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Attenuating the Attentional Blink and its Consequences: Support for the Wyble-Bowman-Nieuwenstien model

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Abstract

When participants are asked to detect two targets (T1 and T2) in a stream of rapidly presented visual stimuli, T2 accuracy decreases when it follows T1 by 200 ms to 500 ms, a phenomenon known as the attentional blink (AB). Researchers have been attempting to attenuate the AB through experimental manipulations in order to understand temporal processing in the visual domain. Studies that have successfully attenuated the blink have often (but not always) done so using a concurrent task. One current model of visual temporal attention, the Wyble-Bowman-Nieuwenstien model (2009) suggests that a byproduct of the attenuation of the attentional blink would be that participants would be more likely to confuse the order in which the two targets appear (Swaps). This project uses a concurrent task manipulation to a) attempt to reduce the attentional blink and b) test whether the number of swaps increases when participants have to attend to two tasks as compared to 1. The findings after data filtering support the model in that there were significantly larger numbers of swaps that occurred during the concurrent task, relative to the control task, and that the blink was significantly attenuated. The implication of these findings for our understanding of visual temporal attention are discussed.

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Executive Summary

Rapid serial visual presentation (RSVP) is a commonly used experimental paradigm in which visual stimuli are flashed sequentially at a rapid rate (usually about 1 per 100 ms). This type of experiment allows researchers to examine individuals' ability to recognize items with a limited time restriction, and allows for the assessment of the limits of the visual system's ability to process sequential information.

But in the real world, people do not look at items flashing in front of their faces, or do they? Imagine a busy morning. You're late for work and you need to leave, but you cannot find your car keys. When you look at your kitchen counter your eyes dart from item to item- coffee mug, change, tissues, grocery list, keys, magnet, phone charger- until you realize you've seen your keys. Without realizing it, you've processed each item for a fraction of a section. This is exactly what an RSVP paradigm does. Put another way, it allows experimenters to measure a visual search, where people scan an image for a specific item, in time, rather than space.

One commonly used variation of an RSVP paradigm which allows us to examine visual cognition is known as the attentional blink (AB). Instead of having participants search for a single target in the visual stream, the AB task asks participants to detect and report 2 targets (T1 and T2) that are distinct from the distractors in some way (e.g. they could be a different color or from a different category). A typical AB finding is that subjects are worse at identifying the second target item when it follows the first by 200 ms to 500 ms compared to other timing parameters. This is measured through a computation (T2|T1) which indicates how well individuals identify T2 given that they have already correctly identified T2. That is, the conditional accuracy of T2 given correct identification of T1. One important thing to note here is that participants do not need to report the two targets in the correct order, and this reversal of reporting is referred to as a swap. A swap occurs when someone reports the first target item as the second target item (to appear in time) and vice versa, and is still counted as a correct response.

Recently, researchers have been attempting to attenuate the AB through experimental manipulations in order to understand the AB's role in cognition. Particularly, researchers have been successful at attenuating the blink by having participants complete a concurrent task which attenuates the depth of the blink. This seems counterintuitive, because if you are doing two things at once, one would expect performance to be worse. However, there are a handful of experiments that claim to attenuate the AB when subjects have to concentrate on two tasks instead of one (Taatgen et al 2008, Olivers and Nieuwenhuis 2006, Lapointe-Goupil et al 2011).

The Wyble-Bowman-Nieuwenstein (2009) model of visual cognition suggests that when the AB is attenuated (T2|T1 accuracies increase), participants should also have a higher occurrence of swaps because the segmentation size of incoming information is larger, leading to a higher probability that both target items appear in the same "chunk'. When this happens, temporal order is more difficult to distinguish. Put another way, this model suggests that if participants have increased T2|T1 accuracies, they will confuse the temporal order in which targets occurred.

To test the concurrent task manipulation, and to assess the veracity of the Wyble-Bowman-Nieuwenstein model, 93 participants completed two tasks in counterbalance order. In the control task, subjects completed a standard AB task on a background of a still frame of a "starfield". Based on Arend et al's original experiment (2006), a starfield attempts to replicate the flickering of stars. In the experimental manipulation, subjects had to complete the standard AB task, as well as detect the presence of a "superstar" ("|") among the "stars" ("o") of the starfield. The results of our study suggest significantly increased T2|T1 accuracies (attenuated AB) and increased number of swaps (where T1 is reported as T2) both in the experimental condition. This is consistent with the Wyble-Bowman-Nieuwenstein computational model, as well as our hypothesis.

This capstone attempts to examine the use of a concurrent task to attenuate the attentional blink. Moreover, it is the first to assess the consequences of attenuating the attentional blink (increasing T2|T1 accuracy) by specifically looking at the frequency of swaps across experimental and control conditions. Furthermore, both data analyses show either a significant effect or a trend towards an attenuated AB as well as an increase in swaps for the experimental condition. These data provide preliminary support for the Wyble-Bowman-Nieuwenstein model.

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Introduction

The Attentional Blink and its Correct Measurement. Rapid serial visual presentation (RSVP) is an experimental paradigm where visual stimuli are presented as a stream and in an extremely fast manner. Typically, an RSVP stream is presented to test participants' ability to detect a specific stimulus within the stream. Figure 1 shows three examples of the stimuli presented throughout the entire trial. In the first example, subjects were instructed to identify the green letters among black letters, in the second, letters among numbers, and finally, in the third, images depicting dinner foods. Most commonly, however, numbers are used as distractors and letters are used as targets. In the United States, these two categories of items are taught from a very young age, making these random array of lines easily identifiable from one another (Holmqvist & Tullgren 2009).

The RSVP paradigm allows researchers to test the temporal nature of attention. In a way, it can be seen as a visual search through time, rather than space (Raymond 1992). Jane Raymond, one of the original researchers examining the attentional blink using the RSVP paradigm, describes this comparison in more depth.

> It is commonly known that processing a single briefly exposed target is substantially easier than processing the same stimulus embedded in a stream of complex stimuli (Lawrence, 1971). In this sense, RSVP tasks may be viewed as visual search tasks operating in the temporal rather than the spatial domain. Just as visual search studies have been useful in

investigating how visual attentional may be distributed spatially (e.g., Triesman & Gelade, 1980), the RSVP procedure may be used to examine the temporal characteristics of perceptual and attentional processes. (Raymond et al 1992)

One of the key findings from the RSVP paradigm is the attentional blink (AB). The attentional blink is a psychological phenomenon in which someone trying to identify two targets in an RSVP stream, performs worse when the second target occurs between 200 and 500 ms after the first. Figure 2 shows typical results from an AB task. T2|T11 accuracy reflects participants' accuracy at identifying the second target item, given that they have already correctly identified the first target item. Typical AB data depicts a high initial accuracy (referred to as lag 1 sparing), followed by a significant dip in accuracy (known as the AB), and then an eventual recovery of performance.

Given Raymond's explanation of the RSVP stream of a temporal visual search, it is not hard to understand how this paradigm and the AB have direct implications to our everyday lives. Imagine searching for your lost car keys early one morning. You scan your kitchen counter and see your cell phone, garage door opener, a note from your roommate, a packet of tissues, a mug and finally you see your car keys, a water bottle, a coupon for a new restaurant- and after a moment, you come back to your car keys. Without realizing it, you scanned through each item and processed it individually, until you were able to identify a specific item among the clutter. Each item was the focus of attention for only a moment until the next succeeds the former. A key question that can be asked is: what happens when one is looking for two things at once?

Returning to our real world example, suppose you are now looking for your car keys and your cell phone. You see your coffee mug, a pile of papers, an apple, your grocery list, a fallen magnet, your car keys, your wallet, your cell phone, a crumpled up napkin- and then you recognize your keys. However, you still cannot find your cell phone. You continue searching, recanvasing the area. Your newspaper, your wallet, your phone, a crumpled up napkin- until you realize that you have seen your phone. The AB suggests that unless the two target items directly follow one another (more on this characteristic, known as “lag one sparring” later), a person is significantly less likely to identify T2 if it occurs between 200 and 500 ms after T1.

Experimenters need a way of referring to how far apart two stimuli in a stream are presented. They do this by creating a unit of time called “lag”. Lag refers to the distance an item is from another item.

Figure 3 illustrates the way in which a single trial is represented over time. In this example, ten stimuli are being presented. The two target items are the letters “L” and “M”, or T1 and T2 respectively, among number distractors. Time progresses from the bottom left of the figure to the top right; therefore, the first stimulus presented is “4” and the last stimulus presented is “3”. It is also noted that the time between any two stimuli in this particular example is 100 ms (as noted in the figure); therefore, each item is presented for 100 ms. Finally, it is apparent that the distance between T1 and T2 is a lag of 3 (the distance between "L" and "7", two consecutive stimuli, is a lag of 1).

The effect length, or the "duration", of the AB can be measured by computing subjects' accuracy of reporting the second target item at different lags. By comparing their accuracies at different time points, we can measure the duration (the number of lags over which there is a drop in accuracy) of the blink, as well as it severity (the accuracy drop for each lag) across depth. Furthermore, by collecting data on trials where T2 is presented at variable lags relative to T1, experimenters can compare identification accuracies at discrete distances. As noted earlier, the AB only occurs between 200 ms to 500 ms. Therefore, if each stimulus is presented for 100 ms, accuracies are normal at lag 1 (as this stimulus is replaced prior to the 200 ms mark, more commonly known as lag 1 sparing), are decreased between lags 2 to 5 (because they correspond to the 200 to 500 ms gap) and return to normal at lag 6 and up (as it has been more than 500 ms since T1 was presented).

Finally, in computing the depth of the AB, experimenters must calculate the frequency with which subjects correctly identified the T2. However, what happens in cases where the subject either does not see or incorrectly identifies T1? In these cases, experimenters are not actually measuring the effect of the blink because the blink represents a relative value. Therefore, it is critical that when computing T2 accuracy the accurate identification of T1 must be taken into account. Current practice states that a subject must correctly identify T1 for the frequency of T2 accuracies to be correctly measured; this instance when T2 accuracy is examined, given that T1 has been correctly reported, is called T2|T1 (spoken "T2 bar T1"). If subjects are poor at identifying T1, there is a smaller number of trials in which the experimenters can measure T2|T1. Therefore, T1 accuracies must also be computed and considered acceptable before T2|T1 accuracies, our true measure of the blink, can be analyzed.

Concurrent Task Manipulations as an Attempt to Attenuate the AB. Recently, researchers trying to understand the role and function of the attentional blink have attempted to lessen or attenuate it through experimental manipulation. By eliminating the AB, researchers hope to learn more about how visual attention works. More specifically, if experimenters can find a manipulation that eliminates the blink, researchers with computational models of the visual attention system can test their predictions and better adjust their models to the given results.

In an effort to eliminate the AB, researchers have begun including a second, simultaneous (or concurrent) task, which somewhat surprisingly, improves performance of identifying T2.

Below, I identify the pioneering papers that utilize concurrent task manipulations as an attempt to attenuate the AB. I will discuss a synopsis of the methods and findings as well as why they are important to the literature review. This is not to say that all of the following articles utilize a concurrent task method, although some of them do. The combination of these articles spans AB papers, visual search papers, experiments designed to test the concurrent task manipulation within and across modalities, as well as those that do not.

Concurrent Tasks: Detection Tasks. One of the best examples of a concurrent task manipulation is a paper by Taatgen, Juvina, Schipper, Borst and Martens (2008). In a "revolving dot task", subjects in the experimental condition must attend to an AB task at the center of the screen while a black dot revolves around the stream simultaneously; subjects in the control condition only report the identity of the two target items, while subjects in the experimental condition report both targets detect whether or not the revolving dot changed color at any point during the trial. Their results show a main effect of lag, specifically suggesting that when subjects must respond to both the two target items and the color change of the revolving dot, T2|T1 accuracy increases compared to the control group. Although Taatgen et al did not completely eliminate the blink, this paradigm shows a concrete example of an attenuated AB.

As useful as this is in describing the idea of concurrent tasks, this particular paradigm is subject to eye movements, which can affect the legitimacy of accuracy scores. This single, revolving dot has a set path which inevitably attracts eye movements. Therefore, if there is an eye movement during the presentation of a target item, subjects will not see the target item and this will result in illegitimate accuracy scores. However, if there was not a strong sense of motion to capture the eye, meaning more moving stimuli and therefore a less defined path of motion, eye movements would not be a concern.

It is common knowledge, as well as intuitive, that keeping the eyes fixated on a designated spot and responding to a stimulus in a secondary location is difficult for most individuals. In this light, this type of situation can be interpreted as a concurrent task. Similar to Taatgen et al's design, Wyble, Potter and Mattar (2011) created a paradigm which did just that. They had subjects stare at a central fixation point while an AB stream revolved in the periphery (similar to how Taatgen et al had the dot revolving around the AB stream). When the experimenters ran their analyses, they compared each of the T2|T1 accuracies across lag and found no significant difference, meaning that they had in fact managed to eliminate the AB (as can be seen in Figure 4). These two experiments allow us to deduce that when subjects attend to two different items, ironically, the probability that they will see T2 increases significantly. In Taatgen et al, attending to both the AB stream and the revolving dot led to a reduced AB, while in Wyble et al attending to both the AB stream and the fixation cross led to a reduced AB.

However, Wyble et al's experiment leads to the same limitation as Taatgen et al. If the stream revolves around a fixation cross, eye movements may lead to unreliable measures of target accuracy.

The two items involved in the concurrent task (AB stream and concurrent manipulation), however, do not both have to be of the visual domain. Lapointe-Goupil, Portin, Brisson and Tremblay (2011) developed a bimodal paradigm that successfully attenuated the AB. In this task, participants attended to a tone presented through headphones while also completing an AB task. At the end of each trial, participants in the experimental condition were asked to recreate the tone duration in addition to identifying both target items in the visual stream. In contrast, participants in the control condition only identified the two targets and ignore the sound all together. T2|T1 experimental accuracies (which can be seen in Figure 5) increase compared to control conditions, though they were not completely eliminated. While the aforementioned papers support the notion that when subjects attend to a concurrent task, T2|T1 accuracies increase even with an auditory stimulus. Therefore, this increase is not merely limited to the visual modality.

Olivers and Nieuwenhuis (2005) also used auditory stimuli. In this listen-to-music condition, participants listen to a music soundtrack while performing their AB task. In addition to identifying the targets, they must detect whether or not a yell was present in the music. Their analyses (Figure 6) show that this manipulation led to a dramatic increase in T2|T1 accuracies; Olivers and Nieuwenhuis even went so far as to suggest that the AB "virtually disappeared" (277). Again, we see that the stimuli are not bound to the visual domain, meaning that this attenuation is susceptible to a multimodal paradigm.

Concurrent Tasks: "Free Thinking" Instructions. In this same paper, Olivers and Nieuwenhuis include another condition which they called "free association". Participants randomly assigned to this condition were asked to think of a memory or an event they would be attending later, while completing the AB task. ANOVA analyses (Figure 6) show that T2|T1 accuracies significantly improved in this condition compared to the control condition.

A year later, Olivers and Nieuwenhuis published another paper on this subject. The first experiment approached their "free association" condition from a different perspective. In this paradigm subjects in control and experimental conditions performed a block of an AB task. At the end of the task, experimenters gave the control group similar instructions as before (concentrate as hard as you can) while the experimental group was told be "absent-minded" or treat the task with a "passive attitude". Analyses, presented in Figure 7, showed that the experimental group had significant improvements between blocks while the experimental group did not.

The problem with these two installments from Olivers and Nieuwenhuis is that these paradigms are unreliable and did not replicate well (DiLollo, personal communication). In other words, researchers from different labs have attempted to replicate these paradigms in an effort to reach the same results. However, some of these attempts have failed, producing no attenuation (DiLollo, personal communication).

Smilek, Enns, Eastwood and Merikle (2007) performed a very similar experiment to what Olivers and Nieuwenhuis explored, however, Smilek et al did not use an AB task. In a visual search task, participants search for some specific target item on the screen. Participants search for a target item; some received instructions to concentrate very hard while others were told to adopt a passive attitude. Analyses, available in Figure 8, reveal that reaction times (RT) for the experimental group (passive attitude) are significantly lower than the control group, suggesting that finding the target was easier with dispersed attentional resources. This article, though it does not use the AB paradigm, is important because it supports the notion that Olivers and Nieuwenhuis (2005) discovered that when attentional resources are dispersed, participants perform better. Furthermore, because the Olivers and Nieuwenhuis results could not be replicated, perhaps this means that this paradigm was not strong enough to continuously elicit the same, significant effects every time.

Concurrent Tasks: Memory Tasks. Olivers and Nieuwenhuis also included another experiment in their 2006 paper which involved a memory task. Prior to performing an AB task, participants viewed a line array. They then completed an AB trial, but prior to the start of the next trial, participants had to detect whether or not a presented line array was identical to the previous display. Analyses (pictured in Figure 9) show that subjects who had to remember the line array while performing the AB trial had higher T2|T1 accuracies than those in the control condition.

Smilek et al (2007) executed a similar paradigm as a visual search. Participants viewed a memory display followed by a visual search trial. Finally, they had to confirm or deny a memory display as identical to the one previously presented. Result, available in Figure 10, show that when participants had to remember the study display they had lower RTs, rendering them more efficient than control participants. These two manipulations are important because they show that a memory task is an effective concurrent manipulation for attenuation the AB.

However, Smilek et al's study, while lending support to an AB experiment measures visual search, rather than the blink. The Olivers and Nieuwenhuis experiment again proved unreliable, in that many groups have attempted to replicate these results and failed (DiLollo, personal communication). Yet with the support of ease of search with passive instructions from this visual search article, we can conclude again that the design of this paradigm was not strong enough for replication.

Replication. Arend Johnston and Shapiro's (2006) had participants view an AB stream at the center of a computer screen with a "starfield" in the background (a still frame from their study can be seen in Figure 11). The starfield was a black background with flickering "stars". In this experiment, control participants perform the AB task on a still frame from experimental condition, while participants in the experimental manipulation did completed a standard AB task on a flickering starfield background; subjects were given no instructions to attend to the starfield. Results from these experiments, illustrated in Figure 12, show that the experimental condition led to significantly better at identification of T2|T1 than the control condition, however, these results have not been replicated well (Wyble, personal communication). This study is important because it does not use a concurrent task manipulation; subjects were not required to interact with, monitor or even acknowledge the starfield, however, the blink was still attenuated. However, because there is not actually a concurrent task (subjects are not required to monitor the starfield), it is difficult to know what participants were actually doing (whether they were covertly looking at the starfield for example) it is difficult to draw conclusions from this paper. The goal of this capstone is to extend the Arend et al paradigm by using the same basic setup but asking participants to attend to detect whether a target ('superstar') appeared in a starfield presented around the visual stream, thus explicitly making the Arend task a concurrent one and to see whether this attenuated the AB. Further predictions were based on the Wyble-Bowman-Nieuwenstien model and are presented below.

The Effect of Cognitive Load. According to the Wyble-Bowman-Nieuwenstien (2009) computational model, the AB occurs because an individual's brain separates visual information into smaller, more manageable segments. Therefore, when a subject perceives T1, his brain is busy segmenting this piece of information to tag it as a target, If the T2 is presented during this processing timeframe, the brain "blinks", and as a result, T2 is not perceived. In a typical AB experiment, a subject can devote all of his cognitive resources to the task and continue segmenting in small chunks.

However, when a subject is given another task to perform simultaneously, the available resources remain constants and have to be divided between the two tasks. Because the full cognitive load cannot be designated to the single AB task, it is hypothesized that stimuli from the stream cannot be segmented as often, creating larger chunks of information for the brain to process. If this is true, subjects' ability to perceive the order of stimuli should be affected (as discrete time segments are not possible) (Wyble et al 2009); because of the increased number or stimuli in the perceived chunks, it is much more likely that T1 and T2 occur in a single chunk and that as a result the order of the stimuli are more likely to be confused, or swapped (ie T1 is reported as T2 and T2 is reported as T1).

Hypothesis. Given that the majority of experiments that have attenuated the AB had participants complete a concurrent task, we hypothesize that the AB would be attenuated in our concurrent task, compared to our control task in which participants performed only the AB target detection. Further, we hypothesized that there would be more swaps in the concurrent task relative to the control task.

Methods

Participants. Ninety-three (seventy-one female) Syracuse University students from an introductory psychology study pool participated in this experiment and were given class credit for their time. All subjects were fluent in English and had normal or corrected-to-normal vision.

Stimuli. In two different blocks with 180 trials each, subjects viewed a RSVP stream of 30 stimuli, including 2 target items. Stimuli were numbers and uppercase letters in 20 point Kartika font presented on a Windows machine with a 19 inch CRT monitor with a 75 Hz refresh rate. Stimuli were 1.5° x 1° of visual angel. MATLAB 2007a and Psychtoolbox 3 were used to execute the experiment. Stimulus onset asynchrony was 80 ms. Stimuli were black (RGB values 40, 40, 40) on a light grey background (RGB values 150, 150, 150). Block order was counter balanced.

Procedure. After signing a consent form outlying the risks and benefits of the study, participants sat down at a desk to complete the experiments. Subjects sat 50 cm away from the computer screen and completed both blocks of the experiment. In the control block, subjects had to correctly identify the two target letters among numbers in the RSVP stream. The target letters could be separated by a lag of 1, 2 or 10 items. In the experimental block, subjects had to complete this same task while simultaneously completing the concurrent task. The concurrent task had twenty "stars" ("o"'s) flashing in the periphery of the stream every time an item in the stream was presented. On twenty percent of the trials, a "superstar" ("|") appear among the stars. Subjects had to detect whether or not the superstar was present. Therefore, during the experimental block, subjects were required to complete two tasks (identify the two target items and detect the superstar). All procedures were approved by the Internal Review Board at Syracuse University.

MATLAB Code. This subheading attempts to relay the specific details of the experiment, as seen from a participant's perspective. Anyone wishing to read the full MATLAB script from this capstone should refer to appendix B.

To begin the experiment, each participant would fill out a demographic questionnaire screen. This questionnaire would ask subjects about age, gender, hand dominance, amount of time spent on a computer daily and amount of time spent playing video games daily.

Subjects would then see a gray screen with black letters giving instructions for this experiment:

> "In this experiment you will see rapidly flashing digits on the screen. There will be TWO letters on every trial, try to find them and enter them at the end of the trial. If you're not sure feel free to guess, but do not guess randomly if you have no idea what the letter was. Keep your eyes fixed on the center of the screen, and don't let them move. This task is easier if you keep your eyes still. Now please press Space to continue."

Each trial contained 28 digits and 2 target letters. Additionally, in the experimental trials, 30 stars appeared for each stimulus. The superstar occurred on 20% of the total trials.

Results

Analyses are presented as a function of lag (1, 3 and 10) and accuracy reflects percent correct (number of correct responses/total number of trials). All experimental trials where the superstar appeared, 36 of 180 trials, were removed from further analyses in the event that the identification of the superstar led to an AB of a target item.

The analyses reported in Figures 13 (Overall analysis) and 14 (Top 20) are T1 hit, T2|T1 hit and swaps. "T1 hit" is the accuracy of T1 report. "T2|T1 hit" is the percentage of times that subjects reported T2 correctly given that they had already reported T1 correctly. "Swaps" measures the percentage of times that subjects reported T1 as T2 and T2 as T1, given all of the trials in which they reported T1 and T2 correctly.

Demographic Information. Demographic information (Figure 15), including age, sex, handedness, daily time spent on a computer and daily time spent playing video games, was collected for each participant. Of the 93 subjects who participated, 71 were female (M = 76, S.D. = .427), 84 reported they were right handed (S.D. = .297), they spent an average of 4.62 hours on a computer daily (S.D. = 2.186), an average of .59 hours playing video games daily (S.D. = .2442) and had a mean age of 18.67 (S.D. = .993). A one way ANOVA with the demographic factors of video computer time etc and the dependent variable of gender was conducted. No gender differences were noted with the exception that males were more likely to play video games than females (F = 13.049, p = 0.001).

Testing for Order Effects. To test whether the order of task presentation made a difference with respect to task performance paired t-tests comparing the two control and the two experimental blocks were completed. No significant differences between T1 or T2|T2 measures overall and when separated out by lag (all significance was equal to or greater than .119 for both comparisons) were found for either the control task (T1 p = 0.307, T2|T1 p = 0.941) or the experimental task (T1 p = 0.894, T2|T1 p = 0.703). Because the blocks were not significantly different, all analyses are computed using data collapsed across blocks.

Overall Analyses. These analyses were computed using data collapsed across blocks, from all 93 subjects.

A repeated measures ANOVA of T1 accuracy with factors condition (control vs. experimental) and lag (1, 3 and 10), showed a significant difference of lag, F(2, 248) = 224.247, $p < 0.001$. Accuracy at lag 1 (M = 73.150, S.E. = 1.126) was lower than at lag 3 (M = 83.883, S.E. = 1.044) or 10 (M = 87.687, S.E. = 0.948), illustrating a characteristic pattern of competition between the two target items (Potter Staub & O'Connor 2002; Wyble, Bowman & Nieuwenstien 2009). A graph of lag across condition can be seen in Figure 16.

A repeated measures ANOVA was conducted for T2|T1 performance with the factors of condition (control vs. experimental) and lag (1, 3 and 10). There was a significant overall effect of lag, F (2, 248) = 50.833, $p < 0.001$, as well as a significant condition by lag interaction, F (2, 248) = 5.583, $p < 0.004$. Classic attentional blink characteristics were found, such that accuracy at lag 1 was high (M = 68.387, S.E. = 1.289), dropped significantly at lag 3 (M = 60.433, S.E. = 1.575) and recovered significantly at lag 10 (M = 71.540, S.E. = 1.543). Furthermore, there were significant differences between lag 1 and 3 ($p < 0.001$) as well as lag 3 and 10 ($p < 0.001$). For the control condition, significant differences in accuracy were found for each lag: lag 1 (M= 68.240, S.E. = 1.435), lag 3 (M = 59.467, S.E. = 1.720) and lag 10 (M = 73.280, S.E. = 1.744). Lag 1 and 3 were significantly different from each other ($p < 0.001$), as were lag 3 and 10 ($p < 0.001$). For the experimental condition, significant differences were found between lags 1 (M = 68.533, S.E. = 1.494) and 3 (M = 61.400, S.E. = 1.758) as well as lags 3 and 10 (M = 69.800, S.E. = 1.650), but not for lags 1 and 10. Lag 1 and 3 were significantly different from each other ($p < 0.001$), as were lag 3 and 10 ($p < 0.001$). A graph of lag across condition can be seen in Figure 17.

Finally, a Paired Samples T test was performed to assess the number of swaps across conditions and lag. Swaps were found to be significantly higher in the experimental condition at both lags 1 (experimental: M = 30.067, S.E. = 1.077; control: M = 23.653, S.E. = 0.816; $p < 0.001$) and 3 (experimental: M = 10.533, S.E. = 0.701; control: M = 7.920, S.E. = 0.499; $p < 0.001$), but not lag 10 (experimental: M = 0.967, S.E. = 0.172; control: M = 0.613, S.E. = 0.128; $p <$ 0.289). A graph of swaps across condition can be seen in Figure 18.

Top 20 Participant Analyses. Due to the poor accuracy scores from many of our participants, data were filtered to examine the performance of the participants with the highest accuracy on the superstar task. High performance accuracy on this task suggests that participants were doing the task correctly by attending to the concurrent task. For all participants, we measured the likelihood that they detected the superstar by calculating the number of hits (the number of times they correctly detected the superstar (P(hit)) minus the number of false alarms (the number of times participants reported seeing the superstar in the experimental block when it was not there (P(false alarm)). A scatterplot of these data suggested that 20 participants did very well and separated themselves as a function of performance from the others. Thus, the 20 participants with the best performance were then analyzed separately using the same measures as before.

A repeated measures ANOVA of T1 accuracy, with factors of condition and lag, was performed and found a significant difference of lag, $F (2, 38) = 29.030$, $p < 0.001$. Again, we found that accuracy at lag 1 (M = 83.042, S.E. = 1.790) was significantly lower than both lags 3 (M = 90.938, S.E. = 1.280) and lag 10 (M = 93.042, S.E. = 0.992), a characteristic T1 accuracy finding of competition between target items. Furthermore, lag 1 and 3 were significantly different from each other ($p < 0.001$), as were lag 3 and 10 ($p < 0.001$). A graph of lag across condition can be seen in Figure 19.

A repeated measures ANOVA was conducted for T2|T1 performance with the factors of condition and lag. There was a significant overall effect of lag, F (2, 38) = 11.079, $p < 0.001$, and a near significant condition by lag interaction, F (2, 38) = 3.190, $p < 0.052$. Classic attentional blink characteristics were found, such that accuracy at lag 1 was high (M = 80.270, S.E. = 1.812), dropped significantly at lag 3 (M = 73.937, S.E. = 2.868, $p < 0.029$) and recovered significantly at lag 10 (M = 84.895, S.E. = 1.460, $p < 0.002$). Furthermore, lag 1 and 3 were significantly different ($p < 0.029$), as were lag 3 and 10 ($p < 0.002$). For the control condition, significant differences were found at each lag: lag 1 (M = 79.500, S.E. = 2.336), lag 3 (M = 71.834, S.E. = 2.927) and lag 10 (M = 87.499, S.E. = 1.840). Lag 1 and 3 were significantly different ($p < 0.048$) as were lag 3 and 10 ($p < 0.001$). For the experimental condition, no significant differences were found across lag, suggesting that no AB was noted in these data: lag 1 (M = 81.041, S.E. = 2.351), lag 3 (M = 76.041, S.E. = 3.296, $p = .421$) and lag 10 (M = 82.292, S.E. = 2.025, $p = .305$). A graph of lag across condition can be seen in Figure 20.

Finally, a Paired Samples T test was performed to assess the comparison of swaps across conditions by lag. Swaps were found to be significantly higher in the experimental condition at lag 1 (experimental: M = 31.875, S.E. = 2.461; control: M = 24.833, S.E. = 2.129; $p < 0.014$), but not at lags 3 (experimental: M = 9.583, S.E. = 1.421; control: M = 7.667, S.E. = 1.235; $p < 0.213$) or lag 10 (experimental: M = 0.417, S.E. = 0.287; control: M = 0.333, S.E. = 0.22942; $p < 0.832$). A graph of swaps across condition can be seen in Figure 21.

Discussion

The aim of this capstone was to examine the concurrent task manipulation as a strategy to attenuate the AB, and furthermore, to use a combination of methodologies from the existing literature pool to create a new paradigm in order to test this manipulation.

At the time of this project's conception, the existing literature exhibited promising results from the concurrent task manipulation. However, their design was likely to cause unwanted to eye movements. This is problematic because such eye movements can interfere with correct identification of the target. This would lead to T2|T1 and T1 accuracy data that do not correctly reflect the ability of participants' attentional state. Furthermore, Arend et al's starfield manipulation eliminated eye movements, but did not include a concurrent task, and thus was not able to reliably attenuate the blink. Because of these shortcomings, this capstone combined characteristics from the previous literature to create a concurrent task manipulation without the possibility of eye movements.

With a paradigm devoid of eye movements and other confounds, the Wyble-Bowman-Nieuwenstien model predicts that a concurrent task should reduce the strength of the mechanism which causes and controls the blink. Put another way, the concurrent task forces the visual system to segment visual information less frequently, and therefore into larger chunks. Furthermore, any condition which attenuates the blink should have consequences. This particular model predicts that swaps will increase due to the higher probability of the two target items appearing within the same, large segmentation.

It may be easier to think of this mechanism like a video editor. Under normal conditions, as visual information is becoming available, the brain's video editor is cutting the important bits of visual information, editing it together and finally sending it to another part of the brain which evaluates this edited footage. This process is similar to creating a highlight reel; only important information is present. However, when the video editor must cut together his normal quota, as well as information about the concurrent task, the editor cannot cut the reel together as efficiently. But how can we evaluate declined efficiency? Some consequence must be present, and this model specifically suggests that an increase in the number of swaps would be one such consequence.

Our overall analysis of these data suggests that there was no significant attenuation in T2|T1 accuracy in the experimental group compared to the control group. However, we did find that there were significantly more swaps at lags 1 and 3 in the experimental condition than in the experimental condition, which is consistent with our hypothesis and the Wyble-Bowman-Nieuwenstien model.

In our analysis of the top 20 participants in our study, we found significant differences across all lags of the control group, indicative of classic attentional blink results. However, we found no significant difference across lag for the experimental group, suggesting that there was no AB in this condition, which is consistent with our hypothesis. Furthermore, we found significantly more swaps at lag 1 in the experimental condition relative to the control condition, which is partially consistent with our hypothesis because it only occurred at lag 1, rather than at lags 1 and 3.

To summarize, our overall analysis of participants showed insignificant T2|T1 attenuation at any lag of the experimental condition, however we found significant swaps at both lags 1 and 3 compared to the control condition. Our top 20 participant analysis showed significant attenuation of the AB across all lags of the experimental condition as well as a significant increase in swaps in the experimental condition at lag 1, but not at lag 3. However, if we look at the percent increase of T2|T1 accuracy across data sets we find the same trend. In our top 20 analysis, the percent change in performance of T2|T2 from lag 1 to lag 3 across conditions was a total of 2.66%, enough to warrant significance. In our overall analysis of T2|T1 accuracy, the percent change was 1.69%, in the same direction. That is, even though, the T2|T1 accuracy didn't reach significance in the overall analysis, the percent change between overall and top 20 were similar (i.e. the data were trending in the same direction and at similar magnitudes).

Furthermore, we can see the same pattern of percent change in swaps across data sets. In our overall analysis of swaps, the percent change from lag 1 to lag 3 was a difference of 3.8%, a significant value. In our top 20 analysis of swaps, the percent change was 5.125%, trending in the same direction of our overall analysis. Therefore, even though our overall analysis of T2|T1 accuracy and our top 20 analysis of swaps at lag 3 did not reach significance compared to their respective control condition, it should be noted that they trend similarly to results which did reach significance in a different data set with larger power.

Finally, during the data analysis of this capstone, Choi, Chang, Shibata, Sasaki and Watanabe (2012) published results of a complete attenuation of the AB. They created a training paradigm where T2 was presented in red text at lag 3 in every trial. At the beginning and end of each training session, the AB was measured for each participant using all uniform colored text (T2 was no longer red) to evaluate performance improvement. By the end of the first training session, the AB was completely eliminated.

With this type of training paradigm, participants are being taught a timing identification. That is, T2 was always salient at lag 3 and only at lag 3. Therefore, participants are learning at which time the second target will appear so as to be alert then. Returning to our video editor analogy, this training paradigm changes the editing itself, rather than the efficiency of the editor.

As a part of our discussion on future directions, we have discussed contacting Choi et al for an examination of their data. It is our belief that subjects will show an increased number in swaps, regardless of their use of a training paradigm rather than a concurrent task manipulation.

Furthermore, a possible limitation of our paradigm was the number of stars per trial. For each of the 30 stimuli presented during a trial, 20 stars were present. With this multitude of stars it may have appeared as one background changing, rather than individual, discrete stars moving. Restricting the number of stars for 3 or 4 stars per stimuli is worth considering as a future direction.

Given these limitations, it is still important to note the strengths of this particular paradigm. It combined characteristics from the existent literature, such as Taatgen et al's detection task and Arend et al's starfield, without compromising artifacts such as eye movements. Furthermore, this task limited subjects to a single modality, which keeps the task simple for the participants, but also for the machines to integrate channels.

All things considered, this capstone examined the use of a concurrent task to attenuate the attentional blink. Moreover, it was the first to assess the consequences of attenuating the attentional blink by specifically looking at the frequency of swaps across experimental and control conditions. Furthermore, both data analyses showed either a significant effect or a trend towards an attenuated AB as well as an increase in swaps for the experimental condition. These data provide preliminary support for the Wyble-Bowman-Nieuwenstein model.

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Appendix A: Figures

Figure 1: RSVP stream presented across time

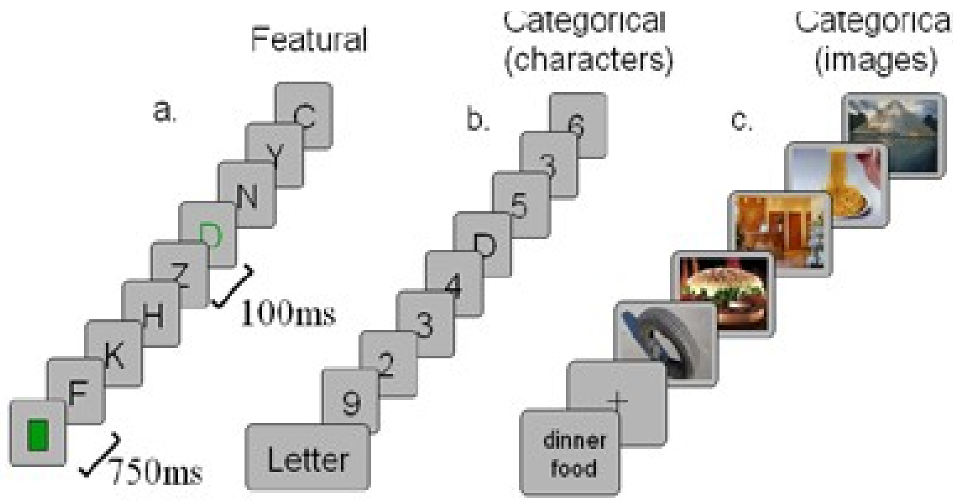

Figure 1: Examples of three RSVP streams containing targets specified by **(a)** featural (e.g. color), **(b)** categorical (e.g.

Figure 2: Graph results of a standard AB

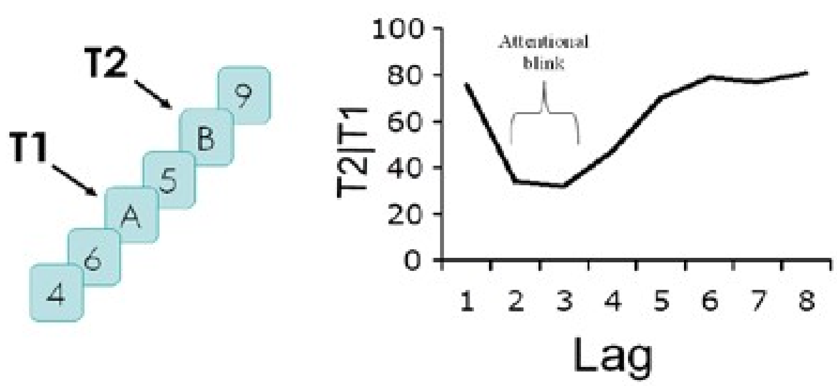

Figure 2: RSVP stream with two targets at a lag of 2. In this case, targets are specified by category. Attentional blink effect from Chun & Potter 1995. The data illustrate a time window of 200 -500ms following the T1 during which report of the second target is impaired in typically developing adult.

Figure 3: Illustration of critical AB characteristics

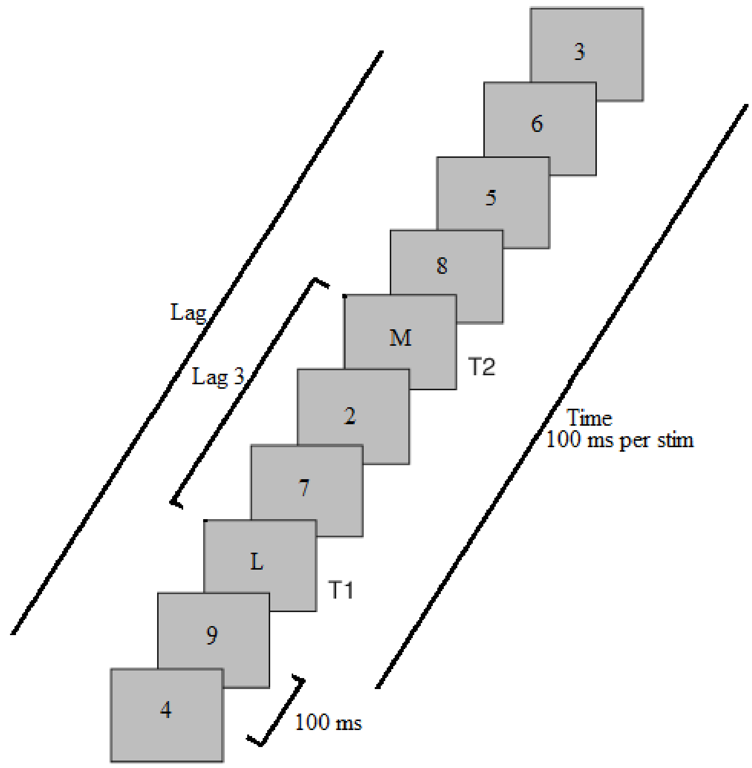

Figure 4: Wyble et al T2|T1 results

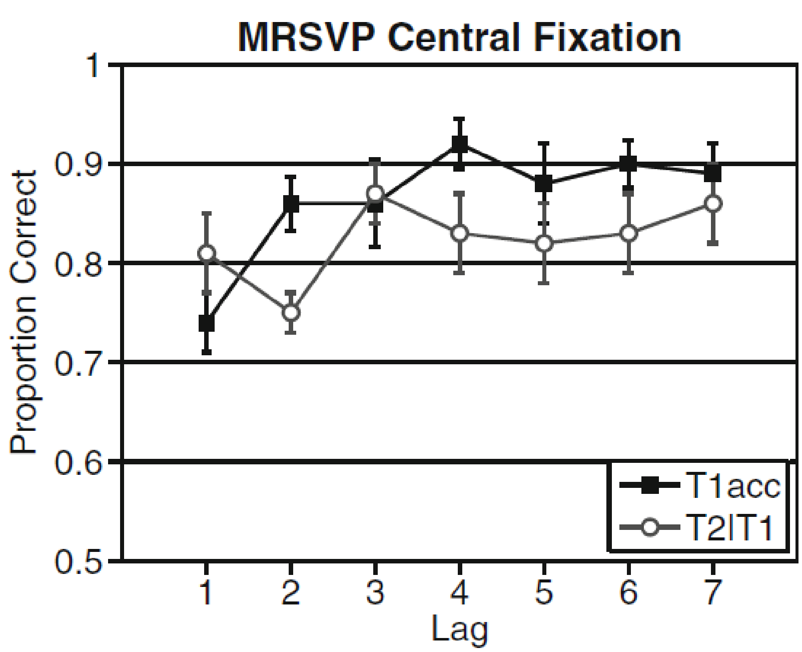

Figure 5: Lapointe-Goupil et al T2|T1 results

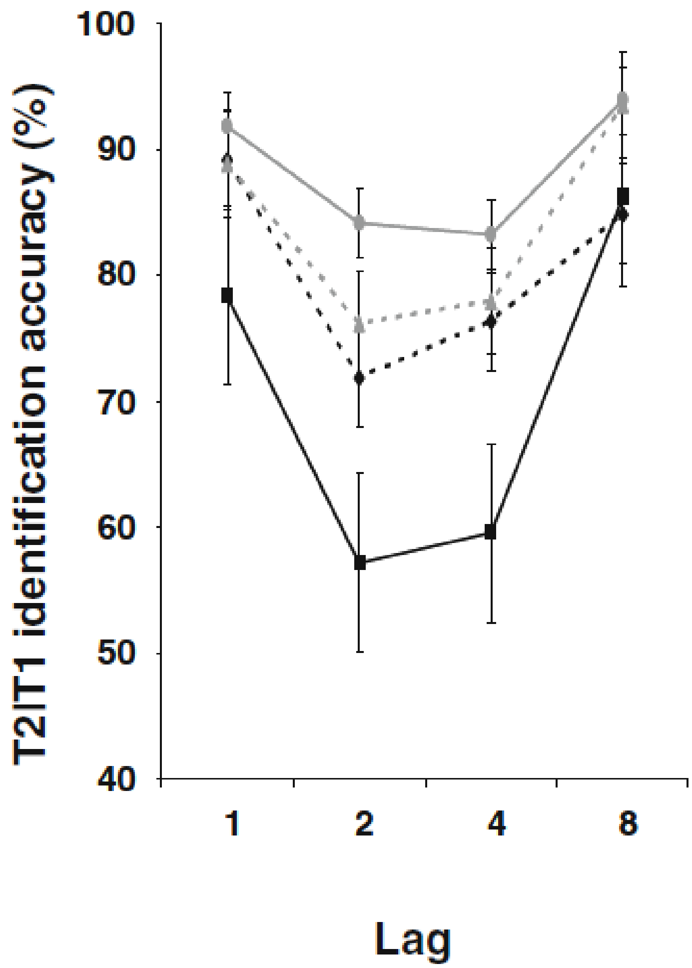

Figure 6: Olivers and Nieuwenhuis (2005) “free association” and “listen-to-music” results

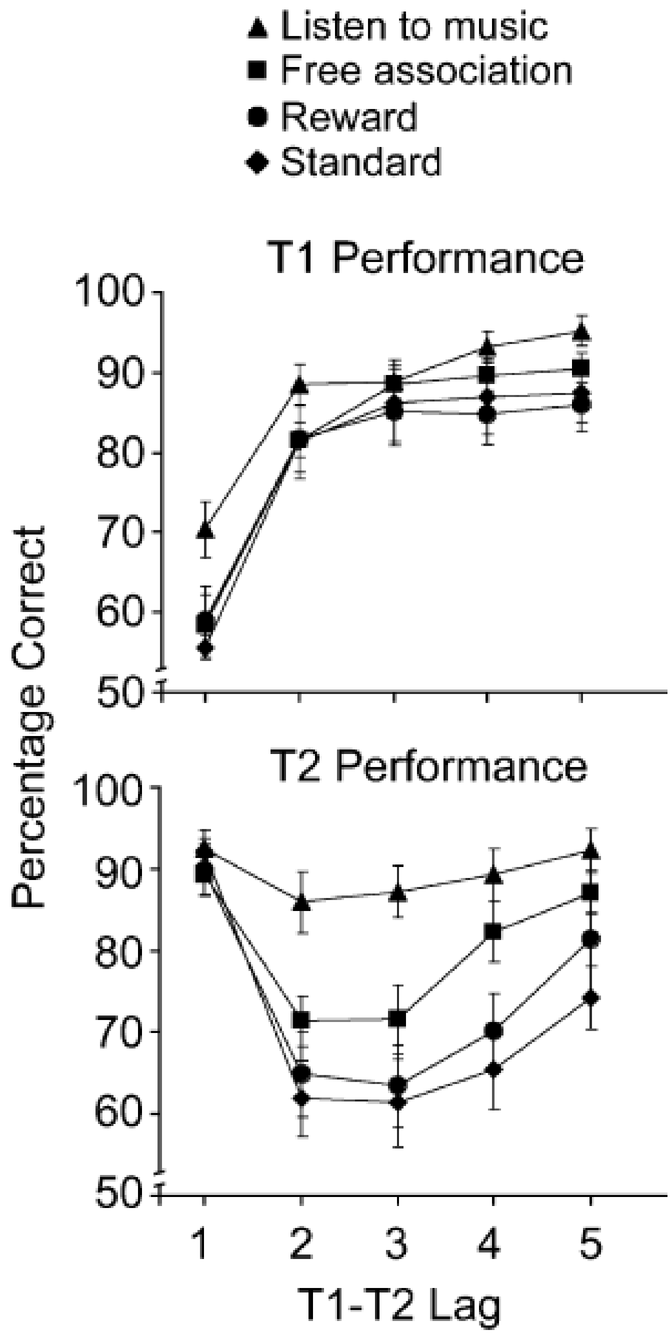

Figure 7: Olivers and Nieuwenhuis (2006) differing instructions T2|T1 results

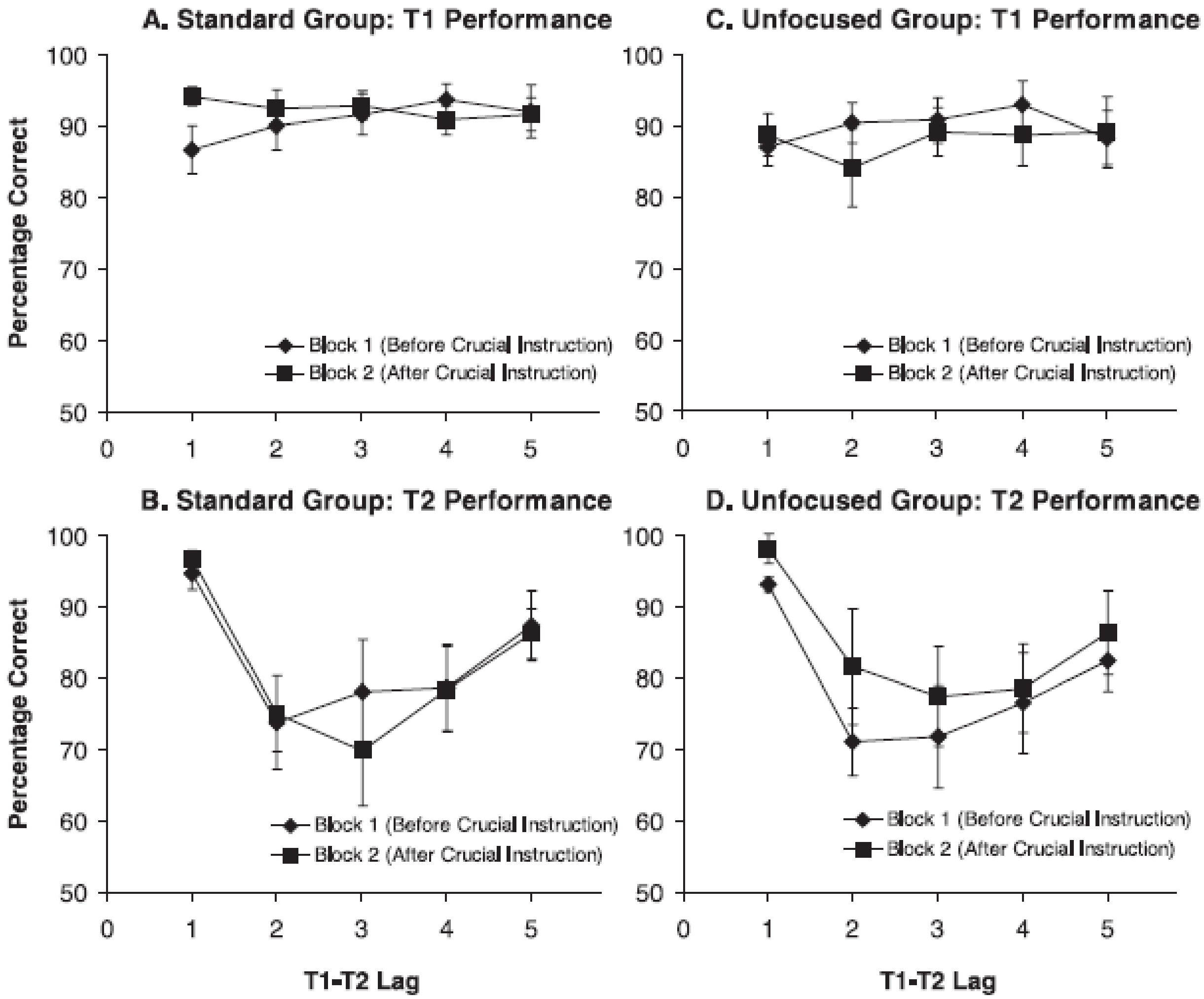

Figure 8: Smilek et al differing instructions RT results

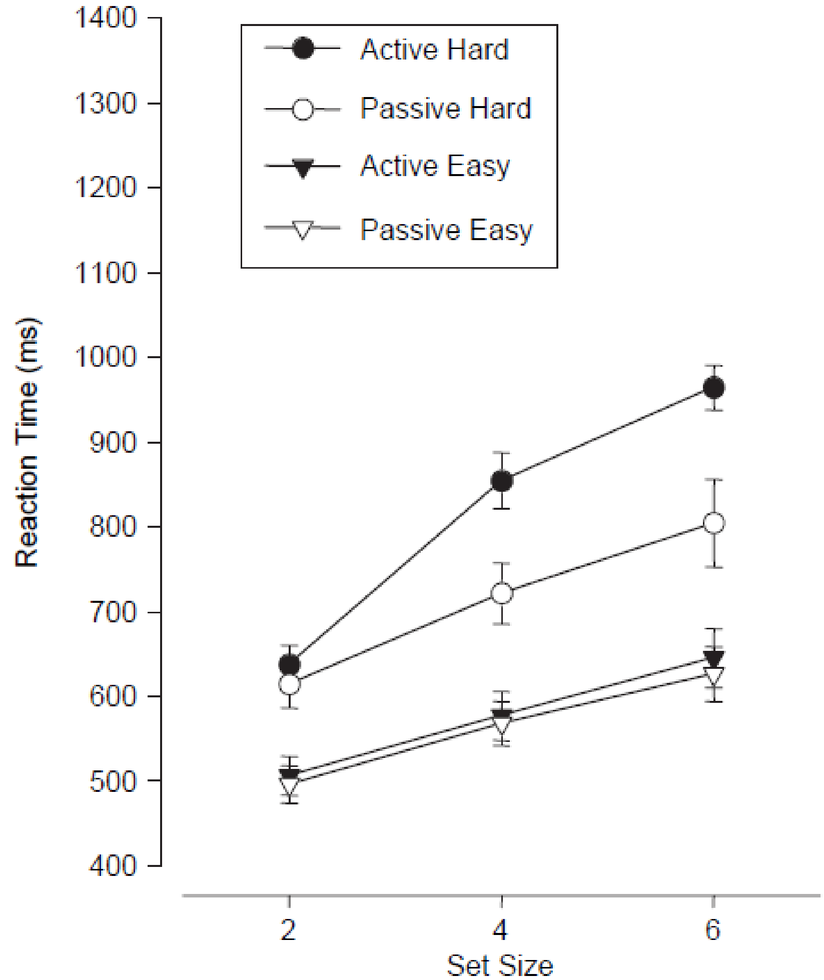

Figure 9: Olivers and Nieuwenhuis line array T2|T1 results

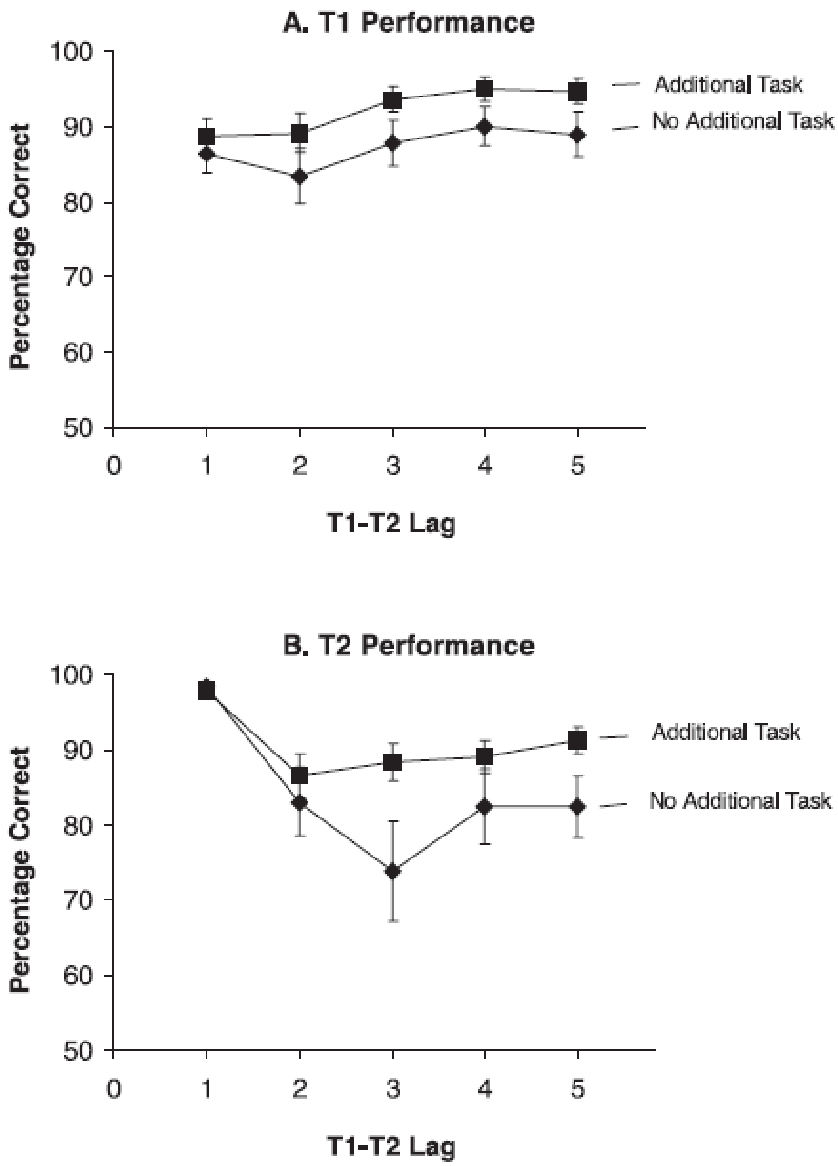

Figure 10: Smilek et al memory task RT results

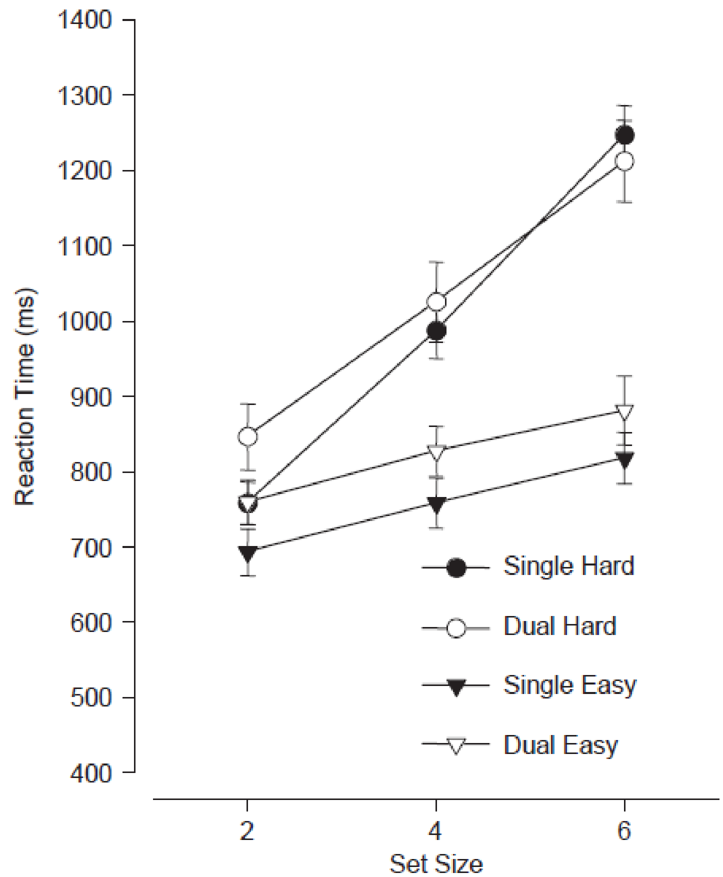

Figure 11: Arend et al still of "stairfield"

Figure 12: Arend et al T2|T1 results

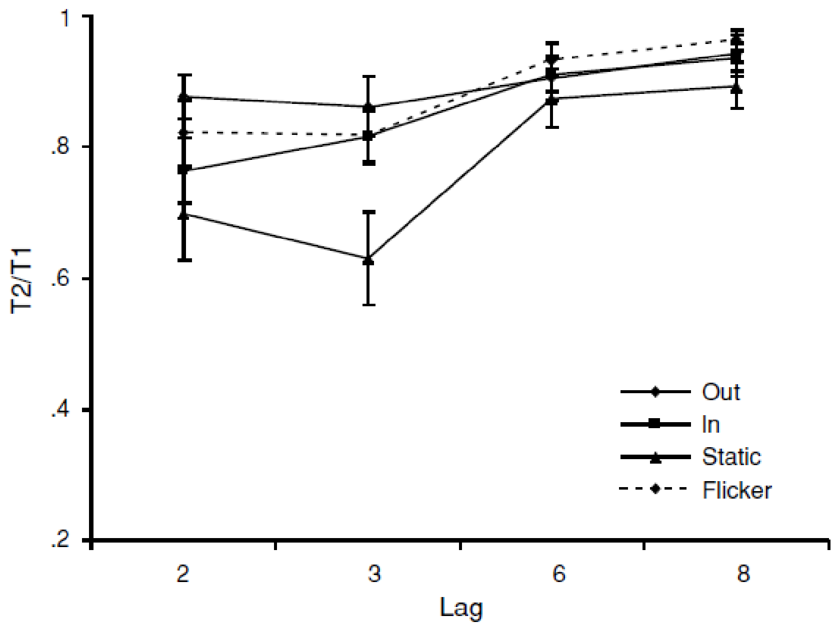

Figure 13: Overall data analysis summary table

	Con	Exp
T1(1)	73.1	73.2
T1(3)	85.1	82.7
T1(10)	88.9	86.5
T2|T1(1)	68.2	68.5
T2|T1(3)	59.5	61.8
T2|T1(10)	73.3	69.3
Swaps(1)	23.7	30.1
Swaps(3)	7.9	10.5
Swaps(10)	0.6	1

Figure 14: Top 20 data analysis summary table

	Con	Exp
T1(1)	82.3	83.8
T1(3)	92.5	89.4
T1(10)	94.8	91.3
T2|T1(1)	79.5	81
T2|T1(3)	71.8	76
T2|T1(10)	87.5	82.3
Swaps(1)	24.8	31.9
Swaps(3)	7.7	9.6
Swaps(10)	0.3	0.4

Figure 15: Demographic information table

	Age	Computer	Games
Mean	18.67	4.62	0.59
Std. Dev.	0.993	2.186	0.2442

Figure 16: Overall analysis T1 results

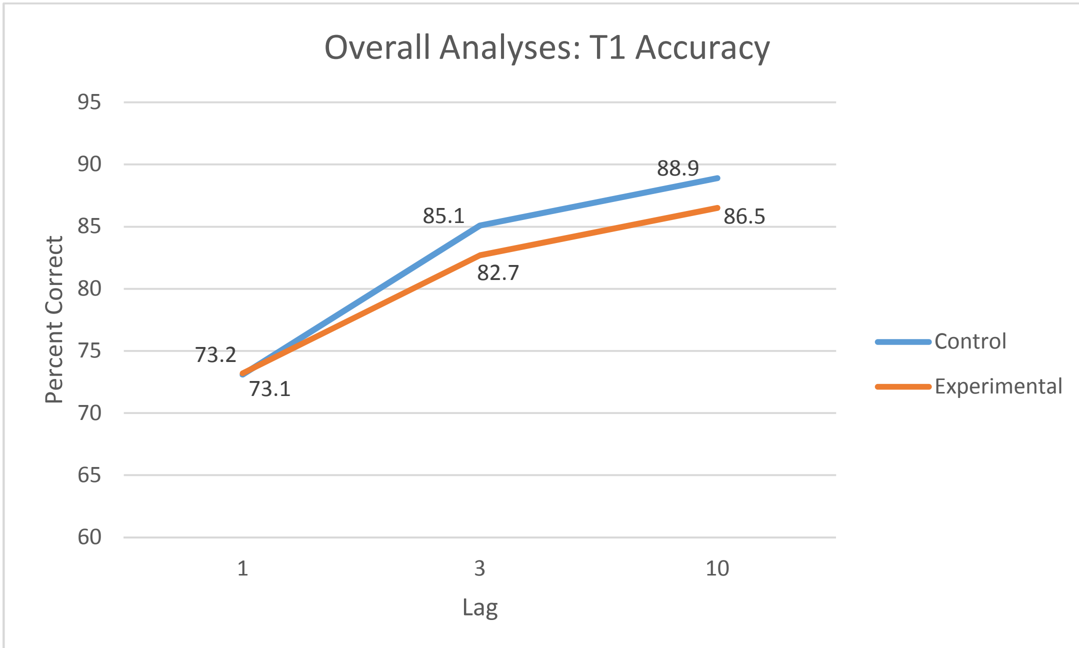

Figure 17: Overall analysis T2|T1 results

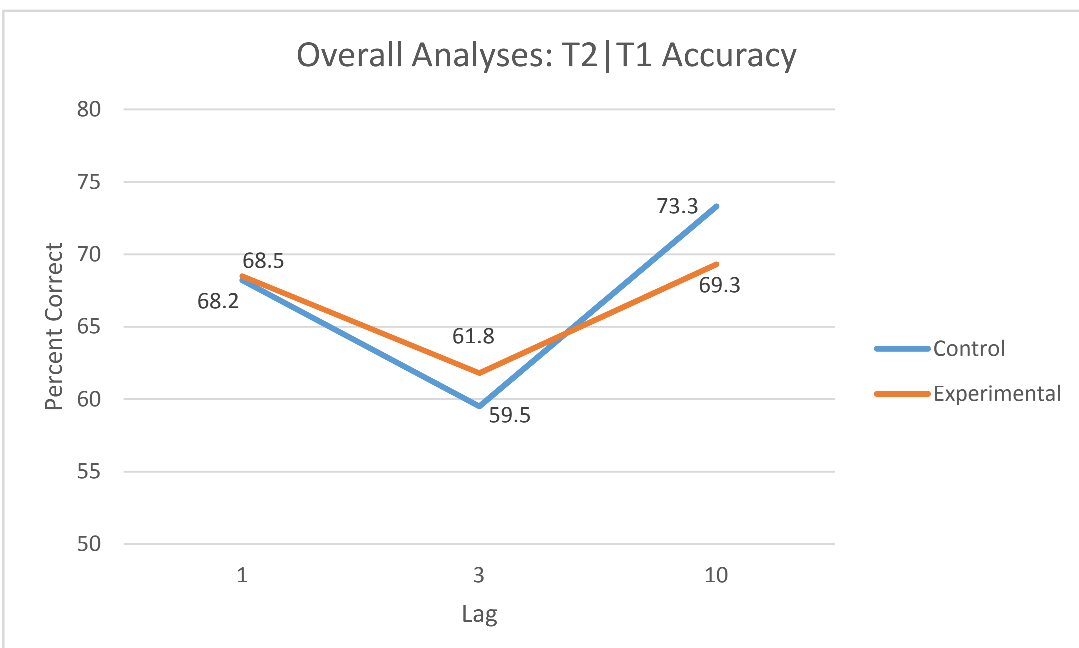

Figure 18: Overall analysis swaps results

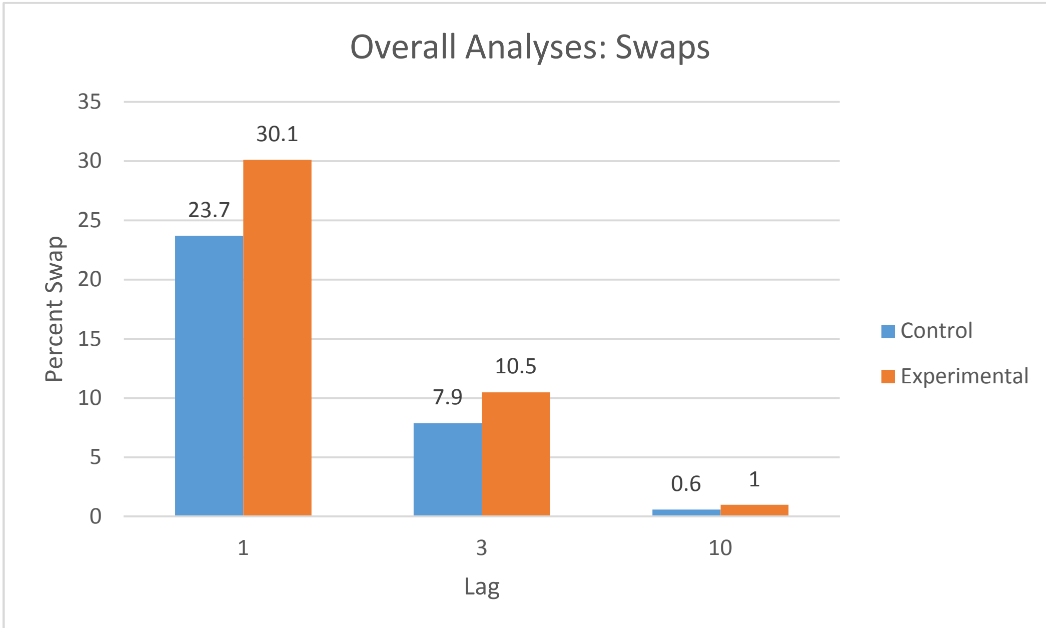

Figure 19: Top 20 analysis T1 results

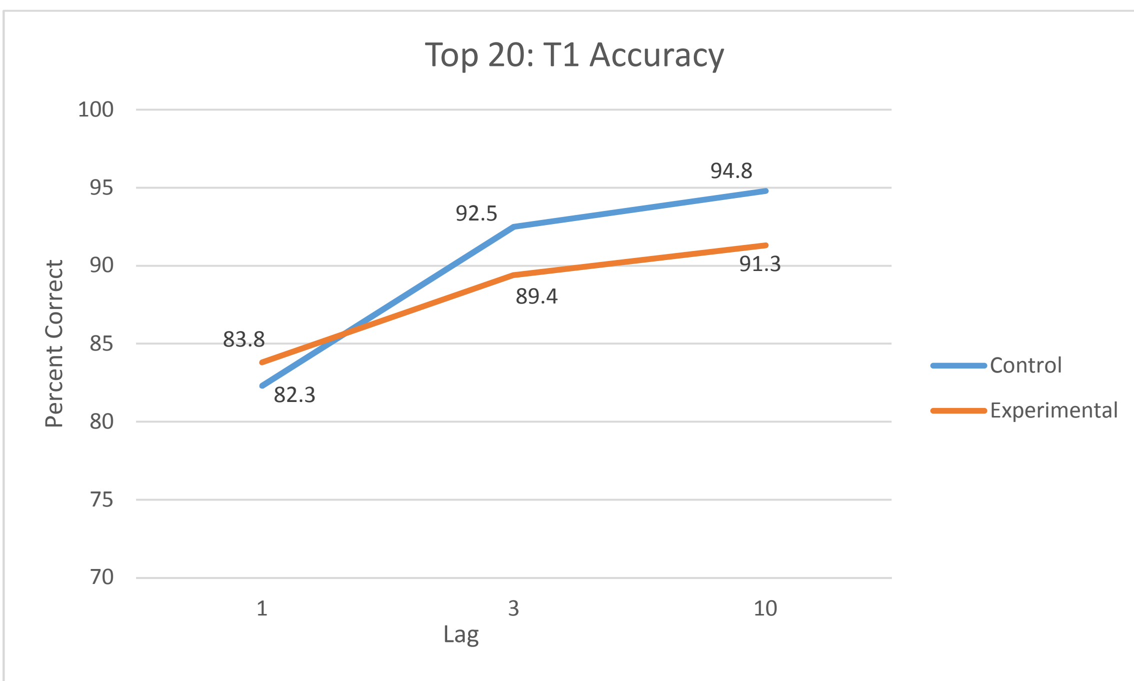

Figure 20: Top 20 analysis T2|T1 results

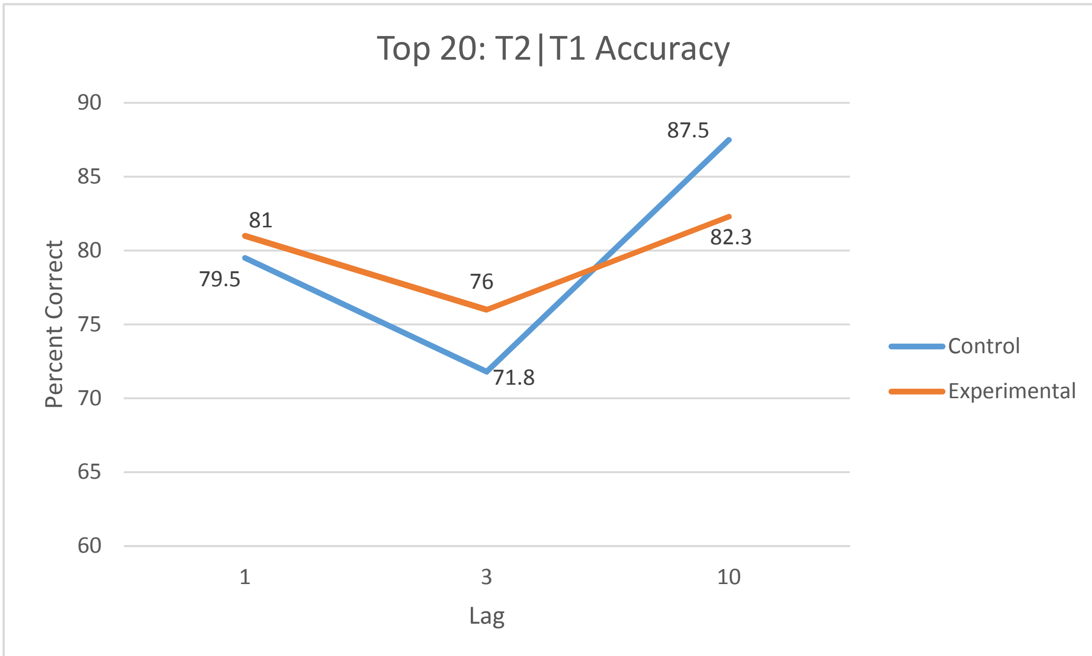

Figure 21: top 20 analysis swap results

Appendix B: MATLAB Code

```
function [Numtrials Events Condition Parameters Stimuli_sets
Responses carryover]=Tutorial4(Parameters, Stimuli_sets, trial,
blocknum, modeflag,Condition,carryover)



%to visualize the timing

% plot(Userdata.Blocks(1).Trials(2).Events.timepasted')





%Set these to default values


Responses=0;

Numtrials = 0;

Events = [];


if strcmp(modeflag,'InitializeBlock');


    Parameters.speedoptimized = 1;



%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%

    %RSVP Experiment.


    a = fopen('Tutorial4instructions.txt','r');


    instructions = fscanf (a,'%c');

    fontsize = 20;
```

```
    font = 'Kartika';

    Screen('TextSize',Parameters.window,fontsize);

    Screen('TextFont',Parameters.window,font);


    %put the instructions on the screen

    [nx, ny, bbox] = DrawFormattedText(Parameters.window,
instructions, 'center',
'center',[0,0,0],Parameters.instructionwidth);

    Screen('Flip',Parameters.window);

    %and then wait for a keypress

    waitforspace();


    briefmessage(Parameters,'Preparing
Stimuli','','Kartika',32,0,0,.1);




    %Stimset #1:  fixation cross and end of stream mask using
Text mode

    stimlist = {'+'};

    Stimuli_sets(1) =
Preparestimuli(Parameters,2,stimlist,'Arial',30,[0,0,0],0,0);


    %Stimset #2:  Set of 16 capital letters, using Text mode

    stimlist =
{'R','L','C','P','F','K','B','G','Y','V','H','X','T','J','D','N'}
;

    Stimuli_sets(2) =
Preparestimuli(Parameters,2,stimlist,'Arial',30,[0,0,0],0,0,1);


    %Stimset #3: Set of 8 digits using Text mode

    stimlist = {'2','3','4','5','6','7','8','9'};

    Stimuli_sets(3) =
Preparestimuli(Parameters,2,stimlist,'Arial',30,[0,0,0],0,0,1);


    %Stimlist #4: dot or comma stimulus
```

```
    stimlist = {',','.','o','O','|'};

    Stimuli_sets(4) =
Preparestimuli(Parameters,2,stimlist,'Kartika',30,[0,0,0],0,0,0);




    Numtrials = 180;


    % This is creating a combination of different possiblities
given

    % the numbers. As it stands, Condition is a 3*32 matrix

    % So Condition(5,1) is the value of Factor1(Xval) on trial 5

    %Factor1 (Xval) is the position in the stream when the first
target

    %Factor2 (Yval) is the position in the stream when the second
target relative to the first

    %Factor3 (Zval) is unused




    Condition = SetupFactorial(Numtrials,  [1 0 0 0 0],[1 2
10],[1 0]);   %Set up the factorial design, returns a randomly
shuffled set of trials




elseif strcmp(modeflag,'InitializeTrial');


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%


    %targets are letters
```

```
    %digits are distractors


    %Parameters

    Distractorset = 3;    %which stimulus set containing the
distractors  in the RSVP

    Targetset = 2;        %stimulus set containing the targets
in the RSVP

    dset = Stimuli_sets(Distractorset); %isolate the set of
distractors

    dlength = length(dset.stimnames);        %find the number of
distractors

    tset = Stimuli_sets(Targetset);   %which stimulus set are the
targets

    numtargets = length(tset.stimnames);   %and how many targets
are there?

    startdelay = .3;

    frametime = 6;  %number of frames for each stimulus... change
this to modify the SOA


    itemduration = Parameters.fliptime * frametime;  %how long
(seconds) is each stimulus on the screen     Will resort to a
minimum of 1 refresh cycle


    triallength = 30;   %number of Stimuli not including the mask
and fixation cross

    fixduration = .3;   %fixation duration


    locx = Parameters.centerx;

    locy = Parameters.centery;


    %set up the factors for this to stream paradigm

    % First factor = T1 position

    % second factor = lag

    % Third factor is unused
```

```
    % This for loop creates sets up the combination of stimulus
sets to be
    % used



    %Setup the distractors in the stream
    %for the entire RSVP, assign the distractor set

    for(i = 1:triallength)
        itemx(i) = locx; % Putting the target in the center of
the X-axis according to the screen
        itemy(i) = locy; % Putting the target in the center of
the Y-axis according to the screen
        stimsets(i) = Distractorset;
        stimnums(i) = ceil(rand*dlength); % Stimnums is the
position (1-8) in the vector.
        % The corresponding number in that position is displayed.
        if i>1
            while stimnums(i) == stimnums(i-1) % Sequential
distractors are not the same.
                stimnums(i) = ceil(rand*dlength)
            end
        end
        % 'rand' generates a random number from (0,1)
        % 'ceil' brings the number to the next integer in the
        % direction of positive infinity.
        % Therefore this is basically selecting a random
character from the
        % Distractorset and setting it in the stimsets matrix
    end



    T1spot = ceil(rand*8)+7;    % Setting up T1 spot as a matrix
```

```
    T2spot = T1spot + Condition(2,trial); % Setting up T2 spot to
occur after T1

    showsuperstar = Condition(1,trial);
    showstars = Condition(3,trial);

    %specify the targets by stimulus set number
    stimsets( T1spot) = Targetset;
    stimsets( T2spot) = Targetset;

    %and the identity of the targets
    stimnums( T1spot) = ceil(rand*numtargets);

    if(Condition(2,trial)> 0)
        stimnums( T2spot) = ceil(rand*numtargets);
        while stimnums( T2spot) == stimnums( T1spot) % Sequential
distractors are not the same.
            stimnums( T2spot) = ceil(rand*numtargets);
        end
    end

    %randomly determine whether to show a dot or comma on this
trial
    dotcomma = ceil(rand*2);

    Events =
newevent_show_stimulus(Events,1,1,locx,locy,startdelay,'screensho
t_no','clear_yes');   %add the fixation cross

    event_time = Events.time(1);

    starcount =0;
```

```
    randstartime = ceil(rand*triallength);


    for (i = 1:triallength)

        %howmanystars = ceil(rand*2)+1;

        howmanystars = 20;

        for (w = 1:howmanystars)

            starcount = starcount + 1;

            startime(starcount) = i;

            numx(starcount) = (round(rand)- .5)*2;
            numy(starcount) = (round(rand)- .5)*2;

        end

    end

    randstarcount = ceil(rand*starcount)


    % Start of each trial
    for(item = 1:triallength)    %add the rest of the events by
going through numlist in order

        if(item ==1)
```

```
            event_time = event_time + fixduration;
        else
            event_time = event_time + itemduration;
        end

        Events
=newevent_show_stimulus(Events,stimsets(item),stimnums(item),item
x(item),itemy(item),event_time,'screenshot_no','clear_yes');
        % Displaying the items in the trial




        if(showstars == 1)
            for (i = 1:starcount)
                if item == startime(i)
                    Events
=newevent_show_stimulus(Events,4,3,((rand*285 +
15)*numx(i))+locx,((rand*285 +
15)*numy(i))+locy,event_time,'screenshot_no','clear_no');
                    %display star
                end
            end

            if(showsuperstar)
                if item == randstartime
                    Events
=newevent_show_stimulus(Events,4,5,(rand*300*numx(randstarcount))
+locx,(rand*300*numy(randstarcount))+locy,event_time,'screenshot_
no','clear_no');
                end
            end
            %display star
        end
```

```
    end

    event_time = event_time+itemduration;

    %Events =
newevent_show_stimulus(Events,4,dotcomma,locx,locy,event_time,'sc
reenshot_no','clear_yes');

    % Displaying the dot or comma at the end of displaying the
letters and numbers

    event_time = event_time+itemduration;

    Events = newevent_end_trial(Events,event_time);

    %specify the feedback string

    s = sprintf('Targets were:
%c',Stimuli_sets(stimsets(T1spot)).stimnames{stimnums(T1spot)});
%create the text feedback

    if(T2spot > T1spot)

        s = sprintf('%s, %c',s,
Stimuli_sets(stimsets(T2spot)).stimnames{stimnums(T2spot)});

    end

    Events.feedback =s;

    carryover.feedback = s;

    %Save all of these variables

    Events.dotcomma = dotcomma;

    Events.T1spot = T1spot;

    Events.T2spot = T2spot;

    Events.T1 = stimnums(T1spot);

    Events.T2 = stimnums(T2spot);
```

```
elseif strcmp(modeflag,'EndTrial' );



    %ask for two questions at the end  of each trial

    [R1 typing] = userresponse(Parameters,'What letters did you
see?',60,'abcdefghijklmnopqrstuvwxyz',{},0,2,'Kartika',32);

    Responses.letter = R1;


    [R2 typing] = userresponse(Parameters,'Did you see a |
?',60,'yn',{},1,1,'Kartika',32);

    Responses.star = R2;




briefmessage(Parameters,carryover.feedback,'','Kartika',24,0,0,1.
5);




elseif strcmp(modeflag,'EndBlock');


    briefmessage(Parameters,'This concludes the RSVP
block','','Kartika',24,0,0,1.5);


else

    error('Invalid modeflag');

end

end
```