the tunnel effect by using search behavior as a measure of perception in primates (2004). Specifically, the macaques viewed a lemon rolling down a ramp until it moved behind an occluding surface. A kiwi emerged from the initial occlusion and rolled down the ramp until reaching a final occluding surface. In order to see if the tunnel effect was present, on some trials the kiwi emerged following a delay. The search behavior of the subjects was recorded and revealed that the monkeys only looked behind the final occluding surface if the kiwi emerged without delay suggesting the kiwi was viewed as the same, albeit transformed, fruit from the beginning of the trial.

Similarly in 2006, Kawachi and Gyoba developed the measure introduced in the previous section which demonstrated the tunnel effect without the use of verbal reports by recording response times of participants. In the experiment, participants initially viewed an object with a target [a specific feature, in this case, a + or O] at one side of the screen. During each trial, they watched the object move across the screen and behind the occluding surface [a gray rectangular box at the center of the screen]. An object then emerged from the occluding surface.

Several manipulations of the stimuli were performed by Kawachi and Gyoba (2006) in order to answer several questions about object representations and the object specific preview benefit. One of the first questions was whether or not object representations, as evident by the object specific preview benefit, were maintained throughout physical occlusion. The answer to this question was found by manipulating the target which appeared on the object emerging from the tunnel. Because the participants were faster at recognizing the previously presented target as being the same one on the emergent object, this is seen as evidence that object representations are maintained during occlusion.

The additional questions of how spatiotemporal discontinuity and manipulations of surface features affect the object specific preview benefit, or more broadly the maintenance of object representations was studied by manipulating the location the objects emerged from occlusion at. The objects either exited occlusion on the same path [spatially continuous] or a different path [spatially discontinuous] as the original movement, see Figure 6. Similarly,

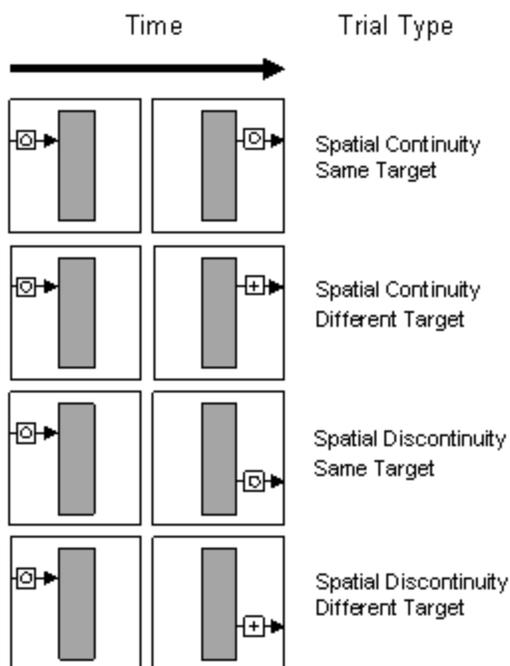


Figure 6. Schematic of method inspired by the Kawachi & Gyoba (2006) study of the object specific preview benefit.

surface features were changed on some trials. Specifically, while behind the occluding surface, the color of the object or size was changed in some of the trials.

The results of four experiments reported by Kawachi and Gyoba (2006) indicate that the use of a response time measure provides an additional quantitative means to measure the persistence of object representations through occlusion, which is potentially more relevant to real world situations, as the object specific preview benefit was found. This can be seen in Figure 7 with the increase in response time in the spatial continuity-same surface feature bar for different target [the first black bar]. This significant difference between response time for the different and same target trials is the object specific preview benefit. Kawachi & Gyoba's (2006) participants were significantly faster at recognizing

the target as old as compared to recognizing that the target was new. Because participants only responded more quickly to the same target when the object followed a continuous path, see Figure 7, the results of the current study support the supposition that object representations are based, at least in part, on spatiotemporal information. This can be seen in the increase in response time for the two sets of spatial-discontinuous trials at the right of the graph. Additional findings of the current study were in concordance with previous object file research; specifically, that surface features such as color and size are only supplementary, if facilitative at all, to object specific preview benefits.

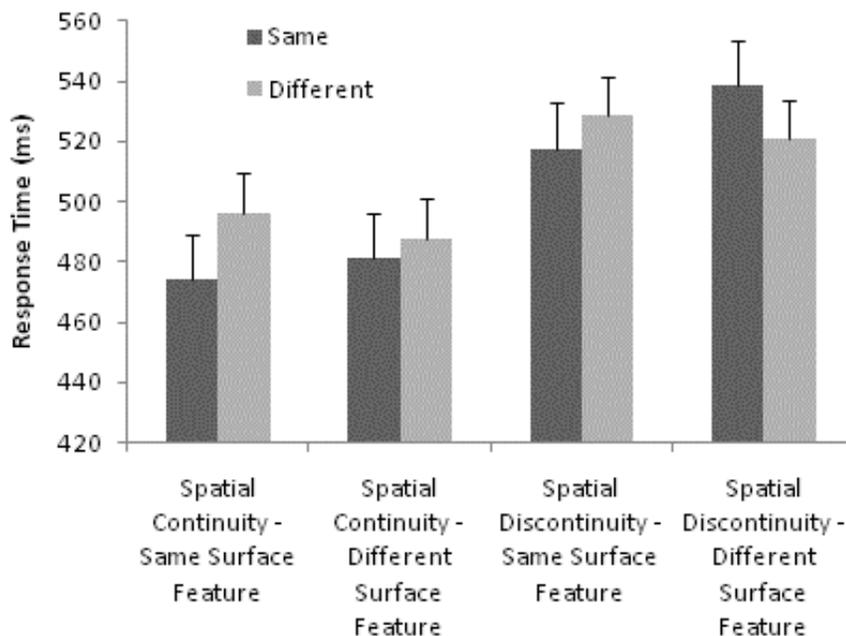


Figure 7. Depiction of the object specific preview benefit inspired by Experiment 1 of Kawachi & Gyoba (2006). Each set of bars corresponds to an experimental condition given in Figure 6.

The Role of Attention in Object Representation Maintenance

Previously the role attention plays in object perception was discussed as pertaining to Feature Integration Theory. However, attentions' part in object perception does not end following recognition and identification. Attention continues to exert influence during maintenance of the object representation. For example, the representation of an object is necessary for the object specific preview benefit. If there is no object representation accessible for comparison, there can be no benefit as a new representation must be created. If an object is perceived but then attention is directed elsewhere, the object representation will be lost. These attentional influences are the next topic of discussion.

Divided Attention

Divided attention is another aspect of attention which has the potential to greatly affect object perception and is demonstrated in the world outside the laboratory. In addition to providing an outlet for further exploration in the laboratory, the effects of dividing attention have numerous real world applications. Consider that several recent laws prohibit cell phone usage while driving due to the prevalence of cell phone related accidents (Governor's Highway Safety Association, 2009). The inability to accurately perceive a car stopping in front of you because of the distraction of a task like dialing a phone number illustrates that the study of divided attention has the potential to shape future policies.

As with using the term "object", it is important to define the term divided attention. For the purposes of this document, divided attention refers to the

simultaneous performance of two or more tasks. The majority of studies which will be introduced use a dual task paradigm, which involves concurrent performance of two tasks.

Studies of how divided attention affects object perception and object representation have been undertaken by researchers such as Hutton & Tegally (2005), who analyzed the effects of dividing attention on the ability of participants to track objects. The results indicate that only when the secondary task was demanding was performance impaired suggesting that only when sufficient attention is diverted is performance negatively affected. Specifically, under dual task conditions when attentional resources must be devoted to two separate tasks the performance decreased, as evidenced by larger errors in object tracking. Further non-spatial discrimination secondary tasks were associated with larger errors which are explained by the greater difficulty in distinguishing the audio, as opposed to the visual, stimuli used (Hutton & Tegally, 2005).

Dual Task Interference

Dual task interference refers to a decrease in performance while two tasks are undertaken simultaneously. This decrease in performance is associated with an increase in time whereby the undertaking of the two tasks simultaneously takes more time than performing each task serially would and/or a decrease in performance accuracy from performing the tasks serially to performing them simultaneously (Herath, Klingberg, Amunts, & Roland, 2001).

One additional means of measuring dual task interference was devised by Sperling and Melchner (1978) with the AOC (attentional operating characteristic)

method which is better able to quantitatively describe how dual task interference functions in shaping performance. Specifically, this method, which was developed from signal detection theory, measures the extent to which two tasks use the same cognitive resources.

According to the AOC, there are four fundamental ways in which two tasks, performed simultaneously, can interact, see Figure 8. If both tasks use the same resources, performance declines on one task as it increases on the other [line C, the square on line C indicates a perfect tradeoff between the two tasks whereby performance on each task is at a level 50% lower than individual performance, line D indicates a less severe decrease in performance associated

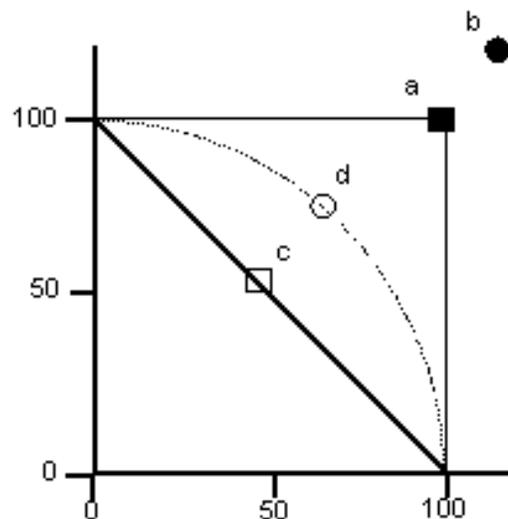


Figure 8. Schematic of the Attentional Operating Characteristic, which plots dual task performance of two tasks, X and Y. The line through A indicates that the two tasks are mutually exclusive and can be performed jointly with no detriment to performance on either task X or Y. B illustrates dual task performance whereby performance on both tasks is facilitated by simultaneous performance. The line through C indicates performance if both tasks use the same resources. This is referred to as the tradeoff line and illustrates that performance on tasks X and Y are inversely related when performed jointly. In other words, high performance on one task results in lower performance on the other task.

with dual task performance]. It is also possible that there are situations where the tasks can be performed simultaneously, with no detriment to either. This is represented by the point A in Figure 8. It is also postulated that there can be situations where dual task performance is higher than performance of the two tasks separately. This is indicated in the Attentional Operating Characteristic, shown in Figure 8, at point B (Sperling & Melchner, 1978; Alvarez, et al., 2005).

While the AOC method is very useful for describing the performance levels when two tasks are performed at the same time, an elucidation for why the performance declines, remains steady, or increases is needed. Recent neuropsychological work may provide some explanation of this.

Cortical Areas Associated with Divided Attention

Neurological studies have postulated a biological mechanism for dual task interference (Klingberg & Roland, 1997; Klingberg, 1998; Roland & Zilles, 1998; Herath et. al, 2001). Specifically, the cortical field hypothesis and its predictions have been offered as an explanation for interference during two concurrent tasks. The cortical field hypothesis posits that all of the neurons within a cortical functional field, loosely defined brain regions sharing a function, function cooperatively. A central prediction of this hypothesis is that if two or more tasks make use of overlapping regions, performance will be inhibited as evident by increased reaction latencies or increased errors (Klingberg & Roland, 1997; Roland & Zilles, 1998). For example, if a person is performing two simultaneous tasks (A and B) which have both been shown to cause activation in the same cortical region, it would be predicted that the performance on the tasks would be

worse than the combined individual performances, as evident by increased response time or an increase in performance errors, which could be seen on the AOC as any point below line A, see Figure 8.

Evidence for the cortical field hypothesis and the central prediction discussed just previously is provided via neuroimaging experiments. Specifically, experiments using PET scans, which measure regional cerebral blood flow, showed that only tasks which revealed activation of overlapping parts of the cortex demonstrated interference between concurrent working memory tasks, as evident by a decline in accuracy (Klingberg & Roland, 1997; Klingberg 1998, Roland & Zilles, 1998). Roland and Zilles (1998) recorded brain activation using PET scans during the performance of two working memory tasks: a visual working memory task and an auditory working memory task. Performance and brain activation were analyzed for the performance of the tasks alone and simultaneously. When performed at the same time, error rates as well as response time increased for both tasks. In this specific study, the interference was associated with multiple cortical overlaps in the prefrontal cortex, anterior cingulate cortex, and inferior parietal lobule.

If the cortical field hypothesis is correct, a plausible expectation would be that the magnitude of decrease in performance could be predicted in two simultaneous tasks by manipulating the task type and thus, manipulating the underlying cortical areas that are recruited for each task. Specifically, by selecting two tasks which activate the same cortical space, it would be predicted that an increase in interference would be seen, as evident by an increased

response time and/or an increase in errors. Alternatively, if two tasks do not use the same brain regions, it would be expected that there would be no tradeoff for task performance and performance on each task would be the same as performance under single task conditions. An example of this would be with hemispheric lateralization whereby due to differential processing in the left and right hemisphere, attention can be divided without a decrease in performance. This phenomenon was demonstrated by Herdman and Friedman (1985) in a study which analyzed performance on left versus right ear auditory and verbal tasks.

Thus, the cortical field hypothesis could potentially posit an explanation for some instances of loss of an object representation. It could be a lack of attentional resources due to the performance of a simultaneous task which could cause a decrease in the ability to maintain an object representation. Inability to maintain the object representation would lead to a loss of the object specific preview benefit.

Visual Processing

Research has shown that visual processing does not rely on a single cortical area for object perception. Rather, two “streams” of visual processing have been suggested (Kolb & Whishaw, 2003, & Bear, Connors, & Pardiso, 2007), see Figure 9. The dorsal stream, which stretches from the primary visual cortex in the occipital lobe forward into the parietal lobe, is believed to be involved in spatial awareness, the guidance of movement, and the perception

and interpretation of spatial relationships. Due to its functions, the dorsal stream is often referred to as the “Where” pathway (Kolb & Whishaw, 2003, & Bear, Connors, & Pardiso, 2007). Due to its emphasis on spatial awareness, the object, as it is defined in this document, would be thought to be processed, in large part, by the dorsal stream. Thus, it is postulated that object representations would be created and maintained primarily in the dorsal stream. The ventral stream which exits the primary visual cortex and moves through secondary visual and various areas of the inferior temporal lobe, is associated with feature and form analysis. It is commonly referred to as the “What” pathway (Kolb & Whishaw, 2003, & Bear, Connors, & Pardiso, 2007).

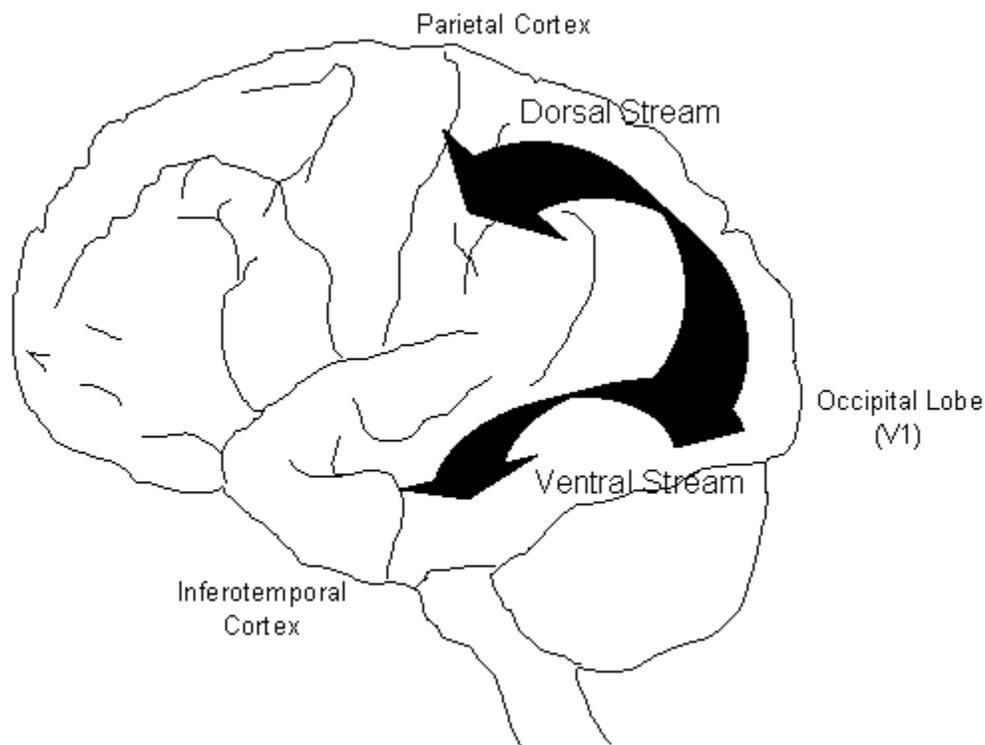


Figure 9. Depiction of the dorsal/ventral visual pathways.

Using the predictions of the cortical field hypothesis, if two concurrent tasks lead to activation of overlapping regions (for example, two ventral tasks) interference should result in a drop in performance. Alternatively, if the two tasks use separate brain regions (for example, one task makes use of the dorsal stream and one task uses the ventral stream) a person should be able to divide attention more successfully, as would be shown by a smaller decrease in performance. Referencing back to Figure 8, the AOC figure, performance which uses the same regions would be expected to be similar to the performance marked by line c. Similarly, tasks that use different cognitive resources should result in performance more closely resembling line d. Thus, it appears that by activating different pathways or the same pathway the amount of inhibition of task performance (or error) can be manipulated. More specifically, the larger the area of overlap in brain area associated with two tasks is the larger the interference you would expect to see. This increase in interference would result in a decrease in performance. Further, according to the cortical field hypothesis, the further in cortical distance the areas used by two tasks are the less interference you would expect to see (Klingberg & Roland, 1997; Klingberg 1998, Roland & Zilles, 1998). Thus graded declines in performance are possible for multiple tasks as the distance between the two relevant brain areas increases, so does the ability to perform the tasks simultaneously without a decline in performance.

Pilot Study

The review of the literature suggests that it would be possible to predict the extent to which participant performance decreases by manipulation of the two simultaneous tasks being performed. A pilot study was designed and conducted to replicate the success of the tunnel effect paradigm, introduced by Kawachi and Gyoba (2006), to study the object specific preview benefit. Further, the pilot study was designed to study the effect the manipulation of secondary task type has on the maintenance of object representations. The tunnel effect paradigm allows for introduction of a simultaneous task. Specifically, the movement of the object behind occlusion makes available the time and space necessary to introduce a secondary task, such as a letter task.

The design of the secondary task was based on the theory that in order for participants to demonstrate the object specific preview benefit, they must maintain a representation of the moving object during occlusion. The logic of employing a secondary [dual] task is that if it draws enough resources away from the object task, it will interfere with maintenance of the object representation, and diminish or eliminate the object specific preview benefit. In particular, the strength of this interference should vary as a function of the 'cortical' distance of the secondary task from the object task.

To test the previous theory, the pilot study used a similar design to that of Kawachi and Gyoba (1996). The largest deviation was that in addition to having the participants respond to the target [same or different] they were asked to complete a secondary task during each trial. To eliminate confusion about the

tasks, each participant first underwent two training phases on the two single tasks: the Kawachi and Gyoba (2006) tunnel effect paradigm, which will subsequently be referred to as the object task, and the letter task. Each participant was trained to perform the object task with the right hand and the letter task with the left hand.

Letter task was a between-subjects condition in the pilot study. Half of the participants [34] participated in a dorsal or “where” letter task which required them to respond to the relative location of two flashing letters. The other half of the participants [34] were required to respond to the features of the letters which flashed. Specifically, they were asked if the letters which flashed were the same or different. This is referred to as the ventral or “what” task.

Selections of the letter tasks were made using two converging lines of research. The first support for task selection is provided by the neuropsychological studies discussed previously. In particular, the dorsal and ventral research which assigns specific tasks types to certain cortical areas. Secondly, research on individuals with Balint’s syndrome suggests that object feature binding occurs in the dorsal path. In particular, experiments with the patient, R.M., who suffers from bilateral parietal lesions show that he is unable to bind the features he is presented with into objects, as evident by a dramatic number of reported illusory conjunctions (Treisman, 1998b). Previous work of Treisman (2006) demonstrates that individuals with bilateral parietal lesions (in the dorsal stream) do not have the ability to localize objects spatially.

It was hypothesized that dual task interference would be present in both secondary tasks types, whether dorsal or ventral. However, it was further hypothesized that less interference would be present in participants assigned to the ventral task condition during dual phase due to the emphasis of spatiotemporal processing in object file maintenance found by previous researchers (Kahneman & Treisman, 1984; Kawachi & Gyoba, 1996; Mitroff & Alvarez, 2007).

The presence of interference was hypothesized to negatively affect the maintenance of the object representation which can be measured by analyzing the object specific preview benefit. Thus, the object specific preview benefit was expected to decrease most in performance in the dorsal condition participants during dual task trials.

The results obtained did not reflect all the hypotheses set forth. Specifically, there were no object specific preview benefits for either the dorsal or ventral participants in the object phase in the standard condition which is a spatially continuous path with no feature changes, see Figure 10.

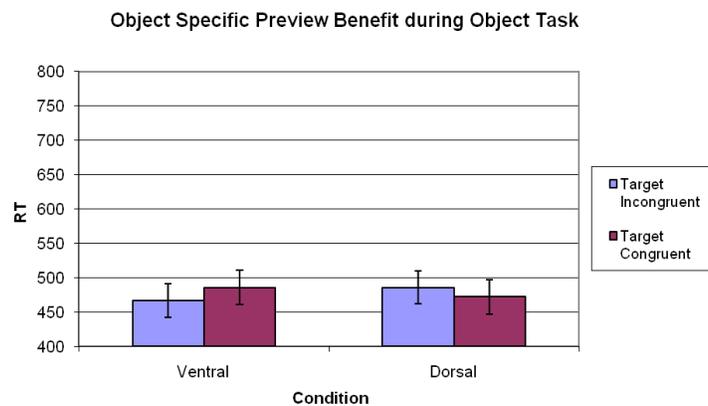


Figure 10. Response times for the target different/target same trials for both experimental groups: ventral and dorsal.

In addition, the only significant object specific preview benefit found was during dual phase in the ventral condition, see Figure 11. This was unexpected in that object specific preview benefits were not found in the single letter phase. The fact that the ventral condition had an object specific preview benefit while the dorsal condition did not agree with the hypothesis that the dorsal task would interfere more with object representation maintenance due to previous findings concerning the importance of maintaining spatiotemporal properties (Kahneman, Treisman, & Gibbs, 1992; Kawachi & Gyoba, 1996).

The results of the pilot study reveal that the tunnel effect paradigm can be used to measure the maintenance of object representations during divided attention. As not all hypotheses were supported by the results, there are necessary changes to the experimental design which should increase the paradigm's ability to measure the object specific preview benefit under single and dual task conditions.

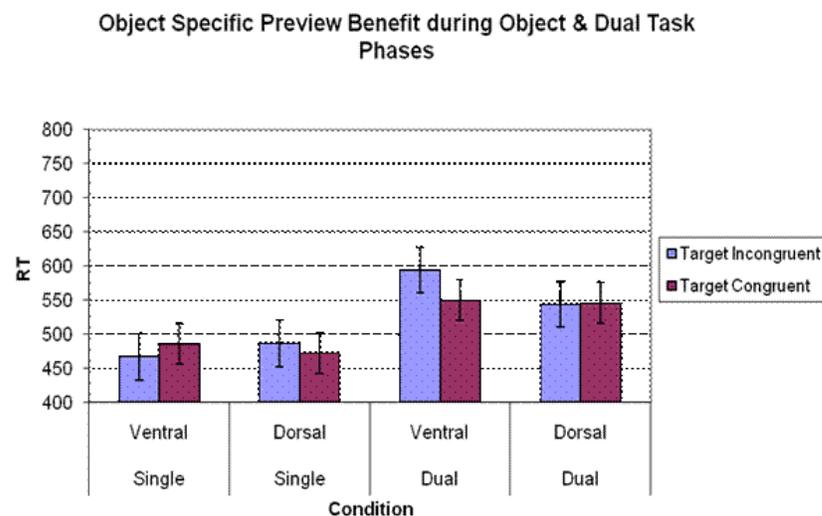


Figure 11. Response times for the target different/target same trials during both single and dual phases for each experimental condition: ventral and dorsal.

CHAPTER 3

HYPOTHESES

The present study investigated the differential effects of secondary task type on dual task interference as well as the maintenance of object representations, as measured by the object specific preview benefit. Specifically, performance on two single tasks, the object task and the letter task, was compared to performance of both tasks simultaneously. Additionally, the secondary task type varied between subjects so that approximately half of the participants were assigned to a ventral letter task and approximately half of the participants were assigned to a dorsal letter task.

The tenets of Object File Theory and the Cortical Field Hypothesis suggest several hypotheses for the results obtained using the paradigm outlined previously. Specifically, object specific preview benefits would be expected in trials where the target is the same one present before and after occlusion, as compared to performance on trials where the target on the object emerging from occlusion is different. However, the Cortical Field Hypothesis would predict a decrease in performance, in this case an increase in response time and a decrease in accuracy, during the performance of simultaneous tasks which use the same, or overlapping, brain regions. Thus, overall performance would be predicted to decline in specific experimental conditions because of dual task interference. As a consequence of this interference the object specific preview

benefit could be lost. Specifically, three hypotheses are at the core of the proposed study.

- Hypothesis 1: Performance, as measured by accuracy rate and response time, during dual task will decline as compared to performance on the single tasks, both object task and letter task.
- Hypothesis 2: The decline in performance during dual task will be lesser for the ventral condition.
- Hypothesis 3: The object specific preview benefit will remain in the ventral dual task condition while it will be lost in the dorsal dual task condition.

Hypothesis 1

The first hypothesis, that performance during dual task will decline as compared to performance on the single tasks, can be subdivided into two sub-hypotheses. First, accuracy during dual task will be lower than the accuracy achieved during performance of the single task. Secondly, overall response time will be higher during the dual task phase than it will be during the performance of the single task phases.

Overall performance will be expected to decline as previous research has found that the performance of two tasks simultaneously typically results in a decrease in performance, as measured by response time or accuracy, when the tasks make use of the same cognitive resources (Klingberg & Roland, 1997; Roland & Zilles, 1998). As both tasks which will be performed by the participants involve visual processing and object perception it will be expected that there will be an overall decline in performance, in both experimental conditions.

Hypothesis 2

The second hypothesis that the decline in performance during dual task will be smaller for the ventral condition is able to be subdivided into two additional sub-hypotheses. Firstly, it is hypothesized that the drop in accuracy from single to dual task will be smaller for the ventral, as compared to the dorsal, condition. Similarly, the increase in overall response time from single to dual task will be greater for the dorsal, as compared to the ventral, condition.

The second hypothesis is grounded in the principles of the cortical field hypothesis which states that tasks which use overlapping brain regions will display greater interference when performed simultaneously (Klingberg & Roland, 1997; Klingberg 1998, Roland & Zilles, 1998). The proposed experiment involves two different letter tasks which are assumed to make use of separate cortical areas. Because the “where” task is presumed to use primarily dorsal brain regions, it is predicted that more interference will be present as the object task is believed to also use primarily dorsal brain regions, due to the spatiotemporal nature of object representations.

Hypothesis 3

The hypothesis concerning the presence of the object specific preview benefit during the object task during dual phase can be subdivided into two sub-hypotheses. Firstly, the object specific preview benefit, the decrease in response time in recognizing an old target as old, will be present in both the single and dual task phases for the ventral condition participants. Further, the object specific

preview benefit will be present in the single object task, but not the dual task, for the dorsal condition participants.

The reasoning behind the third hypothesis is very closely related to the theory behind the second hypothesis. Because the dorsal letter task is assumed to make use of the same cortical areas as the object task, it is hypothesized that the object representation will be lost due to the competition for cognitive resources between the dorsal letter task and the object task.

CHAPTER 4

METHODS

This study was an expansion of the experiments conducted by Kawachi & Gyoba (2006). Specifically, the present experiment used the tunnel effect paradigm, introduced by Kawachi & Gyoba (2006), in a study of dual task interference and its effects on the maintenance of object representations. An additional secondary task was introduced, a letter task, in order to create and study the presence of dual task interference.

Participants

A sample size of (102) was obtained for the current study. All participants were recruited from an introductory psychology course (PSYC 102). Each participant received course credit for their participation. All participants had normal or corrected to normal vision. Consent forms were signed by all of the participants in accordance with the policies of the Human Subjects Committee at Southern Illinois University of Carbondale.

Materials

All experimental stimuli were presented on computer monitors located in the Developmental Science Lab located at Southern Illinois University of Carbondale. Each computer monitor was 30.5 cm by 40.6 cm with a screen resolution of 1024 X 768, where one degree of visual angle is approximately equal to 25.5 pixels. Each participant sat approximately 61 cm from the computer

monitor. The frame rate, or frequency of subsequent image presentation to create the perception of motion was 16.7 ms/frame.

Four keys were used by participants to respond: “~”, “Ctrl”, “-”, and “enter.” Key assignment is discussed in greater detail in the Procedure section.

Object Phase

The stimuli for the object task portions of the experiment consisted of a green or red square with a target located at its center, a gray occluder located midway across the computer screen, and a white fixation dot located on the gray occluder at the very center of the screen. All stimuli were presented against a black screen.

The square was 1.96 by 1.96 visual angle degrees. It moved across the screen at a rate of .078 visual angle degrees per frame or .41 visual angle degrees/second. A target was located at the center of each square. This target was either a crosshair or an open circle which fit inside the square, see Figure 12. The occluding surface was 5.88 by 19.61 visual angle degrees. It was located at the center of the screen. During those trials in which the square changed paths during occlusion, the square emerged 6.86 visual angle degrees directly below the spatiotemporally congruent location. The fixation test stimulus was present on the gray occluding surface at the center of the screen. It



Figure 12. The object stimuli presented during the object tasks. Each green square contained one of the targets, + or o, which appeared white in the

experiment. They are shown against a black backdrop to show detail in the figure.

consisted of a white dot, .588 by .588 visual angle degrees, which changed

colors during fixation test trials. During the color change, the dot appeared to be

one half red and one half green, see Figure 13.

Letter Phase.

The stimuli for the letter task portions of the experiment consisted of white letters which flashed in one of four screen quadrants and masks which were used to cover the letter stimuli when not flashing. The letters presented filled a 5.88 by 5.88 visual angle degrees box. Throughout the experiment the letters which flashed were randomly selected from a list which contained the letters: A, B, C, D, E, F, and G. When the letters were not visible they were covered by masks which were 5.88 by 5.88 visual angle degrees, see Figure 14. In addition, the fixation dot stimuli, described in the previous section, were displayed at the

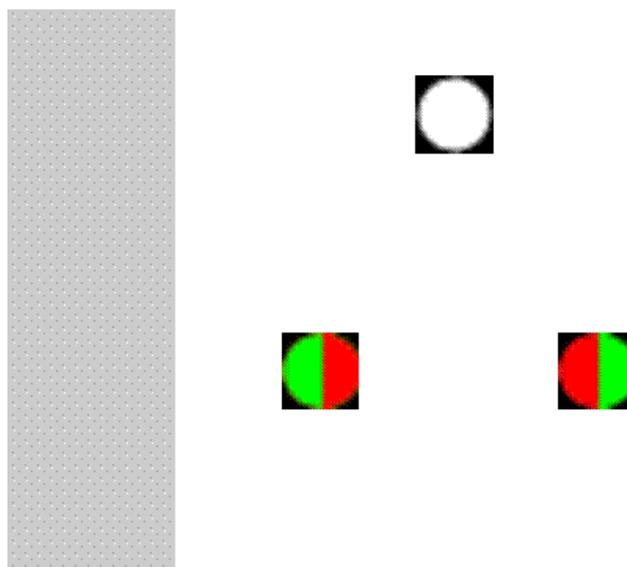


Figure 13. The occluder stimuli presented during the object tasks. The fixation dots beside the occluding surface are enlarged to show detail while the occluder stimulus is smaller than actual size.



Figure 14. Examples of the stimuli presented during the letter task portions of the experiment.

center of the screen during the letter task portions of the experiment.

Dual Phase.

During dual phase, all of the stimuli from the object and letter tasks were presented on the screen simultaneously.

Procedure

At the commencement of the study session, participants were given an explanation of the experimental tasks and instructed to fixate on the white dot present at the center of the screen on all trials. Specifically, each participant was advised to use his/her peripheral vision to engage in the experimental tasks.

The experiment consisted of three parts: the letter phase, the object phase, and the dual phase. Both the object phase and dual phase were split into 4 blocks of 36 trials, with a voluntary rest period following each block. The letter phase was not split into blocks, however after every 100 trials a voluntary rest period was offered each participant. At the beginning of each new phase, each participant was exposed to a number of practice trials in order to familiarize them

with the experimental stimuli and instructions. Following these practice trials were the test trials.

Throughout all phases, fixation test trials were randomly placed. There were a total of 16 fixation test trials in both object and dual phases, 4 in each block. The number of fixation test trials during letter phase varied by participant due to the nature of the criterion training used, such that if a participant trained to criterion they would not be exposed to the maximum number of fixation tests. A maximum of 16 fixation trials were present during letter phase.

When a fixation test trial occurred, the fixation dot temporarily changed color from white to green and red. The duration of the color change was 24 ms, in order to prevent participants from moving their visual fixation to the dot from elsewhere on the screen. Following fixation test trials, participants were prompted to respond to the orientation of the color change by pressing either the “G” or “R”, e.g., was green on the right and red on the left? Or vice versa? If the participant did not see the color change they were able to indicate this via a response of “I did not see the change” by pressing the “N” key.

The order of the two single task phases was counterbalanced between participants, such that half of participants completed the letter task first and the other half completed the object task first. In addition the response keys were randomly assigned to each participant. Finally, each participant was randomly assigned to one of two letter task types: dorsal or ventral. Thus, there were 16 possible combinations of conditions that a participant could be assigned to. For example, a participant could be assigned to the Dorsal, Letter First, and

Hand/Key Combination 1, see Table 1. If this were the case, this participant would belong to each cell marked with an asterisk.

Table 1

Schematic of counterbalancing and random condition assignment used in the current study. Each participant was randomly assigned to a letter task condition: dorsal or ventral. Next, they were randomly assigned to a presentation order: letter first or object first. Finally, they were randomly assigned to a specific hand/key combination for the duration of the experiment. The four possible hand/key assignments were: (1) left hand letter task with upper key assigned to same responses, (2) left hand letter task with upper key assigned to different responses, (3) left hand object task with upper key assigned to same responses, and (4) left hand object with upper key assigned to different responses.

Phase	Dorsal Letter Task (DLT) Condition				Ventral Letter Task (VLT) Condition			
1	DLT 1 *	DLT 3	OT 1	OT 3	VLT 1	VLT 3	OT 1	OT 3
	DLT 2	DLT 4	OT 2	OT 4	VLT 2	VLT 4	OT 2	OT 4
2	OT 1 *	OT 3	DLT 1	DLT 3	OT 1	OT 3	VLT 1	VLT 3
	OT 2	OT 4	DLT 2	DLT 4	OT 2	OT 4	VLT 2	VLT 4
3	Dual 1 *	Dual 3	Dual 1	Dual 3	Dual 1	Dual 3	Dual 1	Dual 3
	Dual 2	Dual 4	Dual 2	Dual 4	Dual 2	Dual 4	Dual 2	Dual 4

Object Phase.

At the beginning of the object phase, participants were exposed to 10 practice trials which provided feedback on both accuracy and response time. Individual trials consisted of an object [green square] that contained a target [+ or o] moving from one side of the screen to the other. During its motion, it passed behind a gray occluding surface and emerged on the other side. Participants were instructed to respond to the nature of the target once they were able to determine if the target was the same or different from the target present prior to occlusion.

There were two variables of interest that varied from trial to trial: target congruence and path congruence, see Table 2. Target congruence refers to whether the target changed during occlusion. Path congruence refers to the spatiotemporal congruence of the object's motion. Specifically, if the object emerged from occlusion at a spatiotemporally congruent or incongruent location.

Table 2

Schematic of object trial types in a single block. Throughout the experiment, participants were exposed to 4 blocks of object phase.

Target Change	Path Change	Direction	Repetition	Total
2 Trial Types - Target Congruent - Target Incongruent	2 Trial Types - Path Congruent - Path Incongruent	2 Trial Types - Left to Right - Right to Left		
2	2	2	18	144

Letter Phase.

At the beginning of letter phase, participants were familiarized to the stimuli with five practice trials which provided feedback on both accuracy and response time. Individual trials consisted of the flashing of letters, which were masked when not visible in order to inhibit the influence of iconic memory, in two of four screen quadrants.

Following the flashing of the letters the participants were asked to respond. The response required was dependent on the condition that was randomly assigned between subjects. Half of the subjects ($n=51$) were assigned to the dorsal condition, while the other half were assigned to the ventral condition. Those participants assigned to the dorsal condition were asked to respond to the spatial relationship of the letters which flashed. Specifically, they were asked to make a “same” judgment if the letters which flashed were horizontally or vertically aligned. If the letters were related diagonally they were asked to make a “diagonal” response. Those participants who were assigned to the ventral condition were asked to respond to the identity of the letters which flashed. In particular, if the letters were the same, e.g., two “A”s, the participants were asked to make a judgment of “same.” If the two letters which flashed were different, e.g., an “A” and a “D” flashed, the participants were instructed to make a “different” judgment.

In order to negate any differences in task difficulty and allow for equation of performance between the participants assigned to the two different letter task conditions, a train to criterion paradigm was used, which modified the

presentation time, or flash rate, of the letters. The initial presentation time for the letters was 195 ms. Subsequent presentation times varied as a function of the accuracy of the participant such that correct responses resulted in a decrease in presentation time while an incorrect response resulted in an increase in presentation time. The minimum possible presentation time was 16.7 ms, while the maximum presentation time was 495 ms.

The presentation time continued to vary throughout letter phase until accuracy stabilized at .80 or the maximum of 300 trials was met. Accuracy was considered stabilized when the participant exhibited 15 “cross-overs” of an accuracy of .80. In other words, every time a participant went from an accuracy, as measured by the previous 20 trials, of above 80% to below 80%, a cross-over was said to have occurred. The number of cross-overs completed determined the change in presentation time, or step-size, due to correct and incorrect responses in such a way as to narrow in on a more precise presentation time. For example, changes in presentation time that occurred during early cross-overs, cross-overs 1 to 5, were 45 ms while changes in presentation time that occurred during later cross-overs, cross-overs 11 to 15, were 15 ms.

The final letter presentation time, after the participant had either trained to criterion or completed 300 trials, was recorded and held constant throughout dual phase.

Dual Phase.

During the third phase of the experiment, participants were instructed to perform both of the single tasks, the letter and object tasks, simultaneously using

the same hand/key assignments which were used during the single task phases. Participants were familiarized with dual task with 10 practice trials which provided feedback on accuracy and response time for both single tasks.

Individual dual task trials presented the stimuli from both single tasks. At the beginning of each trial, the object began moving across the screen while the letters were masked. During occlusion, the letters were presented using the presentation time determined in single letter phase. Following the letter flash, the object emerged from occlusion and continued its trajectory across the screen.

During dual phase, participants were instructed to respond in a specific manner as to minimize individual differences in responding. Specifically, participants were asked to respond to the object task first and the letter task second.

CHAPTER 5

RESULTS

Data was excluded from 20 participants, for failure to respond or for of lack of engagement in the experimental task. Specifically, all of those participants whose letter task performance was less than 70% accurate on the last 20 trials of single letter task with no fixation test and responses recorded were excluded from the data analyses. The use of these criteria resulted in an N of 76. Additionally, individual participants were excluded from specific analyses if no responses were recorded for specific trial types. These individual exclusions are noted with each analysis in which they occurred.

In order to equate performance across the two versions of the letter tasks, each participant from the dorsal condition was paired with a participant from the ventral condition on the basis of letter task accuracy, using each participants' performance on the last 20 trials of the single letter phase. Each pairing was created by matching participants within a 5% accuracy interval. Of the 38 pairs used in the final analyses, 29 were matched exactly on the single letter phase performance of the last 20 trials. After following the exclusion criteria outlined previously and the pairing of the participants, no additional participants were eliminated. The mean performance of the two groups of paired participants, dorsal and ventral, were not significantly different on either of the single task performances as indicated by a series of independent samples *t*-test on the two paired group participants. The results are summarized in Appendix A.

Data were included in the analyses for both right- and left-handed participants. The decision to include both sets of participants was based on the rationale that the counterbalancing measures used in the paradigm for hand and key assignment would remove any systemic biases due to handedness. After the exclusion procedures outlined previously, only 3 left-handed participants, of the 7 total, were included in the data set. The mean performance, as measured by accuracy on single letter task, of right-handed and left-handed participants did not differ significantly on the letter task, $t(74)=1.021$, $p=.311$.

Data were also included for participants, regardless of their fixation test performance for several reasons. A summary of fixation test performance is presented in Appendix B. The necessity of including all of the participants regardless of fixation test performance is discussed in the following section.

In addition, data were included for participants regardless of their train to criterion performance during the letter task. Overall, 46 of the 76 participants trained to criterion in under 300 trials. A comparison of letter task performance between those participants who trained to criterion and those who did not was conducted which showed there were no significant differences in letter task performance between the two groups. A summary of the findings is presented in Appendix C. Further, a one way ANOVA illustrated that there was no significant difference between the two letter task groups, dorsal and ventral, for the number of trials for each participant in single letter phase, $F(1,74) = .928$, $p=.339$. A summary of findings is presented in Appendix D.

All response time analyses used the data obtained from accurate trials only. In addition, only the data collected from trials without a fixation test were used in the analyses as it was desired to analyze performance unaffected by the influence of a third task, the fixation test.

A specific group of trials was used as the data source for all of the letter performance measures. This range was determined by the phase in question. Specifically, single letter performance was determined with the last 20 trials of single phase. Dual letter performance was determined by the first 20 trials of dual phase. These specific groups of trials were selected in order to focus on the presence of dual task interference. These sets of trials were only used for letter task performance analyses. The decision was made to analyze object task performance for the entire duration of the experiment, all of the object data from both single and dual phase, because of the counterbalancing of several factors within the object trial types; for example, the counterbalancing of target and path congruence. As the trial types were randomly placed throughout each phase in such a manner that each participant is likely to have seen a different series of trials, it would have been impossible to equate the individual participants' experiences if trial selection was limited to a number of trials at a specific time in the phase.

Overview of Analyses

Four separate ANOVAs were used to analyze single versus dual task performance. Specifically, there were two performed for each task type: letter and object. Within each task type, there was one performed for each dependent

variable measured: accuracy and response time. Each of these ANOVAs were 2-factor with phase as the within-subjects factor and letter task as the between-subjects factor. Additional 3-factor ANOVAs were used to analyze the data for the presence of the object specific preview benefit via the dependent variable of response time. These analyses included target congruency and phase as within-subjects' variables and letter task as the between-subjects variable. The analyses reported here did not include the variable of path congruency, whether the path of the moving object switched. The decision was made not to include the analysis of path congruency because it was not central to the hypotheses which guided the current study.

The two dependent variables, accuracy and response time, were first analyzed with respect to the influence of two nuisance variables, task order and hand/key assignment. Accordingly, 4-factor ANOVAs were conducted for the two letter task performance dependent variables, accuracy and response time, which included the within-subject factor of phase and the between-subjects factors of letter task, order, and hand/key assignment. The same analyses were performed for overall object task performance. Additional analyses allowed for the examination of the object specific preview benefit. For these analyses, a 5-factor ANOVA was performed for the dependent variable of response time, which included target congruency and phase as within-subjects variables and letter task, order, and hand/key assignment as between-subjects variables. The results of these analyses are presented in Appendices E through J. In 3 of these 4 analyses, there were no main effects or interactions involving the nuisance

variables and so the data sets were subsequently pooled across these factors. In the fourth analysis in which a significant effect occurred, the effect is presented and described.

Single versus Dual Task Performance

The first hypothesis was that performance during dual phase, as measured by mean accuracy and response time, would be lower than performance on the two single tasks: object and letter. The second hypothesis was that the expected decrease in performance during dual task would be smaller for the ventral as compared to the dorsal letter task condition.

Object Phase.

Figure 15 and the ANOVA table presented in Appendix J illustrate the findings concerning the effects of phase and letter task on object task accuracy. The ANOVA for object task accuracy found a main effect of phase ($F(1,74) = 35.928, p < .001$). Specifically, there was a decrease in accuracy from single to dual phase: single phase ($M = .864, SE = .020$), dual phase ($M = .772, SE = .014$). There was no significant effect for the factor of letter task ($F(1,74) = 1.031, p = .313$). There was also no significant interaction for phase X letter task. In order to evaluate hypothesis 2, a change score was computed for each subject by subtracting dual-phase object task accuracy from single-phase object task accuracy. A t -test comparing these change scores as a function of the two letter task assignments, dorsal ($M = .068, SE = .027$) and ventral ($M = .115, SE = .015$), revealed no significant differences ($t(74) = 1.561, p = .123$).

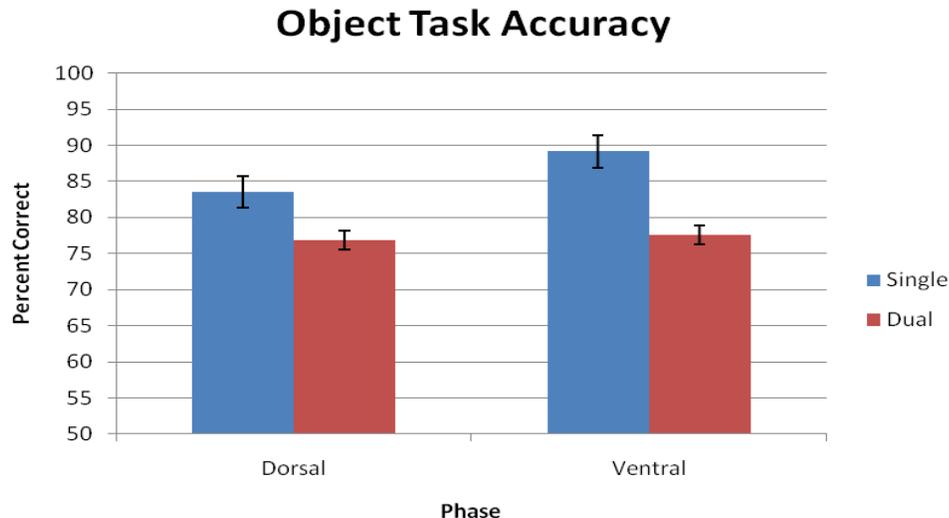


Figure 15. Object task accuracy in single and dual phases for each letter task condition.

Therefore, only phase was found to significantly affect object task accuracy. This supports the first hypothesis, that dual task performance would be lower than single task performance. The second hypothesis that the decline in performance would be lesser for the ventral, as compared to the dorsal, letter task conditions was not supported by the object accuracy data, as evident by the insignificant interaction and non-significant ANOVA result.

Figure 16 and the ANOVA table presented in Appendix K illustrate the findings concerning the effects of phase and letter task on object task response time. The ANOVA found a main effect of phase ($F(1,74)=72.196$, $p<.001$). In particular, there was an increase in response time from single ($M=387.892$, $SE=12.404$) to dual phase ($M=496.739$, $SE=14.819$). There was no effect found for the factor of letter task ($F(1,74)=.021$, $p=.886$). There was also no significant interaction for phase X letter task. A *t*-test comparing the change scores for object

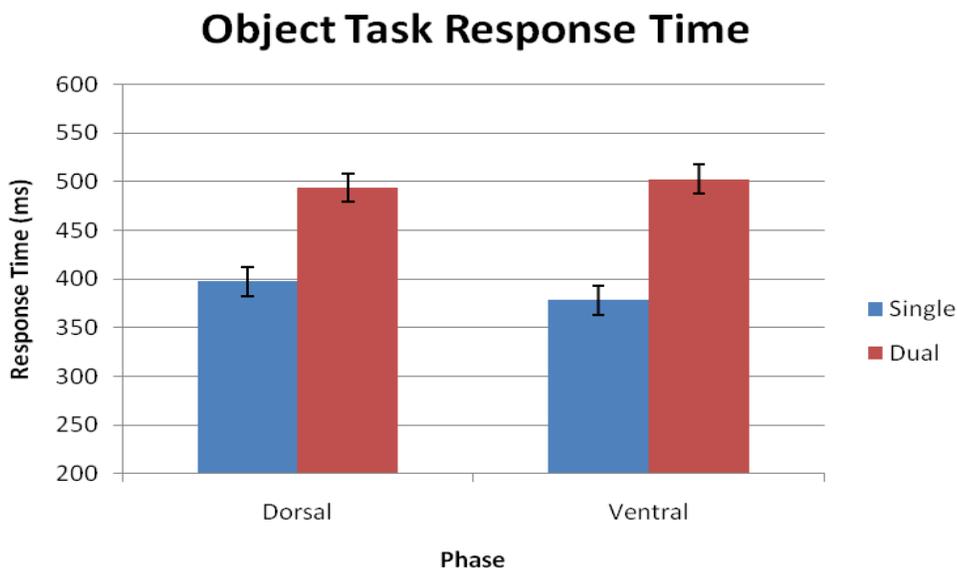


Figure 16. Object task response time in single and dual phases for each letter task condition.

task response time from single to dual phase for the two letter task assignments, dorsal ($M=96.691$, $SE=18.89$) and ventral ($M=124.615$, $SE=17.134$), revealed no significant differences ($t(74)=1.104$, $p=.273$).

Therefore, only phase was found to significantly affect object task response time which supports the first hypothesis. However, the second hypothesis that letter task assignment would have a significant effect on response time was not supported by the data.

Letter Phase.

A 2-factor ANOVA tested the first two hypotheses for letter accuracy. These results are illustrated in Figure 17 and Appendix L. A main effect of phase was found ($F(1,74)=62.067$, $p<.001$) with accuracy being greater in the single ($M=.80$, $SE=.007$) versus dual ($M=.661$, $SE=.017$) phase. There was no effect found for the factor of letter task ($F(1,74)=0.01$, $p=.975$). There was also no

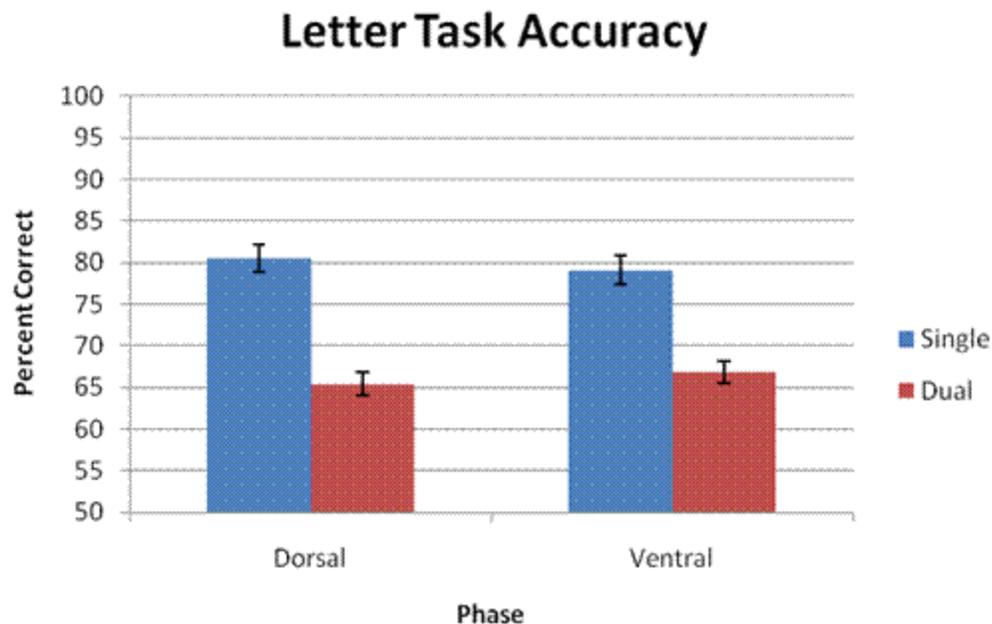


Figure 17. Letter task accuracy by phase for each letter task condition.

significant interaction for phase X letter task. A *t*-test comparing the difference in letter task accuracy from single to dual phase for the two letter task assignments, dorsal ($M=.152$, $SE=.028$) and ventral ($M=.125$, $SE=.021$), revealed no significant differences ($t(74)=.782$, $p=.437$). Therefore, only phase had a significant effect on letter accuracy performance. While the decrease in letter accuracy from single to dual phase was predicted by hypothesis 1, it is important to note that this result is due, at least in part, to the fact that participants were instructed in the dual phase to delay responding to the letter task until after their object task responses. The predictions of hypothesis 2, however, were not met as there was neither a significant letter task x phase interaction, nor was there a significant difference in the change scores between phases as a function of letter task.

The results of ANOVA testing the first two hypotheses for letter response time are illustrated in Figure 18 and Appendix M. A main effect of phase ($F(1,74)=210.179, p<.001$) was found with there being a significant increase in response time from single ($M=633.406, SE=12.637$) to dual ($M=1132.084, SE=33.820$) phase. There was no effect found for letter task ($F(1,74)=1.695, p=.197$). Additionally, there was no significant interaction between phase and letter task. A t -test comparing the difference in letter task response time from single to dual phase for the two letter task assignments, dorsal ($M=467.705, SE=50.875$) and ventral ($M=529.652, SE=46.308$) revealed no significant differences ($t(74)=.900, p=.371$).

Thus, phase was the only significant factor of influence on letter task response time. This significant effect was predicted by hypothesis 1. The lack of a significant interaction between letter task and phase as well as the lack of a significant difference in the change scores between phases as a function of letter

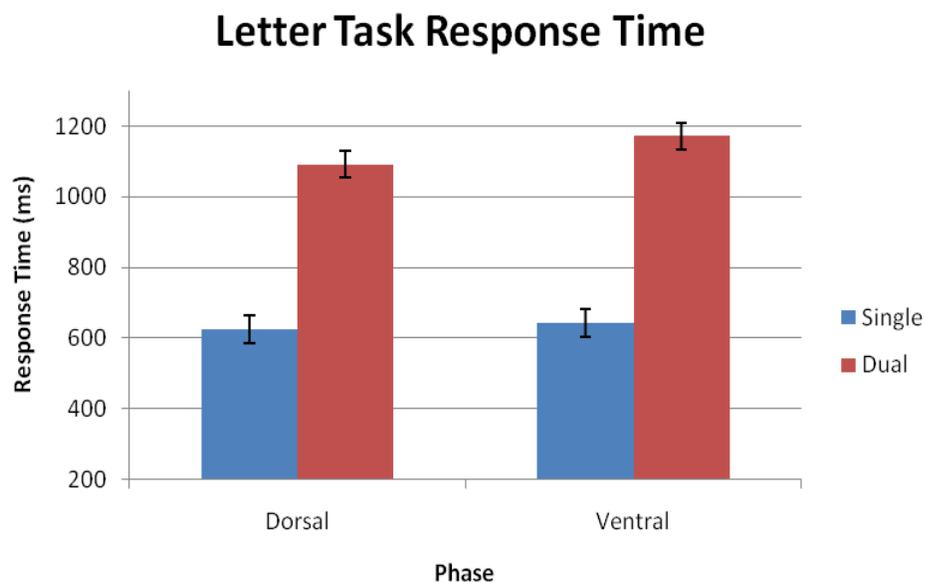


Figure 18. Letter task response time by phase for each letter task condition.

task provide no support for hypothesis 2, that there would be differential effects on performance from single to dual phase due to letter task assignment.

Dual Task Interference

The mean performance of participants on each individual task, letter and object, as measured by accuracy for each phase, single and dual, was used to create an AOC plot in order to better illustrate the presence of dual task interference in the current study, see Figure 19.

The data points located on each of the axes represent performance, as measured by mean accuracy, during each of the single phases. Specifically, the points on the y-axis indicate letter task performance and the points on the x-axis indicate object task performance. The points labeled with a “B” indicate the actual performance of the participants during dual phase. The points labeled with an “A” indicate the theoretical point of mutual exclusivity. If actual dual task performance had been near this level, it would appear that the two single tasks, object and letter, are able to be performed simultaneously with no detriment in functioning.

There are several interesting facets of the data visible in the AOC plot for accuracy. First, the dual task performance of both letter task groups, dorsal and ventral, appears to be nearly identical, indicating that both of the letter task groups were equally affected by interference. This concept of mutual interference is also indicated by the results of the ANOVAs discussed in the previous two sections. Secondly, the mutual interference provides evidence that participants complied with the instructions given in the experiment to distribute their attention or effort equally to the two tasks.

AOC Plot for Accuracy

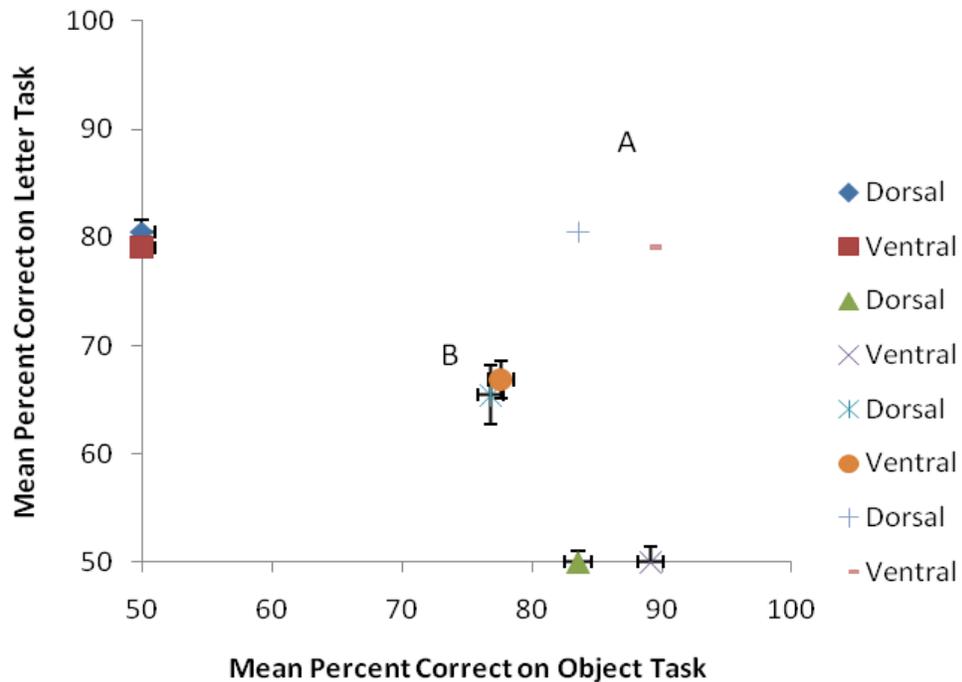


Figure 19. AOC plot of mean accuracy on each task type for each phase. Symbols on the axes illustrate mean single task performance. A) indicates the theoretical points of mutual exclusivity for the two single tasks for this data set. B) indicates actual mean accuracy of performance of the two single tasks simultaneously. Thus, the results indicate that there were similar levels of mutual interference for the two task types for both the dorsal and ventral participants.

Object Specific Preview Benefit

It was hypothesized that the object specific preview benefit would be found in the single object phase for both letter task conditions. It was further hypothesized that the object specific preview benefit would be lost for the dorsal letter task participants during dual phase, while the object specific preview benefit would remain in the ventral letter task condition participants.

The object specific preview benefit was first analyzed in each phase. Following these analyses, the effect of Phase was examined using an additional ANOVA in order to test hypothesis 3 that the object specific preview benefit would be lost for dorsal letter task participants but not for ventral letter task participants.

The initial 5-factor ANOVA to assess the influence of the nuisance variables of presentation order and hand/key condition had several significant main effects and interactions, see Appendix I. The effect of hand/key condition was significant ($F(1,74)=2.817, p=.047$). The left side letter task and upper key same condition had the shortest response time ($M=400.513, SE=21.206$), followed by the left side letter task and upper key different condition ($M=440.032, SE=23.053$). The right side letter task and upper key same condition ($M=454.724, SE=24.136$) had a longer response time than the two left side letter task conditions but a shorter response time than the right side letter task and upper key different condition ($M=491.095, SE=23.492$). Thus, it appears that assignment of the right- or dominant-hand to the object task was an advantage. Also, it would seem that assignment to the upper key same condition provided a similar advantage.

Object Phase.

In order to examine the data for the presence of an object specific preview benefit in object phase an ANOVA considering target congruence and letter task was conducted. Figure 20 and Appendix N illustrates these findings. First, there was a significant effect of target congruence ($F(1,74)=5.06, p=.037$) with trials

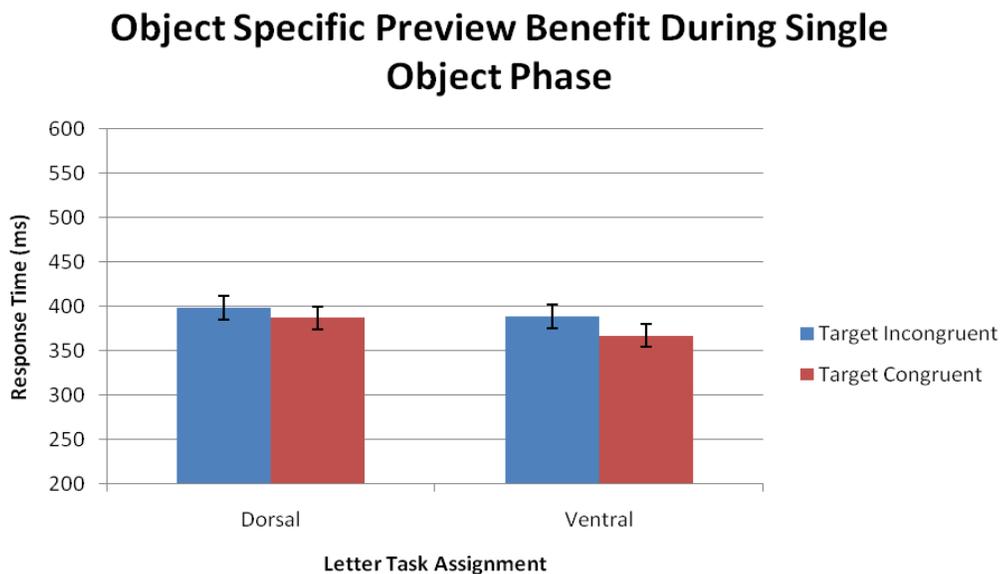


Figure 20. Target congruence (object specific preview benefit) by letter task during single object phase.

having no target change [target congruence] ($M=376.537, SE=12.609$) having shorter response times than trials with a target change [target incongruence] ($M=393.260, SE=13.292$). There was no effect of letter task ($F(1,74)=.360, p=.551$). Thus, the data from the current study provide support for hypothesis 3, which predicted that there would be an object specific preview benefit present in single object phase. Further it was expected that there would be no difference between the two letter task conditions during object phase.

This predication was also supported by the data as evident by the insignificant interaction between target congruence and letter task as well as the results of an independent samples t -test on the object specific preview benefit as measured by a difference score using letter task, dorsal ($M=11.593, SE=12.145$)

and ventral ($M=21.719$, $SE=10.418$), as the grouping variable ($t(73)=.634$, $p=.528$).

Dual Phase.

Figure 21 and the ANOVA table in Appendix O illustrate the results of the ANOVA which analyzed target congruence and letter task for dual phase. There was a significant effect of target congruence ($F(1,74)=9.397$, $p=.003$). Specifically, response times when there was target congruency ($M=487.163$, $SE=16.429$) were shorter than response times when there was target incongruence ($M=514.566$, $SE=15.402$). There was no significant effect of Letter Task ($F(1,74)=.252$, $p=.617$). An independent samples t -test on the object specific preview benefit during dual phase as measured by a difference score using letter task as the grouping variable found that there was no difference in the object specific preview benefit between the two letter task groups, dorsal ($M=10.648$, $SE=.14.576$) and ventral ($M=41.217$, $SE=11.016$), ($t(72)=1.685$,

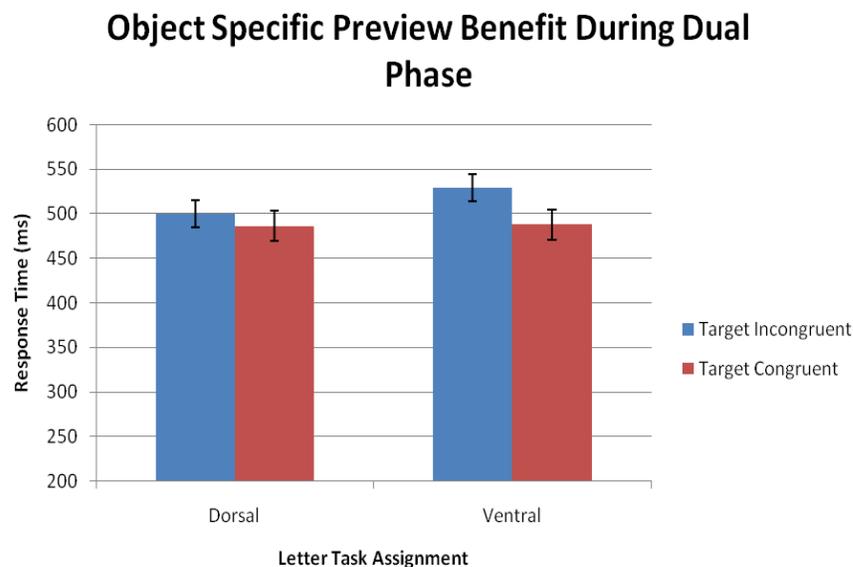


Figure 21. Target congruence (object specific preview benefit) by letter task during dual phase.

$p=.096$).

Thus, the data provided no support for the supposition that letter task assignment would have an effect on the object specific preview benefit, as predicted by hypothesis 3. Specifically, the prediction that the object specific preview benefit would be lost for those participants assigned to the dorsal letter task and not those assigned to the ventral letter task was not met in the current study.

Effect of Phase.

The additional ANOVA with Phase as a factor was conducted in order to test hypothesis 3; the results of this test are presented in Figure 22 and the ANOVA table in Appendix P. The decision was made to run an additional ANOVA in order to preserve power in the previous two object specific preview benefit analyses, as in previous studies the object specific preview benefit has needed large experimental power to be significant. There was a significant effect of target congruency ($F(1,74)=9.289$, $p=.003$) with response times being larger for target incongruence ($M=452.382$, $SE=13.759$) as compared to target congruence ($M=432.606$, $SE=13.308$). Thus, when the target changed the mean response time was greater. There was also a significant effect of phase ($F(1,74)=65.979$, $p<.001$) with response times were significantly longer during dual phase ($M=499.030$, $SE=15.881$) than during single phase ($M=395.958$, $SE=12.788$).

There was no significant effect of letter task on the object specific preview benefit, as was predicted by hypothesis 3. An additional ANOVA, see Appendix

Q, which analyzed the object specific preview benefit, as measured by a difference score, with phase and letter task found that there was no significant effect of letter task on the object specific preview benefit ($F(1,71)=3.246, p=.076$).

Thus, as predicted by hypothesis 3, the object specific preview benefit was, as measured by the effect of target congruency, present in both single and dual phases. However, the prediction that the object specific preview benefit would be lost for the dorsal letter task participants was not met as indicated by the ANOVA which analyzed the object specific preview benefit, as measured by difference scores and the finding that letter task had no significant effect on the response times.

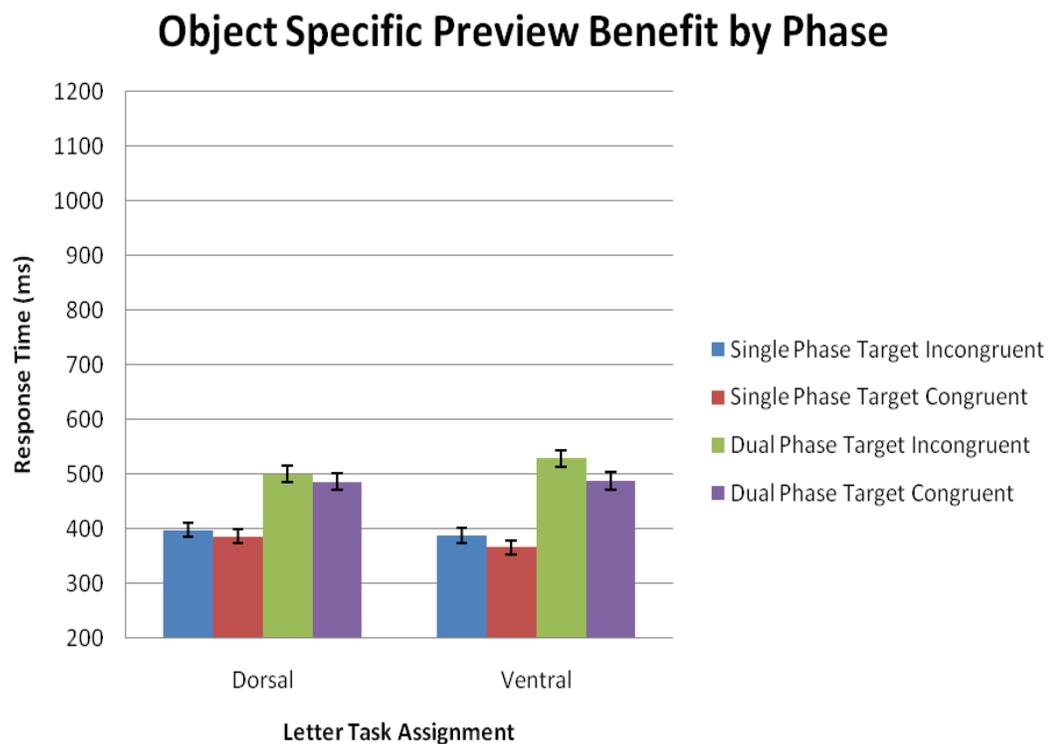


Figure 22. Target congruence (object specific preview benefit) by letter task and phase.

CHAPTER 6

DISCUSSION

Several of the initial findings from the Kawachi & Gyoba (2006) were replicated in the current study. Additionally, data obtained in the current study provide support for several of the posited hypotheses concerning dual task interference and the maintenance of object representations as measured by the object specific preview benefit. In this section, the hypotheses are summarized and the implications of the current study's results are interpreted in relation to these hypotheses. Following this discussion, several ideas are introduced for future experimental manipulations that are suggested by the current study. Specifically, several possible future manipulations which might enable us to better understand the phenomenon underlying the results of the current study are discussed. Then, the results of the current study are examined with respect to the discussion of object perception theories discussed in the literature review. Finally, the implications of the current study and future studies are explored.

The first hypothesis for the current study was motivated by the dual task interference research, which has shown that the performance of two simultaneous tasks results in a decrease in accuracy and an increase in response time (Herath, et al., 2001; Hutton & Tegally, 2005; Sperling & Melchner, 1978). Additionally, the cortical field hypothesis proposes that this decline in performance from single to dual phase occurs when the two tasks make use of the same (or overlapping) cortical regions (Klingberg & Roland, 1997; Roland &

Zilles, 1998). As both tasks in the current study involve visual processing and object perception it was predicted that there would be an overall decline in performance for both letter and object tasks from single to dual phase, for both letter task conditions. Specifically it was hypothesized that there would be a decrease in mean accuracy and an increase in response time during dual phase for both object and letter tasks.

The results of the current study provide support for the first hypothesis. There was an overall decrease in accuracy from single to dual phase for both tasks, object and letter. This global decrease is illustrated in the AOC plot of accuracy in the results section (See Figure 19). Similarly, there was an increase in response time from single to dual phase for both tasks.

An important aspect of the experiment must be noted in the discussion of the letter task response time findings, particularly during dual phase. Because participants were instructed to keep their letter task response in memory until after responding to the object task stimuli, the increase in response time can be seen as an artifact of the experimental design. Nevertheless the object task response time findings paired with the decline in accuracy for both letter and object tasks provide strong evidence for dual task interference in the current study.

The second hypothesis was an elaboration on hypothesis 1. Specifically, it predicted that the decline in performance during dual task would be lesser for the ventral condition. In particular, this hypothesis was grounded in the principles of the cortical field hypothesis, which holds that tasks which use overlapping brain

regions will result in greater interference when performed simultaneously (Klingberg & Roland, 1997; Klingberg 1998, Roland & Zilles, 1998). In respects to the current study, this hypothesis was based on the assumption that the two experimental letter tasks would make use of differing cognitive resources. Specifically, the “where” task was presumed to use dorsal brain regions, so it was predicted that more interference would be present as the object task is believed to also use primarily dorsal brain regions, due to the spatiotemporal nature of object representations. Alternatively, it was predicted that the decline in performance from single to dual phases would be of a lesser magnitude for those participants who were assigned to the ventral letter task condition because it was presumed that the ventral or “what” letter task would make use of fewer or no overlapping cortical areas.

The results of the current study did not support hypothesis 2. The decline in performance from single to dual phases was not significantly mediated by letter task condition. Specifically, the decline in letter accuracy was not significantly different between dorsal and ventral condition participants; nor was the decline in object accuracy. Similarly, the increase in response time from single to dual phase was not significantly different for those participants assigned to the dorsal versus ventral letter task conditions for either the object task or the letter task.

The third hypothesis posited that the object specific preview benefit would remain in the ventral dual task condition while it would be lost in the dorsal dual task condition. Like hypothesis 2, the third hypothesis was grounded in the

cortical field hypothesis and the presumption that the tasks selected for the current study would make use of specific cognitive resources. Because the dorsal letter task was assumed to make use of the same cortical areas as the object task, it was hypothesized that the object representation would be lost due to the competition for cognitive resources between the dorsal letter task and the object task.

There were actually two sub-hypotheses of hypothesis 3 that were tested. The first sub-hypothesis was that the object specific preview benefit, the decrease in response time in recognizing an old target as old, would be present in both the single and dual task phases for the ventral condition participants. Further, it was hypothesized that the object specific preview benefit would be present in the single phase only for those participants assigned to the dorsal letter task condition. In other words, it was predicted that the object specific preview benefit would be lost for dorsal, but not ventral, letter task participants from single to dual phase.

The results of the current study supported part, but not all, of hypothesis 3. Specifically, there was a significant object specific preview benefit during single phase for both dorsal and ventral task condition participants. This was predicted by the first sub-hypothesis of hypothesis 3. There was also a significant object specific preview benefit during dual phase for both dorsal and ventral task condition participants. While it was predicted that the object specific preview benefit would remain for the ventral task participants, it was not predicted for the dorsal task participants. It was anticipated that there would be a differential

effect of letter task assignment on the object specific preview benefit. This element of hypothesis 3 was not supported by the data, however, as letter task assignment had no significant effect on response time during dual phase.

There are several possible explanations for why the results of the current study did not provide evidence in support of the second and third hypotheses. The first probable explanation is that the secondary tasks that were selected and used in the current study did not make use of the cortical space predicted. Secondly, the nature of the object task and object representation could be different from that envisioned during the planning stages of this experiment. Also, it could be that there are additional modifications needed in order to ensure that the paradigm of the current study is valid. Finally, it is possible that the theoretical frameworks used to design the current study are not accurate reflections of reality. Each of these possible explanations will be explored in greater detail.

First, the secondary tasks selected for the current study, could provide explanation for the experimental findings in question. Specifically, it could be that the secondary tasks make use of cortical areas not predicted. For example, both letter tasks have a spatial component as the flashing letters must be localized. If the ventral task of the current study makes use of both dorsal and ventral stream processing resources, it would be expected that there would be no difference in dual task performance between the two letter task groups as both would be using overlapping cortical space during dual phase.

Second, the nature of the object representation as studied by the object task of the current study could recruit cognitive processes outside the dorsal

stream.. Specifically, it could be that the object representation is not as spatiotemporal in nature, as originally believed. While numerous studies, introduced in the literature review, indicate that object representations are spatiotemporal in nature (Kahneman & Treisman, 1984; Kahneman, Treisman, & Gibbs, 1992; Mitroff & Alvarez, 1997), the work of Kawachi & Gyoba (2006) indicated that surface features play a complementary role in the maintenance of object representations (Kawachi & Gyoba, 2006). If object representations are not based solely on spatiotemporal information; it could then be argued that the cortical areas being activated by the formation and maintenance of the object representation are not necessarily dorsal in nature. If features are important for the formation and maintenance of object representations it might be predicted, based on previous findings concerning the two streams of visual processing, that ventral cortical areas would also be activated by object representations.

There are additional modifications for the current experimental paradigm which could increase the likelihood of uncovering any differential effects of letter task assignment. For example, the fixation test could have confounded the experiment. Participants may have used different scanning strategies, depending on their specific letter task condition. Due to the increased complexity of the ventral task, the need to not only localize but recognize the flashing letters, it is possible that participants had to move their eyes from the central fixation in order to complete the experimental tasks. However, the dorsal letter task could have been successfully performed without the necessity of an eye movement. If this was indeed the case, the use of two different strategies could have been a

confound for the current experiment and have led to performances by the two letter task groups which could not be equated due to differing strategies underlying them.

Finally, it is possible that the theoretical framework upon which the present study was designed does not accurately reflect reality. Specifically, it is possible that the cortical field hypothesis is not applicable to the dual task performance present in the current study.

A number of possible modifications to the experimental paradigm are suggested by the findings from the current study. The first modification would be the use of different stimuli in order to address the concerns introduced in the previous discussion of secondary task type. For example, the task stimuli could be manipulated in order to make each task more exclusively dorsal or ventral. The use of faces as ventral stimuli is one such idea.

An even more interesting and possibly fruitful modification stems from research on hemispheric lateralization. In particular, previous research indicates that each hemisphere makes use of different cortical resources in such a manner that attention can be divided successfully for tasks that make use of differential processing in the left and right hemisphere (Friedman & Poison, 1981; Herdman & Friedman, 1985; Yoshizaki & Nishimura, 2008). This phenomenon has been demonstrated using various stimuli, often using differing sensory modalities. For example, Herdman & Friedman (1985) analyzed performance on left versus right ear auditory and verbal tasks and found that there was no significant interference for those tasks which used processing resources in separate hemispheres. Thus,

modification of the current paradigm could exploit these previous findings by introducing a secondary task which makes use of the differential hemispheric processing. This secondary task could make use of additional sensory modalities, such as audition.

An additional modification of the current experimental paradigm which would serve to elucidate the biological phenomenon underlying the current findings would be the use of neuroimaging techniques to localize the cortical areas associated with each experimental task. These neuroimaging techniques could include the use of EEG, ERP, or fMRI throughout the running of the experimental tasks. The use of neuro-imaging techniques would provide two benefits for the current experimental paradigm.

First, the use of measures such as EEG or ERP would provide a validity check for which cortical areas are, in actuality, being recruited by the experimental tasks. Further, this would enable the experimenter to make inferences about the nature of object representations. For example, if both dorsal and ventral areas are active during the object task it could be inferred that the information maintained in object representations is not solely spatiotemporal but also may contain data on an object's features.

Second, the use of neuro-imaging techniques may also provide a means of measuring the degree to which specific cortical areas are recruited by the experimental tasks. Specifically, these measures have the potential to reveal the strength of neural activity which would elucidate the degree to which dual task interference would be expected.

While the results obtained in the current study did not coincide with all of the hypotheses set forth they did enable the drawing of several conclusions and garner support for several theories. As stated previously, the current findings did provide support for the theory of dual task interference, or a decrease in performance when performing two tasks simultaneously, as opposed to serially,

Further, the current findings have implications for the object perception theories introduced in the literature review of this document. Specifically, the findings indicate that features are an important component of object perception as target congruence was a significant factor in the maintenance of object representations as indicated by the object specific preview benefit ANOVAs. Thus, because the targets present on the objects are, in essence, a feature, it appears that this feature information is encoded in the object representation and maintained. Thus, the results of the current study can be seen as providing evidence for the theories introduced which emphasize the role that features play in the perception of objects and thus, the formation of object representations. These theories include Pandemonium Theory and Feature Integration Theory, as both theories stress that it the features of an object which are integral to the accurate perception of an object. Alternatively, theories which are model or template-based are not supported by the current study as the congruence of an objects target, which is a feature of the object, was a significant factor in maintaining the object representation.

Additionally the findings of the current study do not provide support for the Recognition-by-Components theory as the objects presented were not 3-

dimensional. Because they were not 3-dimensional and still resulted in accurate object perception and representation formation, it could be argued that object must not be 3- dimensional to be perceived accurately as an object.

In addition to the implications for object perception theory, there are numerous real world implications for the current study and the future research that will stem from this thesis. In particular, the results of the current study concerning dual task interference have significance in discussions of cell phone usage and work productivity.

The current research has consequences for the topic of cell phone usage while driving, which was introduced earlier in this document. Specifically, the results of the present experiment indicate that two tasks are not able to be performed simultaneously with as much accuracy and speed as those tasks performed one at a time. Thus, the results of the current study indicate that additional policies prohibiting the performance of secondary tasks while driving would be sound public policy as the results indicate that there would be a decrease in response time when performing an additional task while driving. For example, it would be expected that it would take a longer amount of time before braking at an obstacle when also using a cell phone versus not using a cell phone.

Similarly, the findings of the current study have implications for work place procedures regarding multi-tasking. Specifically, the decrease in accuracy during dual phase suggests that workplace productivity, as measured by a decrease in errors, could be increased by encouraging the completion of tasks

serially as opposed to simultaneously. For example, the dual task interference findings suggest that an air traffic controller would be more likely to make a mistake if he or she was also trying to complete a secondary task such as paperwork at the same time as monitoring the air field.

While the findings of the current study have implications for the presence of dual task interference in the performance of simultaneous tasks, they tell a somewhat different story regarding the formation and maintenance of object representations. Specifically, the presence of an object specific preview benefit during both single and dual phases for both Letter Task assignment groups, dorsal and ventral, suggests that object representations are robust in nature. Indeed, it is possible that the overall decrease in task performance from single to dual phase is due to allocation of cognitive resources to preserve object representations.

If it is the case that the maintenance of object representations takes priority over the secondary tasks used in the current study, additional research questions become relevant. For example, what types of secondary tasks, if any, would take precedence over the maintenance of object representations? In other words, what secondary tasks would lead to the sacrificing of object representations in order to achieve high accuracy or lower response times on the additional task? Another line of research spawned from the current study's findings concerning the maintenance of object representation would investigate the possibility of degrading the object representation by manipulating the attentional resources of experimental participants; perhaps by instructing

participants to direct their attention in specific ways, such as to devote 80% of attentional resources to performance of the letter task.

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APPENDICES

APPENDIX A

Table 3

Comparison of single task performance between the dorsal and ventral participants. There were no significant differences between the dorsal and ventral participant for the performance measures included in the analyses.

Single Task Performance Measure	Letter Task	Mean Value	Degrees of Freedom	<i>t</i>	Significance
Mean Accuracy for Letter Task*	Dorsal	.8053	74	1.011	.315
	Ventral	.7908			
Response Time for Letter Task*	Dorsal	624.3284	74	.718	.441
	Ventral	642.4826			
Mean Object Task Accuracy	Dorsal	.8358	74	1.39	.169
	Ventral	.7908			
Mean Object Task Response Time	Dorsal	397.5046	73**	.755	.441
	Ventral	378.2792			

APPENDIX B

Table 4

Comparison of fixation test performance between phases. Mean fixation test performance is based upon the use of the exclusion criteria outlined in the Results section. The final column indicates the number of participants which would have remained had a fixation test criterion of .75 been used for inclusion into the analyses.

Phase	Mean Fixation Test Performance	Standard Deviation	N	N with a Fixation Test Criterion of .75
Letter	.6817	.21519	76	30
Object	.8853	.14081	76	30
Dual	.7139	.22491	76	30
Overall	.7603	.15855	76	30

APPENDIX C

Table 5

Comparison of training to criterion Ns. There were no differences in letter phase performance between those participants who trained to criterion in under 300 trials and those who did not.

Letter Phase Measure*	Trained to Criterion?	N	Letter Phase Mean	Degrees of Freedom	<i>t</i>	Significance
Mean Letter Accuracy for Letter Phase	Yes (# of Trials less than 300)	46	.80	74	.339	.735
	No (# of Trials equal to 300)	30	.7950			
Mean Letter Response Time	Yes (# of Trials less than 300)	46	626.2661	74	.699	.486
	No (# of Trials equal to 300)	30	644.3527			

APPENDIX D

Table 6

Comparison of training to criterion between the dorsal and ventral participants. There was no significant difference in the mean number of trials in letter phase between the two participant groups, dorsal and ventral.

Letter Task	# of Participants who Trained to Criterion (< 300 trials)	Mean # of Trials in Letter Phase	Degrees of Freedom	<i>F</i>	Significance
Dorsal	21	259.18	1,74	.928	.339
Ventral	25	267.50			

APPENDIX E

Table 7

Results of the 4-factor ANOVA used to assess the effects of the two nuisance variables, Order and Hand/Key Condition, on Object Accuracy.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	F	Significance
Phase	1	.325	36.580	.000
Phase * LetterTask	1	.017	1.859	.178
Phase * Order	1	.013	1.474	.230
Phase * Hand/KeyCondition	3	.006	.695	.559
Phase * LetterTask * Order	1	.006	.665	.418
Phase * Order * Hand/KeyCondition	3	.002	.208	.890
Phase * Order * Hand/KeyCondition	3	.009	.999	.400
Phase * LetterTask * Order * Hand/KeyCondition	3	.015	1.675	.182
LetterTask	1	.026	.705	.404
Order	1	.048	1.318	.255
Hand/KeyCondition	3	.023	.634	.596
LetterTask * Order	1	.106	2.886	.095
LetterTask * Hand/KeyCondition	3	.047	1.276	.291
Order * Hand/KeyCondition	3	.011	.294	.829
LetterTask * Order * Hand/KeyCondition	3	.037	1.010	.395

APPENDIX F

Table 8

Results of the 4-factor ANOVA used to assess the effects of the two nuisance variables, Order and Hand/Key Condition, on Object Response Time.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	F	Significance
Phase	1	461787.295	72.209	.000
Phase * LetterTask	1	9565.536	1.496	.226
Phase * Order	1	15733.870	2.460	.122
Phase * Hand/KeyCondition	3	1649.262	.258	.855
Phase * LetterTask * Order	1	542.304	.085	.772
Phase * Order * Hand/KeyCondition	3	2184.026	.342	.795
Phase * Order * Hand/KeyCondition	3	4383.003	.685	.564
Phase * LetterTask * Order * Hand/KeyCondition	3	10140.268	1.586	.202
LetterTask	1	2780.863	.144	.706
Order	1	852.024	.044	.834
Hand/KeyCondition	3	51146.842	2.649	.057
LetterTask * Order	1	17304.583	.896	.348
LetterTask * Hand/KeyCondition	3	51792.530	2.682	.055
Order * Hand/KeyCondition	3	39278.329	2.034	.119
LetterTask * Order * Hand/KeyCondition	3	7874.288	.408	.748

APPENDIX G

Table 9

Results of the 4-factor ANOVA used to assess the effects of the two nuisance variables, Order and Hand/Key Condition, on Letter Accuracy.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	F	Significance
Phase	1	.702	57.537	.000
Phase * LetterTask	1	.012	.992	.323
Phase * Order	1	.010	.813	.371
Phase * Hand/KeyCondition	3	.009	.748	.528
Phase * LetterTask * Order	1	.000	.009	.923
Phase * Order * Hand/KeyCondition	3	.003	.254	.858
Phase * Order * Hand/KeyCondition	3	.024	1.981	.126
Phase * LetterTask * Order * Hand/KeyCondition	3	.006	.491	.690
LetterTask	1	.001	.042	.839
Order	1	.000	.029	.865
Hand/KeyCondition	3	.000	.026	.994
LetterTask * Order	1	.009	.593	.444
LetterTask * Hand/KeyCondition	3	.014	.929	.432
Order * Hand/KeyCondition	3	.019	1.232	.306
LetterTask * Order * Hand/KeyCondition	3	.006	.366	.778

APPENDIX H

Table 10

Results of the 4-factor ANOVA used to assess the effects of the two nuisance variables, Order and Hand/Key Condition on Letter Response Time.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	9437930.608	212.649	.000
Phase * LetterTask	1	39520.947	.890	.349
Phase * Order	1	7128.634	.161	.690
Phase * Hand/KeyCondition	3	34740.519	.783	.508
Phase * LetterTask * Order	1	17845.456	.402	.528
Phase * Order * Hand/KeyCondition	3	91986.196	2.073	.113
Phase * Order * Hand/KeyCondition	3	52575.723	1.185	.323
Phase * LetterTask * Order * Hand/KeyCondition	3	34921.693	.787	.506
LetterTask	1	101679.126	1.999	.163
Order	1	11693.690	.230	.633
Hand/KeyCondition	3	107644.748	2.117	.108
LetterTask * Order	1	25854.518	.508	.479
LetterTask * Hand/KeyCondition	3	120484.229	2.369	.080
Order * Hand/KeyCondition	3	42110.180	.828	.484
LetterTask * Order * Hand/KeyCondition	3	39906.423	.785	.507

APPENDIX I

Table 11

Results of the 5-factor ANOVA used to examine the effects of the nuisance variables, Order and Hand/Key Condition, on response times for object trial types in order to assess the object specific preview benefit.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	F	Significance
TargetCongruency	1	38452.982	11.969	.001
TargetCongruency * LetterTask	1	7107.958	2.212	.142
TargetCongruency * Order	1	3501.625	1.090	.301
TargetCongruency * Hand/KeyCondition	3	2138.099	.666	.577
TargetCongruency * LetterTask * Order	1	252.806	.079	.780
TargetCongruency * LetterTask * Hand/KeyCondition	3	2738.828	.853	.471
TargetCongruency * Order * Hand/KeyCondition	3	3585.377	1.116	.350
TargetCongruency * LetterTask * Order * Hand/KeyCondition	3	3724.726	1.159	.333
Phase	1	1031392.265	71.697	.000
Phase * LetterTask	1	23839.916	1.657	.203
Phase * Order	1	42541.364	2.957	.091
Phase * Hand/KeyCondition	3	6476.616	.450	.718
Phase * LetterTask * Order	1	1158.443	.081	.778
Phase * LetterTask * Hand/KeyCondition	3	2590.171	.180	.910
Phase * Order * Hand/KeyCondition	3	8716.218	.606	.614

Phase * LetterTask * Order * Hand/KeyCondition	3	19707.114	1.370	.261
TargetCongruency * Phase	1	1753.603	.831	.366
TargetCongruency * Phase * LetterTask	1	1854.201	.879	.352
TargetCongruency * Phase * Order	1	1764.086	.836	.364
TargetCongruency * Phase * Hand/KeyCondition	3	5216.141	2.473	.070
TargetCongruency * Phase * LetterTask * Order	1	373.007	.177	.676
TargetCongruency * Phase * LetterTask * Hand/KeyCondition	3	2863.774	1.357	.264
TargetCongruency * Phase * Order * Hand/KeyCondition	3	1586.436	.752	.526
TargetCongruency * Phase * LetterTask * Order * Hand/KeyCondition	3	2397.179	1.136	.342
LetterTask	1	370.590	.009	.923
Order	1	2.256	.000	.994
Hand/KeyCondition	3	110558.688	2.817	.047
LetterTask * Order	1	22346.323	.569	.453
LetterTask * Hand/KeyCondition	3	101822.147	2.595	.061
Order * Hand/KeyCondition	3	97913.663	2.495	.068
LetterTask * Order * Hand/KeyCondition	3	15546.421	.396	.756

APPENDIX J

Table 12

Results of the 2-Factor ANOVA used to examine the effect of Phase and Letter Task on accuracy on the Object Task.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	.318	35.928	.000
Phase * LetterTask	1	.022	2.437	.123
LetterTask	1	.038	1.031	.313

APPENDIX K

Table 13

Results of the 2-Factor ANOVA used to examine the effect of Phase and Letter Task on response times for the Object Task.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	444212.728	72.196	.000
Phase * LetterTask	1	9321.054	1.515	.222
LetterTask	1	448.376	.021	.886

APPENDIX L

Table 14

Results of the 2-Factor ANOVA used to examine the effect of Phase and Letter Task on accuracy on the Letter Task.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	.729	62.067	.000
Phase * LetterTask	1	.007	.612	.437
LetterTask	1	1.347E-5	.001	.975

APPENDIX M

Table 15

Results of the 2-Factor ANOVA used to examine the effect of Phase and Letter Task on response time on the letter task.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	9449845.463	210.179	.000
Phase * LetterTask	1	36454.844	.811	.371
LetterTask	1	91713.026	1.695	.197

APPENDIX N

Table 16

Results of the 2-Factor ANVOA used to examine the object phase data for the presence of an object specific preview benefit.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
TargetCongruency	1	10627.456	4.506	.037
TargetCongruency * LetterTask	1	948.234	.402	.528
LetterTask	1	8326.279	.360	.551

APPENDIX O

Table 17

Results of the 2-Factor ANOVA used to examine the dual phase data for the presence of an object specific preview benefit.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
TargetCongruency	1	28536.410	9.397	.003
TargetCongruency * LetterTask	1	7250.875	2.388	.127
LetterTask	1	8933.325	.252	.617

APPENDIX P

Table 18

Results of 4-Factor ANOVA for object trial types in order to assess the object specific preview benefit.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
TargetCongruency	1	28502.656	9.289	.003
TargetCongruency * LetterTask	1	9961.514	3.246	.076
Phase	1	931756.960	65.979	.000
Phase * LetterTask	1	23510.368	1.665	.201
TargetCongruency * Phase	1	2812.848	1.249	.268
TargetCongruency * Phase * LetterTask	1	911.474	.405	.527
LetterTask	1	78.698	.002	.967

APPENDIX Q

Table 19

Results of the 3-factor ANOVA used to examine the effects of Phase and Letter Task on the object specific preview benefit, as measured by a difference score.

Effect/Interaction Variables	Degrees of Freedom	Mean Square	<i>F</i>	Significance
Phase	1	5625.696	1.249	.268
Phase * LetterTask	1	1822.949	.405	.527
LetterTask	1	19923.027	3.246	.076

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