ABSTRACT

WELK, ALLAIRE KRISTEN. In Sight but out of Mind? The Effect of Semantic Features on Unexpected Event Detection in an Inattentional Dual Task Paradigm. (Under the direction of Dr. Douglas Gillan.)

Inattentional blindness research suggests that individuals are not “blind” to unexpected events; instead, unexpected information is perceived and processed, and can reach attention, based on the information contained within these events. Factors that have been shown to influence further processing and subsequent attention include luminance (Most, Simons, Scholl, and Chabris, 2000) and color (Welk, Creager, and Gillan, 2014). The current research examined how semantic content of unexpected events influenced the processing of these events in an inattentional dual task. Participants performed a dynamic, computer-based visual task, in which unexpected events occasionally occurred; semantic relevance of these unexpected events was manipulated across trials. Results indicated that the degree of semantic relatedness of unexpected events did not significantly affect primary task performance or the detection of unexpected events. This suggests that semantic content is processed differently from perceptual content in a visual inattention task. The authors propose that the processing of semantic information in visual inattention tasks may be analogous to the processing that takes place in dichotic listening tasks; specifically that the processing of semantic content may be more dependent on the availability of attentional resources than perceptual content. Future directions are discussed.
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In Sight but out of Mind? The Effect of Semantic Features on Unexpected Event Detection in an Inattentional Dual Task Paradigm.

by
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A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Master of Science

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BIOGRAPHY

Allaire K. Welk is a doctoral student in North Carolina State University’s Human Factors and Applied Cognition program in the Psychology Department. Welk received an undergraduate degree in Psychology with a minor in French with Summa Cum Laude honors from North Carolina State University in 2013. Prior to attending graduate school, Welk accepted an internship through the Naval Research Enterprise Internship Program. Within graduate school, Welk developed a paradigm for studying inattentional blindness on a trial-by-trial basis, and participated in cybersecurity research funded by the National Security Agency and decision-making research funded by the Laboratory for Analytic Sciences. In her spare time, Welk enjoys running excessively long distances, working with her family’s Thoroughbred racehorses, and playing with her Army dropout K9: Cairo.
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INTRODUCTION

You are walking across North Carolina State University’s campus to Jimmy John’s for lunch, while maintaining a telephone conversation with a friend; you are engaged in a gripping conversation about the events of your day. When you arrive at your destination, the cashier asks your opinion regarding the unicycling clown that you walked past on your trek across campus. You are shocked. How did you fail to notice this highly salient, unexpected event?

“To see or not to see: that is the question” (Mack & Rock, 1998). How is it possible to look directly at an object but report not seeing it? Inattentional blindness is a cognitive phenomenon that occurs when valuable attentional resources are expended on a challenging primary task; this attentional exertion can result in a lack of remaining resources, causing a failure to notice unexpected events or objects even when they are located in an individual's direct visual path (Mack & Rock, 1998).

Previous inattentional blindness research has aimed to illustrate the power and prevalence of this phenomenon. Hyman, Boss, Wise, McKenzie, and Caggiano (2010) demonstrated a highly salient example of inattentional blindness at Western Washington University. Participants were placed in the aforementioned scenario: they were instructed to walk across campus while engaged in a telephone conversation. Results of this study indicated that 75% of participants who performed
this conversation task did not report that they saw an individual wearing a purple and yellow clown suit, complete with large shoes and a red nose, that unicycled across the street directly in front of them.

In one of the most widely known illustrations of inattentional blindness, Simons and Chabris (1999) examined the impact of a visual monitoring task on the detection of another highly salient unexpected event: a dancing gorilla. These researchers had participants count the number of times a basketball was passed between members of a specified team all of whom were dressed in white or in black t-shirts; distractors, in the form of additional players also passing a ball back and forth all of whom were dressed in t-shirts of the other color, were included. During this basketball pass counting task, a person in a gorilla suit walked in, stopped in the middle of the scene, did a brief dance, and exited. Results indicated that only approximately 50% of participants noticed the highly salient, though unexpected, dancing gorilla.

Whereas inattentional blindness is a well-established occurrence, previous research suggests that the name may not accurately represent the mechanisms through which this cognitive phenomenon operates. The term “inattentional blindness” presupposes a mechanism in which an observer is blind to – that is, does not process – the unexpected event due to focusing attention on a primary event.
Are individuals truly “blind” to unexpected events, or does some information about the unattended event get processed?

Some previous research on inattentional blindness has aimed to determine if inattentional blindness occurs due to an overall lack of perception of unattended events or if the unattended event receives lower level processing, but does not get processed thoroughly enough to reach conscious attention. To make this determination, researchers had subjects complete a computer-based, line-length discrimination task with unattended dot patterns included on some trials (Moore & Egeth, 1997). When the unattended dot patterns included the Muëller-Lyer or Ponzo illusions, individuals’ line-length discrimination performance was influenced, despite not being consciously aware of the dot patterns. Likewise, participants performing a stem-completion task experienced significant priming effects through information presented in unexpected events, though they did not report observing this information (Mack, 2003). These findings suggest that participants perceived and processed the presented unexpected information to a certain degree, though this content did not reach consciousness.

If information related to unexpected events does receive processing, this raises an important question that has not yet been fully explored: under what conditions does a surprising event receive further processing and subsequent
attention? One answer to this question is surface features; previous research suggests that when surface features of a surprising event are similar to aspects of the primary task, unexpected event detection rates increase.

The “Gorillas in our midst” study (Simons and Chabris, 1999) assessed how basic surface features influence inattentional blindness in a naturalistic experiment. Subjects were instructed to count the number of times a specified team wearing black or white jerseys passed a basketball amongst members of their team. Results indicated that when subjects were attending to the black team, they were more likely to notice a gorilla that suddenly entered the scene. Although this research provides compelling evidence that unexpected events that share surface features with an attended object may be more frequently noticed, these findings must be interpreted with caution. This task was implemented in a naturalistic environment with very little experimental control: the location of the unexpected event was not randomized across trials, and the presented background color was inconsistent across trials. Additionally, very few trials were employed.

Most, Simons, Scholl, and Chabris (2000) supported the claim that shared surface features positively influence the correct identification of unexpected events. Researchers had subjects fixate on a central point and cognitively track the number of times a specified object collided with a line in the middle of the grey-scale, computer-based display. During one inattention trial, an unexpected object entered
the display in a horizontal, linear path. Researchers manipulated the luminance of these unexpected events across groups. Results indicated that participants correctly identified unexpected events more frequently when the unattended stimulus shared the same luminance as the attended stimulus. This research must also be interpreted cautiously, as this experimental task was implemented in a grey scale display with unexpected events that consistently moved horizontally and linearly; the visual information utilized in this study and the manner in which this information was presented tends to infrequently occur in real-world scenarios. Furthermore, individuals’ eye patterns were restricted to a central fixation point, which may also generate a situation that may not be generalizable to real-world conditions.

Welk, Creager, and Gillan (2014) aimed to generalize the aforementioned findings and assess the degree to which primary-task relevance of an unexpected event’s surface features influence detection of that event. Researchers implemented a color manipulation of unexpected events within a dynamic, multiple-trial, computer-based program, in which the location of unexpected events was randomized and participants’ gaze patterns were not restricted. Subjects performed a visual monitoring task; they were instructed to count the number of times a specified target transferred. During one half of the total trials an unexpected event occurred: an unattended target’s color changed. Unlike Most, et al. (2000), the location of presented unexpected events was randomized. Unexpected events could either
match or mismatch the color of the attended target; these conditions were considered task relevant and non-task relevant, respectively. Results indicated that when an unexpected event was task relevant (i.e. shared surface feature information with the primary task), participants noticed those events significantly more than when an unexpected event was non-task relevant. These findings suggest that surface features of an unexpected event, do in fact, play a role in the processing and subsequent detection of these events.

As illustrated by the previous discussion, prior research has explored how the similarity of perceptual features between attended and unattended stimuli influences the detection of this unattended information; however, little research has examined the impact of shared semantic information between the primary task and an unexpected event. In one relevant study (Koivisto & Revonsuo, 2007), researchers provided subjects with four images or four words, and subjects were asked to identify the items in each display. Subjects each experienced one inattention trial, in which a word or image was presented in the center of the screen. This unexpected event was either congruent or incongruent with one of the items in the display. Results indicated that subjects more frequently detected the unexpected event in conditions that were congruent with the displayed item than those that were incongruent.
Although this study provides evidence that semantic features may play a role in detection of unexpected events, several limitations should be considered. First, the paradigm used in this study largely differs from those implemented in typical inattentional blindness research. The primary task is not dynamic and as such, does not require extensive attentional resources; it is likely that this scenario leaves subjects with a sufficient amount of remaining resources to allocate to a secondary task - processing the unexpected event. Additionally, the primary task implemented was largely semantic and somewhat unrealistic; this image identification task is not a task that individuals frequently encounter in the real world.

An understanding of the role of semantic features within an inattentional dual task paradigm has both theoretical and practical implications. Firstly, if semantic features play a role in unexpected event detection, this suggests that information related to these unattended stimuli is being processed semantically, as well as perceptually, without conscious awareness until it becomes relevant to the primary task. Furthermore, this would demonstrate that a surprising event would attract attention based on semantic relatedness to a primary task, which could be used to minimize distractions in various areas of technology design.

The current research evaluates how primary-task relevance of semantic features influence detection of unexpected events in a dynamic, multiple-trial computer-based task. The present study is based on the hypothesis that
semantically related features of an unattended stimulus will result in an increase in
the correct identification of these semantically related unexpected events.
Furthermore, researchers hypothesize that this will negatively impact primary task
performance by pulling attention to the task of processing and detecting unexpected
events.

Instead of investigating this phenomenon using a traditional inattentional
blindness paradigm, this research treats it as a dual task, in which participants are
aware of an explicit primary task, but are not explicitly informed of a secondary task
or its demands; this implicit secondary task is often a surprising event that would be
noticed if the primary task were not there, but is not necessarily as salient as a
gorilla or a clown. This paradigm aims to mimic those that are present in everyday
situations: many real world tasks involve an explicitly defined primary task, and a
secondary task that has not been explicitly defined for a user and is not in their direct
control. For example, drivers are likely focused on the explicit task(s) of maintaining
the speed and direction of their vehicle, while a person running into the street would
serve as an unexpected event. The implicit secondary task of monitoring for and
detecting unexpected events is not explicitly defined, but drivers are aware that
when operating a vehicle, this secondary monitoring task is necessary to some
extent. Similar examples can be identified for any ongoing task - walking down the
street, cooking dinner, and/or searching the Internet – where an unexpected event might suddenly require a shift in attention away from a primary task.

In this inattentional dual task paradigm, the effect of the implicit secondary task can be reflected in two ways, including noticing the secondary event or a change in primary task performance. Using the previously mentioned driving example, the effect of the implicit secondary task could be presented as the driver’s detection of the unattended stimulus and/or interference in the driver’s primary task performance (difficulty maintaining constant speed and direction of the vehicle).

The current study implemented an inattentional dual task paradigm that included a visual monitoring primary task. Participants were asked to track a specified object and count the number of times this object transfers to different objects, as it and distractors move around a display. Within one half of the total presented trials, an unexpected event occurred: an unattended object changed to a different object.

Although this primary task is not fundamentally semantic, it does contain some semantic content. While participating in this primary visual monitoring task, participants are also performing a cognitive counting task to log the correct number of object transfers. To manipulate the semantic similarity between the primary task and an unexpected event, information related to this cognitive counting task (specifically numbers) was presented within selected unexpected events. In addition
to numbers, letters were also presented as unexpected events; these letters aimed to serve as control stimuli. Following each trial, participants reported primary and secondary task performance measures; they were asked: “how many transfers did you count” and “did you notice anything unexpected?”

Research question(s) and hypotheses:

The current research aimed to determine whether the semantic relatedness of a primary-task and unexpected events would influence (1) detection of those unexpected events and (2) primary task performance. Accordingly, the hypothesis underlying this research is that the semantic relatedness of the primary-task and unexpected events will increase detection of these unexpected events and decrease performance of the primary task.

METHOD

Research Design

Experiment 1A assessed the effect of task relevant semantic features on detection rates of unexpected events, and experiment 1B was designed to validate the implemented semantic manipulation. The semantic manipulation was intended to minimize and/or eliminate the semantic task-relevance of presented unexpected events. The same computer program was used in both experiments, with all trials remaining exactly the same except for the response in the primary task. All subjects completed both experiments; one half of subjects received experiment 1A first and
one half received experiment 1B first. Presentation order of the experimental tasks was counterbalanced.

**Experiment 1A: Semantic Features**

*Design.* Experiment 1A implemented a 2x3x3x2 factorial design with the following independent variables: primary puck/target color (black/white), unexpected event presentation time (within seconds 1 through 5 of a trial, within seconds 6 through 10 of a trial, within seconds 11 through 15 of a trial), unexpected event type (letter, close number, far number), and the type of trial (control/experimental).

**Participants**

57 undergraduate participants were recruited from an Introduction to Psychology course and compensated with course credit. Participants ranged in age, gender, the college in which they were enrolled, prior experience taking a Psychology course, and prior knowledge regarding inattentional blindness. Table 1 illustrates these demographic and experiential differences.

**Table 1: Participant Demographics.**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>$M = 18.74, SD = 1.36$</td>
</tr>
<tr>
<td>Gender</td>
<td>72% Male</td>
</tr>
<tr>
<td></td>
<td>28% Female</td>
</tr>
<tr>
<td>College</td>
<td>25% First Year College</td>
</tr>
<tr>
<td></td>
<td>22% College of Management</td>
</tr>
<tr>
<td></td>
<td>19% College of Engineering</td>
</tr>
<tr>
<td></td>
<td>13% College of Humanities and Social Sciences</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>21% Other</strong></td>
<td></td>
</tr>
<tr>
<td>Previously Taken A Psychology Course</td>
<td>60% No</td>
</tr>
<tr>
<td></td>
<td>40% Yes</td>
</tr>
<tr>
<td>Previously Heard of Inattentional</td>
<td>92% No</td>
</tr>
<tr>
<td>Blindness</td>
<td>8% Yes</td>
</tr>
</tbody>
</table>

**Materials**

*Experimental Setting.* This experiment took place in a well-lit, noise-controlled laboratory setting. Subjects were assigned to one computer station where they completed all experimental tasks. Floor-to-ceiling dividers separated all computer stations. The experiment was administered to three subjects at one time; directions for each task were administered to all subjects at once.

*Computer Program.* To assess situations of inattentional blindness in a highly controlled environment, a computer program was implemented. Both experiments were programmed in a Unity game environment and played on a Windows 7 computer at 1024 x 768 resolution, displayed on a 17-inch monitor. Within this game environment, twenty two-dimensional pucks bounced around within a square arena. These pucks were each approximately 2.79 cm in diameter, while targets were approximately 1.91 centimeters in diameter. They moved in a frictionless environment without energy loss, gain, or exchange. All pucks maintained a constant velocity magnitude, though their direction changed when they collided with other
pucks; all collisions obeyed normal laws of physics implemented via the NVIDIA PhysX physics engine (NVIDIA PhysX Library, 2008). To limit collision distraction variance, scenarios with a similar number of puck-puck collisions were generated via random computer simulation. A unique scenario – defined by random initial puck positions and velocity directions – was used for each trial.

**Pre-Test Questionnaire.** A pre-test questionnaire assessed the following information: age, gender, college in which participants were currently enrolled, and whether or not they had previously taken a Psychology course.

**Post-Test Questionnaire.** A post-test questionnaire measured participants’ previous experience with the phenomenon inattentional blindness; subjects were asked to rate their familiarity with inattentional blindness using a 5-point Likert scale.

**Procedure.** After providing informed consent, participants completed the pre-test questionnaire that assessed demographic and experiential information.

They then viewed a computer-based display that contained 10 black pucks and 10 white pucks. These pucks moved about at a constant rate in unique and irregular patterns and occasionally collided with one another. One white puck and one black puck contained targets; there was a white target in the black puck and a black target in the white puck in each trial. When a puck containing a target collided with another puck of the same color, the target could (but did not always) transfer to the colliding puck; the probability of a transfer occurring was .75. Participants
counted the number of transfers of the target puck, which was specified at the beginning of every trial. The mean number of presented transfers per trial was 4.70, the mode was 4, the minimum was 0, and the maximum was 12 transfers. Figure 1 illustrates the display that participants observed.

During 50% of the total trials, an unexpected event occurred: a letter or number appeared within the unattended dot. Unexpected events were either a letter (control), a number between zero and nine, which was close to the number of target transfers that had occurred during the trial at the time of the unexpected event’s occurrence (highly task relevant) or a number between fifty-five and ninety-nine, which was far from the number of target transfers that had occurred within the trial at the time the unexpected event appeared (slightly task relevant). These unexpected objects (letter/numbers) appeared in white or black, and consistently contrasted the color of the puck. Figure 2 provides an example of a semantically relevant unexpected event.
Figure 1: Stimuli illustration.

Figure 2: Example of a semantically relevant unexpected event.
To ensure that there was not a unique effect associated with one letter, two versions of experiment 1A were implemented. One half of subjects received version 1 and one half of subjects received version 2; assignment to these conditions was counterbalanced. Table 2 shows a breakdown of the unexpected stimuli.

Participants were allowed one practice trial to ensure that they understood the task and its demands.

Table 2: Stimuli Illustration.

<table>
<thead>
<tr>
<th></th>
<th>Control (Letter)</th>
<th>Slightly Relevant</th>
<th>Highly Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version 1</td>
<td>w</td>
<td>number between 55-99</td>
<td>number between 0-9</td>
</tr>
<tr>
<td>Version 2</td>
<td>r</td>
<td>number between 55-99</td>
<td>0-9</td>
</tr>
</tbody>
</table>

Following each unique trial, participants responded to the following questions: How many transfers did you count? How confident are you in that assertion? Did you notice anything unexpected? How confident are you in that assertion?

Based on the questions above, researchers derived two primary task performance measures -- transfer error and transfer confidence -- and two secondary task performance measures -- unexpected event detection and unexpected event confidence. Transfer error was calculated by subtracting the reported number of transfers from the total number of presented transfers, and participants reported transfer confidence using a 0-100 scale. Unexpected event detection was coded in a dichotomous fashion (correctly detected/incorrectly
detected), and participants reported confidence in their unexpected event detection using a 0-100 scale.

Experiment 1B: Semantic Validation

Design. Experiment 1B implemented the same 2x3x3x2 factorial design as experiment 1A, with the following independent variables: primary puck/target color (black/white), unexpected event presentation time (1-5 seconds, 6-10 seconds, 11-15 seconds), unexpected event type (letter, close number, far number), and the type of trial (control/experimental).

Elimination of Semantic Features. Experiment 1B was implemented to validate the semantic manipulation executed in experiment 1A. To do this, the computer program from experiment 1A was used; all trials remained exactly the same as Experiment 1A. However, the nature of the primary task was modified: subjects were asked to press the spacebar every time they observed a target transfer, instead of counting the number of transfers per trial and reporting this number retroactively as in experiment 1A. This primary task variation aimed to remove the semantic task relevance of the unexpected events, thereby eliminating the semantic task relevant effect and decreasing participants’ detection rates of these unexpected events and primary task interference.

The computer program recorded the number of times participants pressed the spacebar, in addition to the number of actual transfers that occurred in each trial;
these data were used to derive a transfer error measure that paralleled the measure calculated in experiment 1A. All additional dependent measures remained the same as those collected in experiment 1A.

**Participants**

The same participants that completed experiment 1A also completed experiment 1B.

**Materials**

The same experimental setting, computer program, and questionnaires that were implemented in experiment 1A were also used in experiment 1B.

*Procedure.* The procedure for experiment 1B was the same as the procedure for experiment 1A with the only difference being the primary task modification.

**RESULTS**

**Experiment 1A (Semantic Features)**

Participants provided two primary measures of interest while they interacted with the computer program. A transfer error measurement (error in number of transfers counted per trial) represents primary task performance, and detection rate (the percentage of correctly identified unexpected events per trial) provided a measure of inattentional blindness.

*Descriptive Statistics/Frequency Distributions.* Descriptive analyses showed that participants were able to perform both primary and secondary tasks well, resulting in low overall average transfer error scores ($M = .23$) and high overall
unexpected event detection rates ($M = .82$). Furthermore, median and mode scores were exceedingly low for transfer error (median = 0, mode = 0) and high for unexpected event detection (median = 1, mode = 1), again demonstrating elevated performance. However, standard deviation values illustrate the variance of transfer error scores ($SD = .61$) and unexpected event detection rates ($SD = .38$) across trials and subjects.

**Trial Type Repeated Measures Multivariate Analysis of Variance.** All participants completed trials that contained unexpected events (experimental trials) and trials that did not (control trials). Two primary dependent measures, transfer error: an error count that reflects primary task performance and unexpected event detection: a percentage of secondary task performance, were recorded for both trial types.

To determine if subjects’ primary and secondary task performance varied across experimental and control trials, a repeated measures multivariate analysis of variance (RM-MANOVA) was conducted. Results from this analysis indicated that participants’ primary task performance was consistent across trial types; participants mean transfer error scores were .24 in control trials and .22 in experimental trials, which produced a non-significant univariate test for the transfer error measure: $F (1,$
This finding is ideal as it suggests that subjects fostered their primary task performance, keeping it consistent across trial types.

Participants’ secondary task performance varied across experimental and control trials, with subjects more accurately identifying the presence/absence of unexpected events in trials that did not contain an unexpected event \((M = .95)\) than in those that did \((M = .69)\). This resulted in a significant multivariate main effect of trial type: \(F (2, 114) = 35.72, p < .001\), and a significant univariate main effect of trial type on unexpected event detection: \(F (1, 57) = , p < .001\). The finding that subjects were better at correctly identifying whether or not an unexpected event had occurred in trials that contained no unexpected event is consistent with previously conducted inattentional blindness research (Welk, Creager, Gillan, 2014).

**Condition Repeated Measures Multivariate Analysis of Variance.** Participants completed experimental trials that contained stimuli with varying levels of primary-task semantic relatedness, including highly relevant, slightly relevant, and non-relevant stimuli. To investigate if and how participants’ performance varied across trials differing in levels of semantic relevance, experimental trials were coded into one of three conditions: control (letters), slightly task relevant (exceedingly high numbers), and highly task relevant (close numbers) based on the content of the unexpected event. The same primary and secondary task performance measures
discussed in previous sections: transfer error and unexpected event detection, were obtained.

To determine if subjects performed differently on primary and secondary task measures across these three conditions, a RM-MANOVA analysis was conducted. A summary of participants’ mean primary and secondary task performance across conditions is provided in table 3. These results illustrate that neither primary nor secondary task performance was significantly affected by the type of information contained in unexpected events, which produced a non-significant multivariate test: $F (4, 228) = .27, p = .987$, and non-significant univariate effects for transfer error: $F (2, 114) = .05, p = .878$ and unexpected event detection: $F (2, 114) = .04, p = .955$. The absence of an effect of semantic task relevance of unexpected events on primary or secondary task performance directly contradicts this study’s two primary hypotheses.

<table>
<thead>
<tr>
<th></th>
<th>Transfer Error</th>
<th>Unexpected Event Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Relevance</td>
<td>0.22</td>
<td>0.82</td>
</tr>
<tr>
<td>Slight Relevance</td>
<td>0.23</td>
<td>0.82</td>
</tr>
<tr>
<td>No Relevance</td>
<td>0.24</td>
<td>0.82</td>
</tr>
</tbody>
</table>

**Experiment 1B (Semantic Validation)**
The same two primary performance measures that were collected in experiment 1A were also obtained in experiment 1B while participants interacted with the computer program.

Descriptive Statistics/Frequency Distributions. Descriptive analyses illustrated that participants in Experiment 1B were able to perform primary and secondary tasks successfully much as they had in Experiment 1A, resulting in low overall average transfer error scores \( (M = .35) \) and high overall unexpected event detection rates \( (M = .81) \). As in Experiment 1A, median and mode scores were exceptionally low for transfer error \( (\text{median} = 0, \text{mode} = 0) \) and high for unexpected event detection \( (\text{median} = 1, \text{mode} = 1) \). Standard deviation values illustrate the variance of transfer error scores \( (SD = .81) \) and unexpected event detection rates \( (SD = .35) \).

Trial Type Repeated Measures Multivariate Analysis of Variance. Participants completed trials that contained unexpected events and trials that did not. Experiment 1B used the same dependent measures, transfer error and unexpected event detection, for both trial types as in Experiment 1A.

To determine if participants performed differently on primary or secondary tasks across experimental and control trials, a RM-MANOVA analysis was conducted. Results of the analysis indicated that primary task performance remained consistent across trial types; participants’ mean transfer error scores were .37 in
control trials and \( .33 \) in experimental trials. These results produced a non-significant univariate effect on the transfer error measure: \( F(1, 57) = .87, p = .249 \). Conversely, participants’ secondary task performance was significantly different across trial types; results demonstrated that subjects more correctly identified the presence/absence of unexpected events in trials that contained no unexpected events (\( M = .94 \)) than in those that contained unexpected events (\( M = .69 \)). This produced a significant multivariate test: \( F(2, 114) = 17.32, p < .001 \) and a significant univariate effect on unexpected event detection: \( F(1, 57) = 27.33, p < .001 \). These results are consistent with those found from experiment 1A and prior inattentional blindness experiments.

*Condition Repeated Measures Multivariate Analysis of Variance.* Participants again completed experimental trials that contained stimuli with varying levels of semantic relatedness. Experimental trials that contained an unexpected event were coded into one of three conditions: control (letters), highly task relevant (close numbers), and slightly task relevant (exceedingly high numbers), based on the nature of the implemented change. The same primary and secondary task performance measures: transfer error and unexpected event detection, were collected.
To determine if subjects performed differently on primary and secondary task performance measures across these three conditions, a RM-MANOVA analysis was performed. A summary of participants’ mean primary and secondary task performance across conditions is provided in table 4; these results demonstrate that participants’ primary and secondary task performance did not vary across these three conditions, resulting in an non-significant multivariate effect: $F(4, 228) = .47, p = .983$, and non-significant univariate effects on transfer error: $F(2, 114) = .37, p = .829$ and unexpected event detection: $F(2, 114) = 1.06, p = .984$. These findings were consistent with the primary hypotheses for experiment 1B and the results observed in experiment 1A.

Table 4: Mean primary and secondary task performance by condition in experiment 1B.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Transfer Error</th>
<th>Unexpected Event Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Relevance</td>
<td>0.36</td>
<td>0.81</td>
</tr>
<tr>
<td>Slight Relevance</td>
<td>0.35</td>
<td>0.81</td>
</tr>
<tr>
<td>No Relevance</td>
<td>0.33</td>
<td>0.82</td>
</tr>
</tbody>
</table>

**GENERAL DISCUSSION**

Results of this study provide several noteworthy findings that may contribute to a greater understanding of the cognitive phenomenon: inattentional blindness. These findings include information regarding individuals’ performance strategies and
detection criterion, and evidence that semantic content is processed and/or filtered differently from perceptual content in an inattentional dual task.

First, results from this study indicated that subjects correctly identified the absence of unexpected events better than the presence of unexpected events across trials and experiments. This finding is consistent with a previous study that utilized a similar dynamic, inattentional dual task (Welk, Creager & Gillan, 2014) and was replicated in both experiments 1A and 1B. Given the nature of the aforementioned inattentional dual tasks and the performance outcomes recorded, these scenarios can be considered in terms of signal detection theory. The correct identification of an absent unexpected event can be classified as a correct rejection, and the correct identification of a present unexpected event can be classified as a hit. Whereas the failure to identify an unexpected event can be classified as a miss, and the incorrect identification of an absent unexpected event can be classified as a false alarm.

A follow-up signal detection analysis indicated that participants’ detection strategies were consistent across both experiments 1A and 1B, and aimed to minimize false alarms. Descriptive analyses on the signal detection data illustrated that participants’ hit rate was exactly 34% across both studies, and participants’ miss rate was 16%. Additionally, participants’ correct rejection rate was 47% and their false alarm rate was 3% across studies. The results of this study suggest that within
this task and similar inattentional dual tasks, participants consistently set their
detection criterion high to reduce false alarms, and as such, decrease their hit rate.
Future inattentional blindness research should aim to further investigate why
individuals engage in this behavior and what factors may influence the establishment
and utilization of this detection criterion.

Second, the results of this study offer interesting findings regarding the
processing of semantic content in a dynamic, inattentional dual task. We
hypothesized that processing of semantic content would be similar to processing of
perceptual content; that is to say, when unexpected events shared semantic content
with the primary task, these events would be processed more thoroughly and
consequently reach attention more than unexpected events that did not share
semantic information with the primary task. Hypothesis 1 proposed that the effect of
the implicit secondary task would produce increased recognition of the secondary
event and/or a disruption in primary task performance. However, results from this
study illustrated that semantic relevance of unexpected events relative to the primary
task did not significantly affect primary or secondary task performance. The contrast
between this finding and the previous observation that visual similarity between the
unexpected event and the primary task suggests that semantic content may be
processed differently from perceptual content in an inattentional dual task.
Although the semantic relevance of unexpected events has not been extensively examined within the inattentional blindness literature, a similar manipulation has been widely studied within the auditory shadowing literature. Those studies that have examined the effect of semantic relevance within auditory dual tasks may provide results that generalize to visual inattentional dual task paradigms.

Dichotic listening refers to situations in which individuals are presented with a message to one of their ears and a different message to their other ear (e.g., Cherry, 1953). Within this type of task, individuals are explicitly instructed to attend to one message, but are not necessarily aware of information presented to the unattended ear. This scenario parallels the inattentional dual task implemented in this experiment, in that subjects are asked to complete a dual task and are explicitly informed of a primary task. The primary difference between these two dual task paradigms is that the perceptual modalities (auditory/visual) of interest are different. Although there may be additional differences between the two paradigms, the nature of the two tasks is similar and the mechanisms underlying these tasks may be analogous. As such, by investigating previous research that has implemented a semantic manipulation in dichotic listening tasks, we may be able to better explain the results of this study and this phenomenon in visual attention tasks.
Previous dichotic listening research has examined how semantic relevance of unattended and attended information influences the perception and identification of the unattended information. Prior research in this area has identified two primary theories of semantic processing in a dual task: automatic and attention-based. Automatic processing theories consider the processing of semantic content to be automatic and independent of the allocation of attention resources (Bentin, Kutas, & Hillyard, 1995). Conversely, attention-based theories consider the processing of semantic content to be dependent on the allocation of attention and availability of attentional resources; that is, unattended semantic content is only processed to the extent possible given the availability of cognitive resources. Some previous research supports automatic processing -- for example, words presented to an unattended ear can disambiguate the meaning of an attended phrase (Mackay, 1973). However, findings that support automatic processing have not been fully replicated, particularly in visual tasks (Inhoff & Rayner, 1986; Inhoff, 1989). Furthermore, a body of research exists that supports attention-based theories and provides evidence against automatic semantic processing. For example, semantic interference has been shown to occur only during the early trials of a dichotic listening task (Lewis, 1970; Treisman, Squire, & Green, 1974) suggesting an individual’s attentional capacity is available initially until the individual becomes fully occupied with the task,
thereby resulting in the unattended information being excluded from semantic analysis.

Posner and Snyder (1975) discuss the likelihood of an integrated model that supports initial automatic processing of semantic content that decays quickly (in a few hundred milliseconds), then following this decay, an attention-based filtering mechanism prevails. This integrated model suggests that in a divided attention task, the amount of processing of unattended and unprimed semantic content is typically insufficient to have substantial consequences on the primary task. However, when the unattended stimuli are primed, the amount of information necessary for their identification may be reduced such that only partial processing is sufficient to gain full access to semantic memory (Bentin, Kutas & Hillyard, 1995). These findings provide support for a model that contains initial rapidly decaying automatic processing and a longer-term attention-based filtering mechanism.

The current study’s findings can be explained using the automatic/attention-based model. First, the automatic processing of the semantic content of the unexpected event was unlikely because subjects were presented with variable unattended information; the variability in the type and presence of unattended information may have minimized the likelihood of priming semantic content.

Furthermore, a supplemental analysis of unexpected event presentation time and condition illustrated a non-significant interaction, meaning that participants’
detection of semantically relevant, slightly relevant, and irrelevant stimuli did not significantly vary by the time at which these unexpected events were presented within trials. Additionally, an analysis of trial presentation order and condition also demonstrated a non-significant interaction, indicating that participants did not perform differently on semantically related, slightly related, and unrelated unexpected events across earlier and later trials within experimental sessions. Tables 1 and 2 in Appendix A provide mean secondary performance scores as a function of unexpected event presentation time and trial presentation time for experiment 1A. These findings coupled with the dynamic nature of the implemented inattentional dual task, could suggest that individuals expended the majority of their attentional resources on the challenging primary task; this attentional exertion would then have resulted in individuals lacking the additional resources necessary to process and encode semantic content regardless of when it was presented in a trial or an experimental session. We may have observed different degrees of processing with unexpected perceptual and semantic content because perceptual features require less attentional resources to process, and as such, are more easily detected, even when valuable cognitive resources are expended.

Future research should aim to further investigate the previous claims. To promote automatic processing of semantic content, researchers might choose to include primes prior to trials that contain unexpected events to investigate the extent
to which an automatic model of semantic processing applies to a visual inattentional dual task. Furthermore, to examine the attention-based model of semantic processing, researchers might strategically manipulate the primary task difficulty and subsequent attentional resources required to perform the task. By facilitating the primary task, additional resources may be allocated to the processing of semantic content within the secondary task. It should be noted that this manipulation would alter the nature of the task and the current paradigm. This primary task modification would move the primary task away from an inattentional dual task and toward a true dual task, because situations of inattentional blindness, by definition, require a primary task that utilizes the majority of an individual’s cognitive resources. On the basis of this definition, it may be feasible to make the assertion that within situations of true inattentional blindness – in which the majority of cognitive resources are expended on a challenging primary task – semantic content of unattended events may not be processed deeply enough to reach attention. Future research should aim to further scrutinize this claim.

An additional explanation for the current study’s findings is that unattended information is selectively filtered with perceptual information being processed earlier than semantic content. It is possible that perceptual and semantic content are closely interrelated and infrequently mutually exclusive; for example, the color red is frequently associated with danger or immediacy. As a result, it is probable that the
surface information of unexpected events may serve to “pull along” semantic content; that is, individuals process unattended events perceptually first, then, provided the event is deemed relevant on the basis of those perceptual features, it is processed semantically. Let’s revisit the previous example. If an individual is operating an automobile, it is possible that an unexpected event, such as a quickly approaching “Stop” sign, will be processed perceptually first. Following this processing, the individual will likely deem this unexpected event perceptually relevant to their primary task (consciously or unconsciously), based on prior experience with the task of driving. It is possible that only then will this unexpected event undergo semantic evaluation. Future research should aim to investigate this claim by implementing an experimental design in which semantic features are coupled with perceptual features.

In conclusion, although the initial hypotheses of this study were not supported, the current research provides findings with compelling implications. Future research should further examine the aforementioned considerations and possibilities to gain a greater understanding of semantic processing of unattended events in a visual inattentional dual task.
REFERENCES


Ponzo, M. (1911). "Intorno ad alcune illusioni nel campo delle sensazioni tattili sull'illusione di Aristotele e fenomeni analoghi". *Archives Italiennes de Biologie*.


Simons, D. J. (2010). Monkeying around with the gorillas in our midst: familiarity with an inattentional-blindness task does not improve the detection of unexpected events. *Perception*, 1, 3.


APPENDICES
Appendix A. Additional Data Analyses

Table 5: Mean scores for unexpected event presentation time and condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>1-5 Seconds</th>
<th>6-10 Seconds</th>
<th>11-15 Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Relevance</td>
<td>0.84</td>
<td>0.81</td>
<td>0.83</td>
</tr>
<tr>
<td>Slight Relevance</td>
<td>0.82</td>
<td>0.82</td>
<td>0.84</td>
</tr>
<tr>
<td>High Relevance</td>
<td>0.84</td>
<td>0.85</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Table 6: Mean scores for trial presentation and condition.

<table>
<thead>
<tr>
<th>Condition</th>
<th>1/3 Trials</th>
<th>2/3 Trials</th>
<th>3/3 Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Relevance</td>
<td>0.82</td>
<td>0.83</td>
<td>0.82</td>
</tr>
<tr>
<td>Slight Relevance</td>
<td>0.79</td>
<td>0.85</td>
<td>0.84</td>
</tr>
<tr>
<td>High Relevance</td>
<td>0.86</td>
<td>0.85</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Table 7: Participants’ average experience with Psychology and inattentional blindness.

<table>
<thead>
<tr>
<th>Experience</th>
<th>M</th>
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</thead>
<tbody>
<tr>
<td>Previously Taken a Psychology Course</td>
<td>0.62</td>
</tr>
<tr>
<td>Previously Been Exposed to Inattentional Blindness</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Table 8: Correlations between demographic/experiential variables and experiment 1A’s performance measures.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Transfer Error (Primary Task Performance)</th>
<th>Unexpected Event Detection (Secondary Task Performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.04</td>
<td>-0.06**</td>
</tr>
<tr>
<td>Gender (M=0, F=1)</td>
<td>-0.05**</td>
<td>0.01</td>
</tr>
<tr>
<td>Previously Taken a Psychology Course</td>
<td>0.03</td>
<td>-0.06**</td>
</tr>
<tr>
<td>Previously Been Exposed to Inattentional Blindness</td>
<td>-0.03</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Note. *p < .05, **p < .001.
Table 9: Correlations between demographic/experiential variables and experiment 1B’s performance measures.

<table>
<thead>
<tr>
<th></th>
<th>Transfer Error (Primary Task Performance)</th>
<th>Unexpected Event Detection (Secondary Task Performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.06**</td>
<td>-0.06**</td>
</tr>
<tr>
<td>Gender (M=0, F=1)</td>
<td>0.03</td>
<td>-0.02</td>
</tr>
<tr>
<td>Previously Taken a Psychology Course</td>
<td>0</td>
<td>-0.02</td>
</tr>
<tr>
<td>Previously Been Exposed to Inattentional Blindness</td>
<td>0.01</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .001.

Table 10: Mean NASA-TLX scores for experiment 1A and 1B.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1A</td>
<td>36.63</td>
</tr>
<tr>
<td>Experiment 1B</td>
<td>35.43</td>
</tr>
</tbody>
</table>

Table 11: Pearson correlation between experiment 1A and 1B NASA-TLX scores.

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1A</td>
<td>0.76**</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .001.

Table 12: Average reaction time by condition in experiment 1B.

<table>
<thead>
<tr>
<th></th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.53</td>
</tr>
<tr>
<td>Slightly Relevant</td>
<td>0.53</td>
</tr>
<tr>
<td>Highly Relevant</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Table 13: Summary of ANOVA analysis: Condition and reaction time in experiment 1B.

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>p (significance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>1.71</td>
<td>.181</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .001.

Table 14: Mean transfer confidence by condition: experiment 1A.

<table>
<thead>
<tr>
<th></th>
<th>Transfer Confidence (Primary Task)</th>
<th>Unexpected Event Detection Confidence (Secondary Task)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.86</td>
<td>0.86</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Slightly Relevant</td>
<td>0.86</td>
<td>0.86</td>
</tr>
<tr>
<td>Highly Relevant</td>
<td>0.86</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Table 15: Mean transfer confidence by condition: experiment 1B.

<table>
<thead>
<tr>
<th></th>
<th>Transfer Confidence (Primary Task Performance)</th>
<th>Unexpected Event Detection Confidence (Secondary Task Performance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Slightly Relevant</td>
<td>0.82</td>
<td>0.87</td>
</tr>
<tr>
<td>Highly Relevant</td>
<td>0.81</td>
<td>0.88</td>
</tr>
</tbody>
</table>