EFFECT OF INTERRUPTIONS
ON ROUTE RECALL
PERFORMANCE

by

DALTON W. BURCHARDT

BEVERLY ROSKOS, COMMITTEE CHAIR
EDWARD C. MERRILL
JOE WEBER

A THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Arts
in the Department of Psychology
in the Graduate School of
The University of Alabama

TUSCALOOSA, ALABAMA

2021

ABSTRACT

Previous studies have displayed increased error rates and longer task completion times on primary tasks when participants were interrupted with a secondary task. This experiment utilized a virtual maze to examine the effect of an interruption on one’s memory for a previously learned route and manipulated when the interruption occurred to explore the effect of interruption timing on task performance. University students were asked to learn a route through a virtual maze by watching a first-person video of someone successfully navigating it twice. After which, they were guided along the maze and tested on their ability to recall the correct path at each intersection in the maze. During this testing phase, participants were interrupted either early, midway, late, or were not interrupted with a short reading task. The presence of an interruption did not affect the total number of errors made recalling the route or the time needed to complete the route. Similarly, the timing of the interruption did not affect the number of errors made or the time needed to complete the route. These results indicate that navigation in a virtual environment is not affected by interruptions, regardless of their timing. This may be due to landmarks in the environment aiding memory recall.

LIST OF ABBREVIATIONS AND SYMBOLS

a	Cronbach’s index of internal consistency
df	Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data
F	Fisher’s F ratio: A ration of two variances
t	T ratio: Measures the size of the difference relative to the variation of in your sample data
BF	Bayes Factor: The ratio of the likelihood of one particular hypothesis to the likelihood of another hypothesis
M	Mean: the sum of a set of measurements divided by the number of measurements in the set
SD	Standard deviation: the measure of how dispersed data is in relation to the mean
N	Sample size: the number of samples
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
r	Pearson product-moment correlation
t	Computed value of t test
<	Less than
=	Equal to
H1	Hypothesis one
H2	Hypothesis two
RQ	Research Question
VE	Virtual Environment
min	Minutes

ms	Milliseconds

ACKNOWLEDGMENTS

I am more than delighted to thank the mentors, colleagues, friends, and faculty that supported me during the completion of this research project. I would like to thank Beverly Roskos, my advisor and chairman of this thesis. Your wisdom and guidance have been instrumental in shaping who I am. Thank you Ed Merrill and Joe Weber. Your enthusiasm and engagement while serving on my committee made defending this thesis an exciting, enjoyable experience. I also want to thank Ansley Gilpin, Ian McDonough, and Sheila Black. Without your assistance recruiting participants, it is unlikely this research would have been completed.

I want to thank my friends for the respite they offered when my fears would get the better of me. There was never a time where I felt that I had no one I could confide in. Thank you, Hillary Erwin, for being such a caring friend. Your encouragement helped me come out of my shell and experience things I would not have alone. Finally, thank you Mom and Dad. You did everything possible so that I had the opportunity to chase my dreams, and I am forever grateful for you both.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Feeling confident in their ability to walk to class without the use of a map, a student leaves it in their dorm as they make their way onto campus. Navigating is going smoothly, unique buildings and features help to remind them of their next step, and each familiar face passing by is an indicator of their current success. On the way, however, they are hailed by a club representative who informs them of a campus event later in the week and provides them with directions. After ending the conversation, the student realizes in the attempt to memorize the event details they no longer remember which walkway will lead them towards class. While their initial task may have been simple, an unexpected interruption may temporarily disrupt the navigator's objective in working memory, leaving the navigator uncertain of their next step once resumed.

Interruption effects have been reported across numerous, unique task paradigms: VCR programming (Monk et al., 2004), list reading (Ratwani & Trafton, 2008), virtual navigation programming (Drews & Musters, 2015), in vehicle object identification (Borowsky et al., 2016). The results of these studies indicate that interruptions are invariably hindering. While a nuisance in most cases, interruptions can lead to dire consequences during a high-risk activity (such as operating heavy machinery). Though the act of overcoming an interruption seems straightforward, it consists of a multistep process that helps manage our attention and memory as it shifts between two foci. From the moment we are alerted of an interruption until we begin to address it, we enter a phase referred to as interruption lag (Trafton et al., 2003). Interruption lag has been associated with prospective goal encoding and retrospective rehearsal, encoding information about the primary task so when it is returned to after an interruption it can be resumed. After an interruption is addressed, the span of time ranging from the end of the interruption to the resumption of the primary task is referred to as resumption lag (Trafton et al., 2003). During resumption lag, the memories of the primary task are recalled so it can be resumed.

While high error rates and longer task completion time are common consequences of interruptions, characteristics of the interruptions and participants can moderate the strength of the effect. Differences in working memory capacity have been identified as moderators of the effect of interruptions. In Foroughi et al. (2016) and Drews and Musters (2015), participants that were classified as having lower working memory capacity committed more errors after an interruption compared to those with higher working memory capacity. Interruptions that are similar in content to the primary task or sufficiently complex have been found to be more disruptive. For example, participants performing a sentence copying task made more errors when interrupted by a sentence copying task than solving math problems. (Lee & Duffy, 2015). Even in the case of a visual search task, participants had longer resumption times and less accuracy returning their gaze to a previous position when interrupted with a mental rotation task compared to an arithmetic task (Ratwani & Trafton, 2008). Conversely, Wessel (2018) found that surprising tones, which interrupted a verbal task, did not interfere with visuospatial tasks. Gillie and Broadbent (1989) manipulated the difficulty of interruptions that were presented to participants as they played a computer-based adventure game in which they traveled to certain areas in a given order. While a simple mental arithmetic interruption (e.g., 27+56=?) did not lead to more errors being made in the adventure game, when the numbers were coded as letters that had to be deciphered, participants made more errors when they returned to the adventure game even though the content of the interruption was unrelated. Finally, the length of an interruption has been positively related to the percentage of errors made on a primary task and the amount of resumption lag necessary to restart the task. In both Altmann et al. (2017), where participants performing a sequential decoding task were interrupted, and Hodgetts and Jones (2006), where participants completing a tower of Hanoi task were interrupted, the negative effects of interruptions were amplified by the amount of time that the interruption lasted for. Interestingly, the errors that were made in Altmann et al. (2017) were primarily participants forgetting the order of the original steps. Participants were not misremembering what to do but were recalling them in an incorrect order.

The timing of when an interruption occurs also influences its overall disruptiveness. Participants performing a constantly changing task, switching from VCR programming to pursuit tracking every 5 seconds, experienced varied increases to task resumption time (Monk et al., 2004). The VCR task was comprised of multiple sub-tasks, setting the time and changing channels, which allowed for interruptions to occur during and between tasks. Interruptions that occurred between tasks or during a continuous task (channel changing) were less disruptive than those occurring mid task. As well, interruptions with unpredictable lengths and start times resulted in significantly longer resumption times.

Though previous studies have examined the effect of interruptions occurring at different times during a task (Monk et al., 2004), no prior research has examined if tasks of a serialized order are more resistant to the negative effect of interruptions. Serial position effect suggests that our memory for listed items is stronger for those in the beginning of a list (primacy effect) and the end of a list (recency effect) (Murdock, 1962). Even when participants were allowed enough time to encode a list to long-term memory, studies have shown persistent positional uncertainty for items in the middle of a list opposed to those in the beginning or end (Nairne, 1991). If serial position allows for items to be more resistant to the negative effect of interruptions, this could have implications for the order in which tasks are taught.

This protective factor of serialized order synergizes with a commonly utilized theoretical approach to interruption recovery, the *goal-activation* model of Altmann and Trafton (2002). The model proposes that the most active item held in memory is the one that is thought of during recall, with activity being a product of past item usage and its association to mental and environmental cues (Trafton & Monk, 2007). Not only does the remembered item need to remain the most relevant than other items concurrently held in memory, but it also needs to be resilient to activity decay experienced as a result of nonuse (Trafton and Monk, 2002). The serial position effect states that memory for items occurring in the beginning or end of an ordered list are recalled more successfully than those in the middle (Murdock, 1962; Nairne, 1991). When applied to the goal activation model, items in beginning and end positions should have a higher level of activation than those occupying the middle position. Upon returning to a primary task after an interruption, early and late items may remain the most activated items in memory even after the expected activation decay as a result of their increased activity level.

Figure 1.

Theoretical Activation Levels of Items in Serial Order

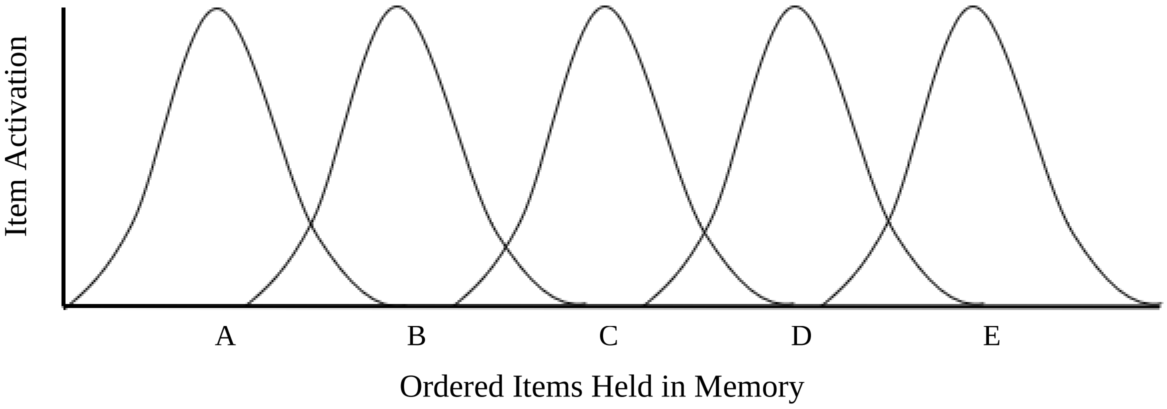
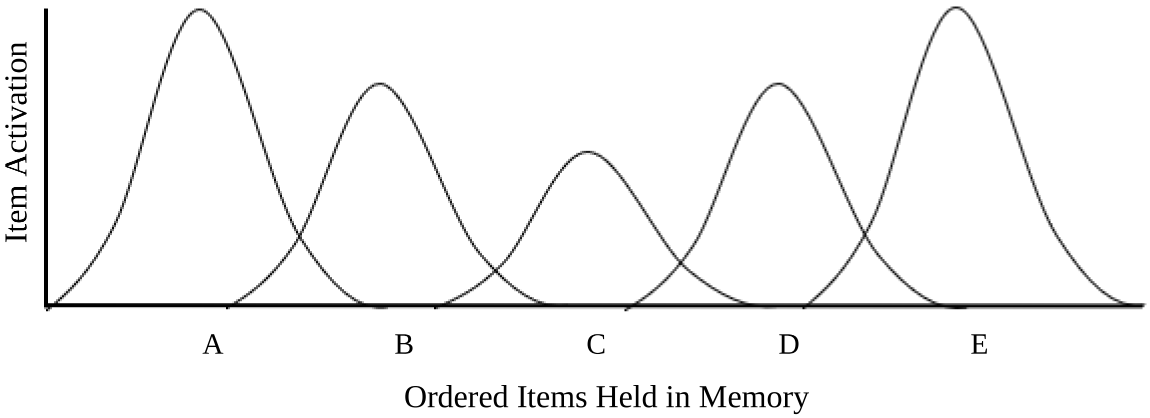


Figure 2.

Theoretical Activation Levels of Items in Serial Order with Serial Position Effect



Current Task

In the current study, participants watched a first-person video of someone traveling through a relatively complex virtual environment twice. Then participants attempted to retrace the route on their own by indicating which direction to go at each intersection. Participants were either disrupted with a secondary task early, midway, or late in their route, or were not disrupted. We measured the total amount of time needed to complete the task and the total number of errors in intersection direction choices. Because the environment included objects located along the route, we also assessed object memory after the route recall task. The current study utilized a one factor, four level (Interruption early, middle, late, or absent) between-subjects factorial design.

Predictions

For the first hypothesis, we predicted that performance on the route navigation task would be worse if there was a disruption at any point, compared to no disruption. Specifically,

H1: Total task time and total number of errors would be higher in the interruption groups than in the no interruption (control) group.

The second hypothesis was that the disruptions would affect performance differently, depending on when the disruption occurred. Specifically,

H2: Total task time and total number of errors would be lower when the disruption occurred early or late in the navigation route compared to when it occurred in the middle.

We did not have a specific hypothesis about object memory, so we asked a research question:

RQ: Will object memory differ as a function of interruption location?

METHOD

Participants

Participants were 46 students recruited from undergraduate psychology courses at the University of Alabama, and they were awarded extra credit in their class for participation.
The sample of students contained a much larger portion of females (84.79%) compared to males (13.04%) and those identifying as non-binary (2.17%). Students ranged in age from 19 to 35 years in age (M = 20.02, SD =3.54). Most of the population identified as White (84.78%), followed by Black (10.87%) and Asian (2.17%). Almost 11% (10.87%) identified as Hispanic/Latinx. Of these students, 73.91% of them identified as solely right-handed, and 4.35% identified as solely left-handed.

Procedure

This experiment was completed using Superlab Remote, which participants downloaded to their personal computers. Psychology instructors at The University of Alabama emailed information about the study to their students. If students were interested, they contacted the researcher who sent a Dropbox link to the SuperLab Remote software, which they downloaded and launched. Once Superlab Remote was opened, participants read and accepted an informed consent form that was part of the Superlab Remote program. Once accepted, they completed a demographic survey, the route recall task, and then an assessment of object memory, all within Superlab Remote. The data file was automatically saved to the participants' desktop and the participant then emailed the data file to the researcher. The study took approximately 45 minutes.

Tasks and Surveys

Demographic survey. A short self-report questionnaire collected participant age, sex, and race alongside theoretical correlates of navigational behavior. Correlates of interest to the current study were participant handedness and sense of direction. Handedness was assessed using the FLANDERS, a ten-question survey gauging participant hand preference with a high level of reliability, Cronbach's alpha = .96 (Nicholls et al., 2013). The FLANDERS includes questions such as "In which hand do you prefer to hold the rubber when erasing a pencil mark?" and "When buttering bread, which hand holds the knife?". Participants responded with the keyboard, pressing 1 for left hand, 2 for either hand, or 3 for right hand. Sense of direction was collected using the Santa Barbara Sense of Direction Scale, a 15-question measure related to a person's ability to orient to an unseen goal (Hegarty, 2002). The Santa Barbara Sense of Direction Scale includes statements such as "I am very good at judging distances" and "I have trouble understanding directions". Participants responded using a seven-point Likert scale to indicate how they identified with the statements, with 1 representing they strongly disagreed and 7 representing they strongly agreed.

Virtual environment and route recall task. We utilized a virtual environment created using the Hammer Editor software. The environment was that of an indoor hallway consisting of 20 intersections (15 three-way intersections, 5 four-way intersections), with incorrect routes leading to dead ends. Along the route were 21 salient objects that stood out in the environment. (ex. wheelbarrow, chair, cone). Some were located at the intersections whereas others were in the hallways between intersections.

Participants were informed that the current experiment would test their ability to correctly navigate through a virtual office building without assistance. The first portion of the route recall task consisted of the learning phase, during which participants watched a first-person video of someone successfully navigating the virtual environment twice. Once participants finished watching these videos, they were tested on their ability to complete the route themselves.

During the testing phase, participants were instructed to navigate the previously learned route as quickly as possible. Unlike the learning phase, where the video correctly navigated the viewer through the environment, during the testing phase the video paused at each intersection. Once paused, numbers were overlaid over the potential paths on screen (1 if the path led to the left, 2 if the path continued straight, and 3 if the path led to the right) and the video did not resume until the participant pressed a computer key matching one of the numbers present on screen. Regardless of the participant's answer, the video continued down the correct path.

Participants in the control condition navigated the virtual environment without an interruption. Participants in the interruption groups (early, middle, or late) had their progress halted at a specific point during the testing phase until the completion of secondary reading task. The interruption occurred in the center of the hallway after the 5th turn for those in the early condition, 10th for those in the middle, and the 15th for those in the late. The interruption, to simulate reading and responding to a long text message, was a short story reading task. Participants were presented with two short stories (*Mercury and the Woodsman* and *The Wind and the Sun*) and had to answer two questions for each. Once the questions were answered, participants were allowed to continue their traversal through the virtual office building.

Performance on the route recall task was measured by two variables: total task time and total number of errors. Total task time was recorded in milliseconds through the VE software. At each intersection the software recorded the time between the pause at the intersection and the participant's response. Total task time was calculated by summing these response times; we converted the times from ms to min for ease of comprehension. At each intersection participants' initial route choice was recorded, and these choices were coded as correct or incorrect after being exported to Excel. The total number of errors was calculated by subtracting participants' total number of correct responses from the number of intersections in the virtual environment.

After the route recall task was completed, participants' memory for objects in the environment was assessed. Participants were presented with 22 images; 16 images were of objects present in the maze and 6 were of objects absent from the maze. The total number of objects correctly recognized (out of 16) was used as their object recognition score.

RESULTS

JASP (JASP Team, 2020) was used to identify outliers in the variables of total interruption time, total task time, and total number of errors. Four participants were excluded for taking more than 10 minutes on the interruption (mean time of 1.57 minutes excluding outliers), one participant was excluded for having a total task time greater than four minutes (mean time of .66 minutes excluding outliers), and one participant was excluded for having a total number of errors equal to 15 (mean number of errors equal to 4.88 excluding outliers). 40 participants were left after these datapoints were removed: leaving 11 in the control condition, 7 in the early condition, 11 in the middle condition, and 11 in the late condition. Descriptive statistics for all variables are in Table 1. The analyses exploring hypotheses one and two were conducted with and without these outliers and the results did not change. The results presented below do not include the outliers.

We used one-way analyses of variance to identify significant differences in handedness and sense of direction among our control and interrupted groups. There were no differences in handedness between those in the control condition (M = 7.91, SD = 6.01) and early (M = 9.43, SD = .98), middle (M = 6.55, SD = 5.99), or late (M = 7.09, SD = 6.41) conditions, F(3,36) = .42, p = .74. Similarly, there were no differences in sense of direction between those in the control condition (M = 62.27, SD = 16.51) and the early (M = 45.57, SD = 9.68), middle (M = 62.27, SD = 16.3), or late (M = 54.64, SD = 15.44) conditions, F(3,36) = 2.29, p = .1. Handedness and sense of direction were not included as covariates in the following analyses due to these similarities. Pearson's Correlations among handedness, sense of direction, total number of errors, total task time (in min), and object recognition were examined to identify potential significant relationships amongst our variables of interest. The relationship between handedness and sense of direction was found to be moderately negative ($r = -.31$, $p = .05$), indicating that left-handed participants reported a better sense of direction. No other relationship was found to be significant among our variables (Table 6).

We also compared the total number of errors made during the beginning, middle, and end of our control group's route recall task to test whether there is a serial position effect for number of errors. Errors were expected to be higher in the middle of the route compared to the beginning or end of the route. We used a one-way repeated measures analysis of variance to identify if serial position effects were present in our task. Beginning errors consisted of the total number of errors a participant made during intersections 1 through 4, middle errors consisted of the total number of errors made during intersections 9 through 12, and end errors consisted of the total number of errors made during intersections 17 through 20. There was a main effect of timing (beginning, middle, or end) on the number of errors made by participants, $F(2,20) = 5.71$, $p < .05$. Post hoc comparisons revealed that participants made fewer errors in the beginning of the task ($M = .46$, $SD = .69$) compared to the middle of the task ($M = 1.55$, $SD = 1.37$), $t(10) = -3.32$, $p < .05$. There were no differences in the number of errors made between the end of the task ($M = 1.18$, $SD = 1.08$) and the beginning or middle of the task. These results indicate that there may have been a primacy effect but not a recency effect in terms of navigation accuracy

For our first hypothesis, we predicted that performance on the route recall task (i.e., total number of errors and total task time) would be worse when there was a disruption at any point, compared to there being no disruption. We combined the three interruption groups into a single group and used t-tests to identify significant differences between the control and interruption groups. For total number of errors, there was no difference between the groups (control *M* = 5.00, *SD* = 3.35; interrupted *M* = 4.83, *SD* = 2.65), *t*(38) = 0.17, *p* = .87. For total task time, differences were analyzed using an analysis of variance with a Brown-Forsythe correction due to an unmet assumption of equal variance. There was no difference between the groups (control *M* = .57 min, *SD* =.15; interrupted *M* = .69 min, *SD* = .32), *F*(1, 36.05) = 2.67, *p* = .11.

Our second hypothesis predicted that a disruption would affect performance differently depending on when the disruption occurred. Specifically, total task time and total number of errors were expected to be lower when the disruption occurred early or late during the testing phase compared to when it occurred in the middle. Analyses of variance were used to identify differences in performance across the interrupted groups (early, middle, and late). For total number of errors, there was no main effect of the timing of the interruption, *F*(2, 26) = .18, *p* = .84. For total task time, there was no main effect of the timing of the interruption, *F*(2, 26) = .30, *p* = .74. A between-subjects analysis of variance was used to compare the amount of time each group spent on the interruption, ensuring they were similarly affected. The timing of the interruption did not affect the amount of time participants spent completing the interruption, *F*(2, 26) = .36, *p* = .70.

One-way repeated measures analyses of variance were used to identify if the interruption resulted in worsened task performance (increased error rates and an increased reaction time) on the intersection following the interruption compared to the intersection before the interruption. There was no difference in error rates between the intersections before the interruptions (*M* = .17, *SD* = .38) and the intersections after the interruptions (*M* = .24, *SD* = .44), *F*(1,28) = .66, *p* = .42. As well, there was no difference in the reaction times between the intersections before the interruptions (*M* = 2218 ms, *SD* = 2481 ms) and the intersections after the interruptions (*M* = 4384 ms, *SD* = 6440 ms), *F*(1, 28) = 3.49, *p* = .07.

Bayesian analyses were used to explore the possibility that the null model was a better fit than our hypothesized alternative. We used the Bayesian t-test framework in JASP (2020) to explore this possibility. Specifically, we retested the predictions found in H1 and H2 pertaining to the dependent variables of total number of errors and total task time. We used the language found in Jefferys (1961) when interpreting the strength of the Bayes factor, where 1-3 represents anecdotal evidence that the null hypothesis is true, 3-10 represents substantial evidence, and 10-20 represents strong evidence.

For total number of errors and total task time in H1, we used Bayesian independent samples t-tests. For total number of errors, our null hypothesis (H_0) stated that the number or errors would not differ among groups, while our one-sided alternative hypothesis (H_-) stated that there would be fewer errors for the control group than the interrupted groups. Figure 3 shows that the Bayes factor supports the H_0, with $BF_{0-} = 3.33$. This means that the data are 3.3 times more likely to occur under H_0 than H_-. This analysis provides substantial evidence in favor of H_0. For total task time, the null hypothesis (H_0) stated that task time would not differ between groups, while our alternative hypothesis (H_-) stated that total task time would be shorter for the control group than for the interrupted groups. Figure 4 shows that the Bayes factor is anecdotal and equally as likely to support H_0 as it would to support H_-, $BF_{0-} = 1.01$.

For total number of errors in H2, we used Bayesian analyses of variance to test the stated null hypothesis (H_0) that total number of errors would not differ among groups against the alternative hypothesis (H_1) that total number of errors did differ among groups. Figure 5 shows that the Bayes factor supports the H_0 with a $BF_{01} = 4.06$, providing substantial evidence in favor of H_0. For total task time in H2, we tested the stated null hypothesis (H_0) that total task time would not differ among groups against the alternative hypothesis (H_1) that total task time would differ among groups. Figure 6 shows that the Bayes factor supports the H_0 with a $BF_{01} = 3.72$, providing substantial evidence in favor of H_0.

Finally, our research questions asked whether object memory differed as a function of the location of the interruption, including the control group. We used a one-way analysis of variance to identify group differences between our control and interruption conditions' object recognition scores. For object recognition, there were no differences between groups, $F(3, 36) = .6$, $p = .62$.

DISCUSSION

We examined whether presenting participants with a short interruption when wayfinding through a complex maze resulted in more navigational errors and increased total task time compared to having no interruption. We discovered that there was no difference in total number of errors or total task time between the control group and our interrupted groups. Comparisons of the interrupted groups revealed that there were no differences in total number of errors or total task time when the interruption was introduced at different time points. There was an effect of serial position present in our route recall task when it was not interrupted, specifically that participants made less errors during the beginning of the route recall task than the middle or the end. An exploratory use of Bayesian analyses revealed support for the null hypotheses over the alternative hypotheses, suggesting that navigation performance is not affected when interrupted mid-navigation. Overall, our results suggest that route memory is robust. After watching someone navigate the route twice successfully, participants on average recalled 15 of the 20 turns correctly. This level of performance was found to be unrelated to self-reported sense of direction and remained even when interrupted by a short reading task. It seems that if we can focus on a route as we are guided along it, we can sufficiently retrace it and do not perform worse in the event of an unexpected interruption.

However, previous research has demonstrated a consistent and strong effect of interruptions on task performance. Specifically, interrupted tasks take longer to complete (Monk et al. 2004; Ratwani & Trafton, 2008) and participants make more errors when resuming a task after an interruption (Drew & Musters, 2015; Borowsky et al., 2016). Our results did not replicate these findings, with participants in our control group and interrupted groups making a similar number of errors throughout the maze task and taking the same amount of time to complete it. Similarly, Monk et al. (2004), found that interruptions presented in the middle of a task increased the time necessary to resume the original task compared to interruptions that were presented between tasks. We theorized that manipulating the timing of an interruption during the navigation task would alter performance on the task; specifically, that the effect of an interruption would be more pronounced if the interruption occurred in the middle of the navigation task compared to interruptions at the beginning or end of the task. In our findings, the timing of the interruption did not result in differences in the number of errors made during the task or the time needed to complete it. In other words, our results strongly imply that an interruption during a route recall task does not affect one's performance.

There are two main reasons why our results may be inconsistent with previous results. One is that the task space was different. In the earlier studies, the tasks were to program a virtual VCR to record a show at a specific time (Monk et al., 2004) and to plan the path of a cursor through a grided map containing obstacles (Drews & Musters, 2015). Though these are serial tasks, just as a navigation task is, the earlier tasks involved small motor (i.e., hand-eye) coordination with discrete steps. A navigation task, even a virtual one, is perceived differently. Phenomenologically, it has a consistent flow to it; there are temporary pauses at the intersections, but the task seems singular. It is also on a larger spatial scale than the other tasks. It may be that spatial environments are represented and used differently than object spaces (Hegarty et al., 2006). Interruptions in an environmental space may not be impacted in the same way as in object space.

A second reason may be that the learning phase was different. Our participants saw the whole route before they navigated it by themselves. For the earlier tasks, this was not the case. Monk et al. (2004) provided participants with a demonstration on how to perform the VCR programming task and provided unique practice trials to familiarize them with the task. In Drew and Musters (2015) participants were provided a 60 second planning phase for each new trial, in which they planned and memorized the steps to move the cursor to the goal. Our route recall task could have benefited by cue priming. In the *goal-activation* model of Altmann and Trafton (2002), something can only be remembered if you pay attention to it. While this is easy when focusing on only one thing, we often hold multiple thoughts in our mind. As we to pay attention to more thoughts, we eventually stop attending to older thoughts and forget them. When learning, we make associations between what we need to remember and cues (an object, sound, smell, etc.) in our environment. Cue priming is when a cue in our environment creates a burst of attention for an associated thought, allowing you to recall that thought and pay attention to it once more. In our route recall task, the landmarks that were present throughout the maze could have acted as cues for the following directional choices, reducing the detrimental effects that we would expect to see following an interruption.

Limitations and Future Directions

There are at least three potential limitations when considering the results of this study. A first limitation concerns aspects of the virtual environment that were used in the route recall task. The virtual environment was designed for and used in a series of experiments that did not center around interruptions and were self-navigated, where the participant used the mouse and keyboard to walk through the environment. Assessing our research hypothesis using an environment that was not designed for our task resulted in too much asymmetry in the maze to explore potentially interesting questions. For example, the distances between interruptions were not equal, even though the number of turns was equal. Also, landmarks in the environment were not placed in equi-distant spaces nor were they equally salient, and some intersections contained landmarks while others did not. Though we do not think these limitations affected our overall results, it would have been better to have an environment that was designed for our specific hypotheses.

A second limitation was the lack of control during data collection. Participants were required to download the SuperLab Remote software to their personal computers to accommodate remote learning requirements due to COVID-19. Though participants were instructed to find a place where they could be alone and focus on the experiment, this was not reinforced and potentially infeasible for some participants. As well, the software was found to be taxing on personal computers, which led to crashes, longer than average load times, and missing data for participants whose computers struggled to run it. While we did not use data from those who experienced a program malfunction that we were aware of, this increased level of variability could have muddled our findings. Running this experiment in a controlled lab environment would have lessened the potential variability in our dataset, allowing for a sounder interpretation of the data.

Finally, the population utilized in this study was another limitation when considering the overall generalizability of the findings. After the removal of outliers, 34 of our 40 participants identified as female, 34 of our 40 participants identified as White, and 36 of our 40 participants did not identify as Hispanic/Latinx. Knowing this, our results can only represent college aged white females. There is evidence for differences in spatial abilities across genders but there is little research on differences in spatial ability between race and cultures. Lacking a sample size diverse enough to examine these group differences prevented us from exploring the extent of the effect of interruptions on route recall.

Future research on the effect of interruptions on spatial navigation could forgo real world validity to test our hypotheses more rigorously. Repeating the experiment with a single interruption while manipulating the presence or absence of landmarks would allow us to identify if the presence of landmarks reduced total task time and/or the number of errors made after an interruption. In addition, one can manipulate the type of interruption (short reading task, long reading task, mental rotation task, mental arithmetic task) to assess if interruption length and difficulty affected route recall performance. In addition, ensuring there is a more diverse population and equal groups of males and females would allow us to investigate whether there are group differences related to spatial navigation interruptions.

Conclusions

Becoming interrupted is a normal occurrence in daily life. We often must pause a task at hand, divert our attention to another situation, and return our focus to our original task. This shifting of attention has been shown to result in more errors on the original task once resumed, and an increase in time needed to remember what one was doing prior to the interruption (Ratwani & Trafton, 2008). The current study examined the effect of interruptions on a route recall task to determine if the timing of an interruption resulted in worsened task performance. Our findings suggest that spatial navigation, at least in a virtual environment, was not affected by an unexpected interruption. This could have been due to landmarks acting as memory aids for route navigation.

REFERENCES

Altmann, E. M., & Trafton, J. G. (2002). Memory for goals: An activation-based model. *Cognitive Science*, *26*(1), 39–83.

Altmann, E. M., Trafton, J. G., & Hambrick, D. Z. (2017). Effects of interruption length on procedural errors. *Journal of Experimental Psychology: Applied*, *23*(2), 216–229.

Borowsky, A., Horrey, W. J., Liang, Y., Garabet, A., Simmons, L., & Fisher, D. L. (2016). The effects of brief visual interruption tasks on drivers' ability to resume their visual search for a pre-cued hazard. *Accident Analysis & Prevention*, *93,* 207–216.

Drews, F. A., & Musters, A. (2015). Individual differences in interrupted task performance: One size does not fit all. *International Journal of Human-Computer Studies, 79*, 97–105.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Foroughi, C. K., Malihi, P., & Boehm-Davis, D. A. (2016). Working Memory Capacity and Errors Following Interruptions. *Journal of Applied Research in Memory and Cognition*, *5*(4), 410–414.

Foster, J. L., Shipstead, Z., Harrison, T. L., Hicks, K. L., Redick, T. S., & Engle, R. W. (2015). Shortened complex span tasks can reliably measure working memory capacity. *Memory & Cognition*, *43*(2), 226–236.

Gillie, T., & Broadbent, D. (1989). What makes interruptions disruptive? A study of length, similarity, and complexity. *Psychological Research*, *50*(4), 243–250.

Hegarty, M. (2002). Development of a self-report measure of environmental spatial ability. *Intelligence, 30*(5), 425–447. https://doi.org/10.1016/S0160-2896(02)00116-2

Hegarty, M., Montello, D. R., Richardson, A. E., Ishikawa, T., & Lovelace, K. (2006). Spatial abilities at different scales: Individual differences in aptitude-test performance and spatial-layout learning. *Intelligence*, *34*(2), 151–176. https://doi.org/10.1016/j.intell.2005.09.005

Hodgetts, H. M., & Jones, D. M. (2006). Interruption of the Tower of London task: Support for a goal-activation approach. *Journal of Experimental Psychology: General*, *135*(1), 103–115.

JASP Team. (2020). JASP (Version 0.14.1) [Computer software]. Retrieved from https://jasp-stats.org

Jeffreys, H. (1961). Theory of probability (3rd Ed.). Oxford, UK: Oxford University Press.

Lee, B. C., & Duffy, V. G. (2015). The Effects of Task Interruption on Human Performance: A Study of the Systematic Classification of Human Behavior and Interruption Frequency: Lee and Duffy Effects of Task Interruption on Human Performance. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *25*(2), 137–152.

Monk, C. A., Boehm-Davis, D. A., & Trafton, J. G. (2004). Recovering from interruptions: Implications for driver distraction research. *Human Factors*, *46*(4), 650-653.

Murdock, B. B. (1962). The serial position effect of free recall. Journal of Experimental Psychology, 64(5), 482–488.

Nairne, J. S. (1991). Positional uncertainty in long-term memory. *Memory & Cognition*, *19*(4), 332–340.

Nicholls, M. E. R., Thomas, N. A., Loetscher, T., & Grimshaw, G. M. (2013). The Flinders Handedness survey (FLANDERS): A brief measure of skilled hand preference. *Cortex*, *49*(10), 2914–2926.

Oswald, F. L., McAbee, S. T., Redick, T. S., & Hambrick, D. Z. (2015). The development of a short domain-general measure of working memory capacity. *Behavior Research Methods*, *47*(4), 1343–1355.

Ratwani, R. M., & Trafton, J. G. (2008). Spatial memory guides task resumption. *Visual Cognition*, *16*(8), 1001–1010.

Trafton, J. G., Altmann, E. M., Brock, D. P., & Mintz, F. E. (2003). Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal. *International Journal of Human-Computer Studies*, *58*(5), 583–603.

Trafton, J. G., & Monk, C. A. (2007). Task Interruptions. *Reviews of Human Factors and Ergonomics*, *3*(1), 111–126.

Wessel, J. R. (2018). A Neural Mechanism for Surprise-related Interruptions of Visuospatial Working Memory. *Cerebral Cortex*, *28*(1), 199–212.

APPENDIX

Table 1
Descriptive Statistics

	Total Errors	Task Time (Mins)	Interruption Time (Min)
Valid	40	40	40
Mean	4.875	0.659	1.570
Median	5.500	0.574	1.635
Std. Deviation	2.812	0.288	1.385
Skewness	-0.135	1.382	0.647
Std. Error of Skewness	0.374	0.374	0.374
Kurtosis	-0.687	2.389	-0.016
Std. Error of Kurtosis	0.733	0.733	0.733

Table 2
ANOVA - Handedness

Cases	Sum of Squares	df	Mean Square	F	p
condition	39.515	3	13.172	0.417	0.742
Residuals	1136.260	36	31.563		

Note. Type III Sum of Squares

Table 3
Descriptives - Handedness

Condition	Mean	SD	N
Control	7.909	6.008	11
Early	9.429	0.976	7
Late	7.091	6.410	11
Middle	6.545	5.989	11

Table 4
ANOVA – Sense of Direction

Cases	Sum of Squares	df	Mean Square	F	p
condition	1584.877	3	528.292	2.284	0.095
Residuals	8326.623	36	231.295		

Note. Type III Sum of Squares

Table 5
Descriptives – Sense of Direction

Condition	Mean	SD	N
Control	62.273	16.511	11
Early	45.571	9.676	7
Late	54.636	15.435	11
Middle	62.273	16.298	11

Table 6
Pearson's Correlations

Variable		Handedness	Sense of Direction	Total Errors	Task Time (Mins)	Object Recognition
1. Handedness	Pearson's r	—				
	p-value	—				
2. Sense of Direction	Pearson's r	-0.308	—			
	p-value	0.053	—			
3. Total Errors	Pearson's r	0.094	-0.116	—		
	p-value	0.562	0.476	—		
4. Task Time (Mins)	Pearson's r	-0.125	-0.086	-0.171	—	
	p-value	0.442	0.599	0.292	—	
5. Object Recognition	Pearson's r	-0.154	0.069	-0.222	-0.150	—
	p-value	0.344	0.674	0.169	0.355	—

Table 7
Within Subjects Effects – Serial Position Effects

Cases	Sum of Squares	df	Mean Square	F	p
Serial Position Effect	6.788	2	3.394	5.714	0.011
Residuals	11.879	20	.594		

Note. Type III Sum of Squares

Table 8
Descriptives – Serial Position Effects

Serial Position Effect	Mean	SD	N
Beginning	0.455	0.688	11
End	1.182	1.079	11
Middle	1.545	1.368	11

Table 9
Independent Samples T-Test for Control vs. Interrupted Groups

	t	df	p	
Total Errors	0.171	38	0.865	
Task Time (Mins)	-1.206	38	0.235	[a]

Note. Student's t-test.

[a] Levene's test is significant (p < .05), suggesting a violation of the equal variance assumption

Table 10
Group Descriptives for Control vs. Interrupted Groups

	Group	N	Mean	SD	SE
Total Errors	No Interrupt	11	5.000	3.347	1.009
	Interrupt	29	4.828	2.647	0.491
Task Time (Min)	No Interrupt	11	0.570	0.150	0.045
	Interrupt	29	0.693	0.322	0.060

Table 11
ANOVA - Task Time (Min) for Control vs. Interrupted Groups

Homogeneity Correction	Cases	Sum of Squares	df	Mean Square	F	p
None	Interruption	0.120	1.000	0.120	1.455	0.235
	Residuals	3.122	38.000	0.082		
Brown-Forsythe	Interruption	0.120	1.000	0.120	2.666	0.111
	Residuals	3.122	36.047	0.087		

Note. Type III Sum of Squares

Table 12
ANOVA – Total Number of Errors for Interrupted Groups

Cases	Sum of Squares	df	Mean Square	F	p
condition	2.605	2	1.303	0.175	0.840
Residuals	193.532	26	7.444		

Note. Type III Sum of Squares

Table 13
Descriptives – Total Number of Errors for Interrupted Groups

Condition	Mean	SD	N
Early	4.429	2.573	7
Late	5.182	2.786	11
Middle	4.727	2.760	11

Table 14
ANOVA – Total Task Time for Interrupted Groups

Cases	Sum of Squares	df	Mean Square	F	p
condition	0.065	2	0.033	0.299	0.744
Residuals	2.830	26	0.109		

Note. Type III Sum of Squares

Table 15

Descriptives – Total Task Time for Interrupted Groups

condition	Mean	SD	N
Early	0.718	0.470	7
Late	0.633	0.239	11
Middle	0.736	0.306	11

Table 16

Within Subjects Effects – Error Rate Before vs. After Interruption

Cases	Sum of Squares	df	Mean Square	F	p
Error Rate	0.069	1	0.069	0.659	0.424
Residuals	2.931	28	0.105		

Note. Type III Sum of Squares

Table 17

Descriptives – Error Rate Before vs. After Interruption

Error	Mean	SD	N
After	0.241	0.435	29
Before	0.172	0.384	29

Table 18

Within Subjects Effects – Response Time (ms) Before vs. After Interruption

Cases	Sum of Squares	df	Mean Square	F	p
Response Time	6.800e +7	1	6.800e +7	3.488	0.072
Residuals	5.459e +8	28	1.949e +7		

Note. Type III Sum of Squares

Table 19

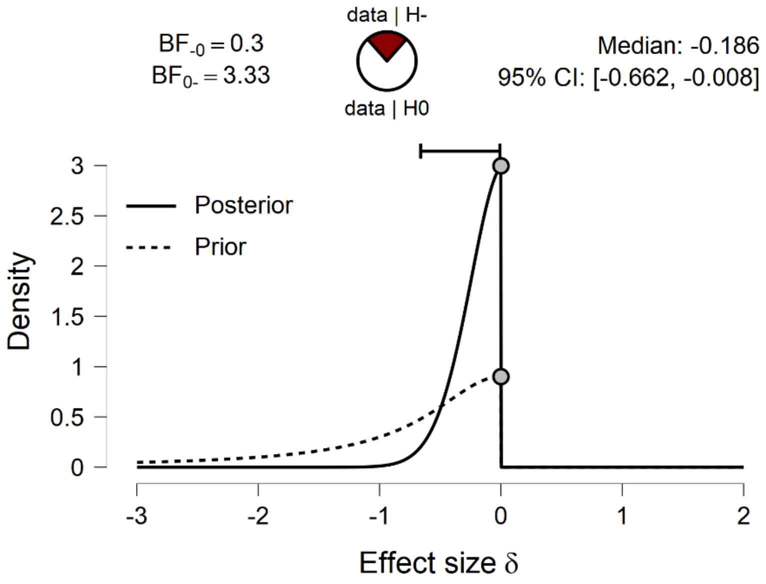
Descriptives – Response Time (ms) Before vs. After Interruption

Response Time	Mean	SD	N
After	4383.828	6440.472	29
Before	2218.310	2481.090	29

Figure 3

Bayesian Independent Samples T-Test for Control vs. Interrupted Groups - Total Number of Errors

Prior and Posterior



Bayes Factor Robustness Check

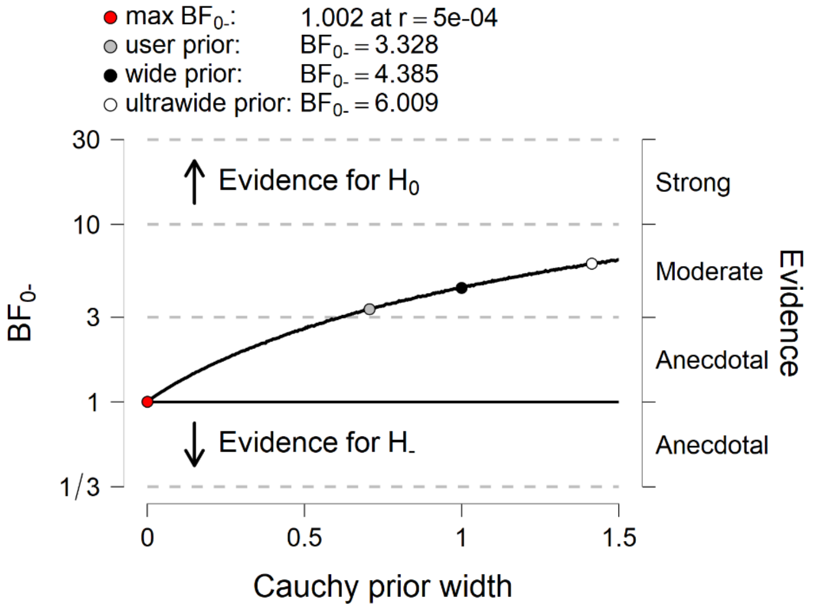
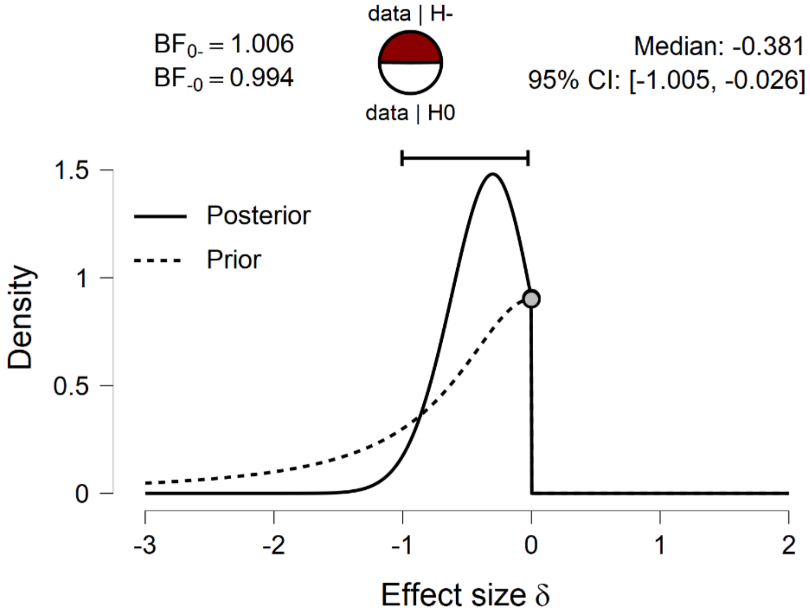


Figure 4

Bayesian Independent Samples T-Test for Control vs. Interrupted Groups - Total Task Time

Prior and Posterior



Bayes Factor Robustness Check

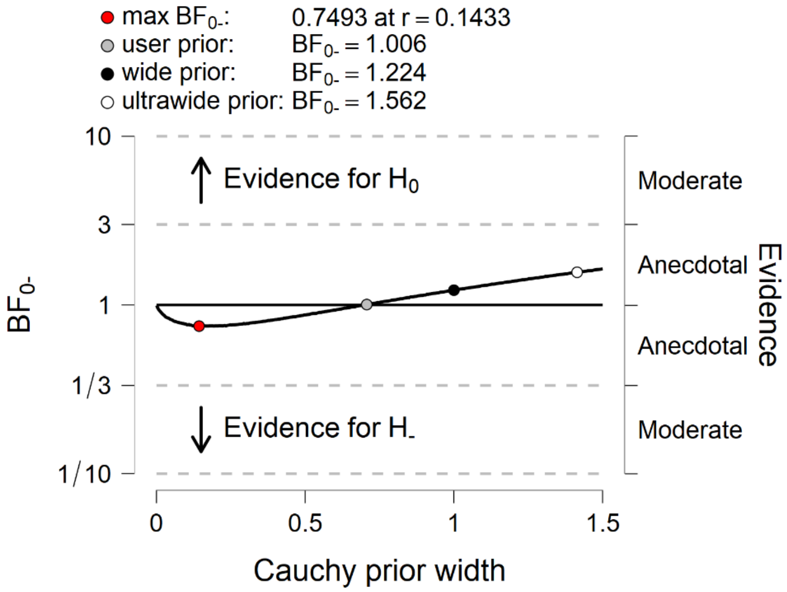


Table 20

Bayesian ANOVA Model Comparison – Total Number of Errors

Models	P(M)	P(M|data)	BF_M	BF_{01}	error %
Null model	0.500	0.802	4.061	1.000	
Condition	0.500	0.198	0.246	4.061	0.037

Figure 5

Model Averaged Posterior Distributions – Total Number of Errors

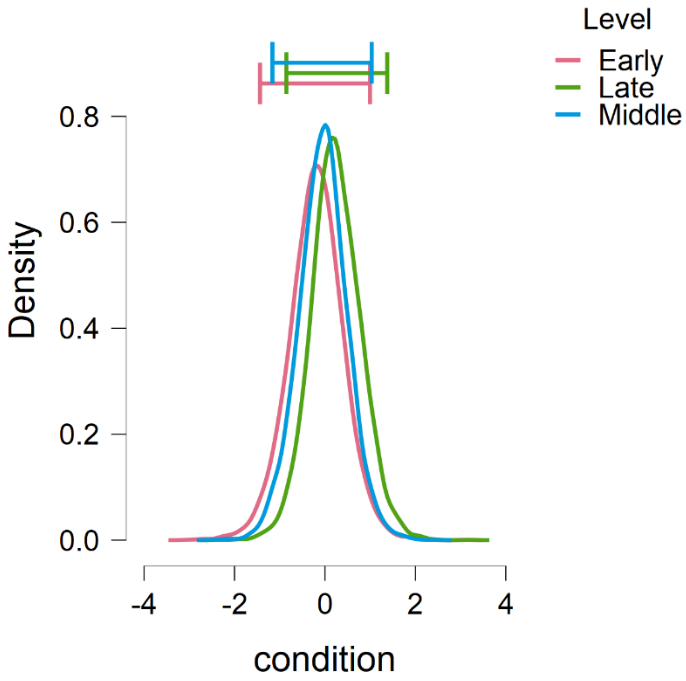


Table 21

Bayesian ANOVA Model Comparison – Total Task Time

Models	P(M)	P(M|data)	BF $_M$	BF $_{10}$	error %
Null model	0.500	0.788	3.721	1.000	
condition	0.500	0.212	0.269	0.269	0.039

Figure 6

Model Averaged Posterior Distributions – Total Task Time

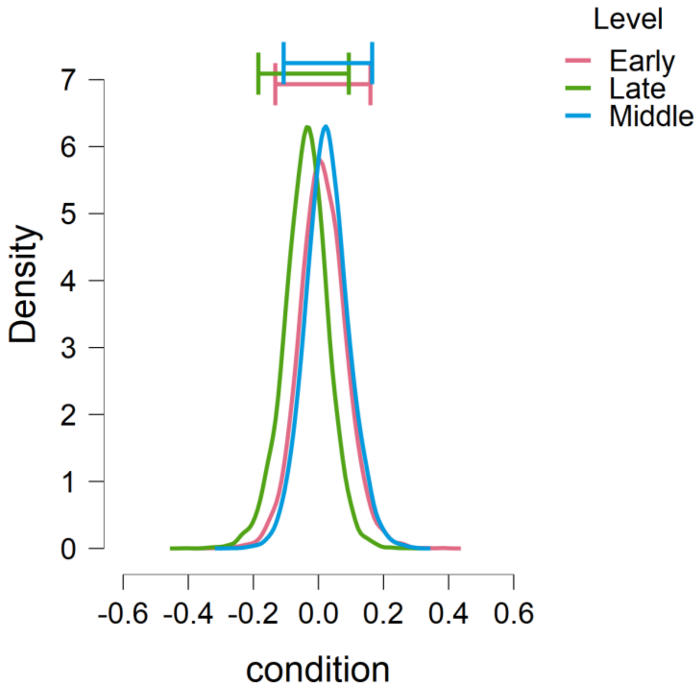


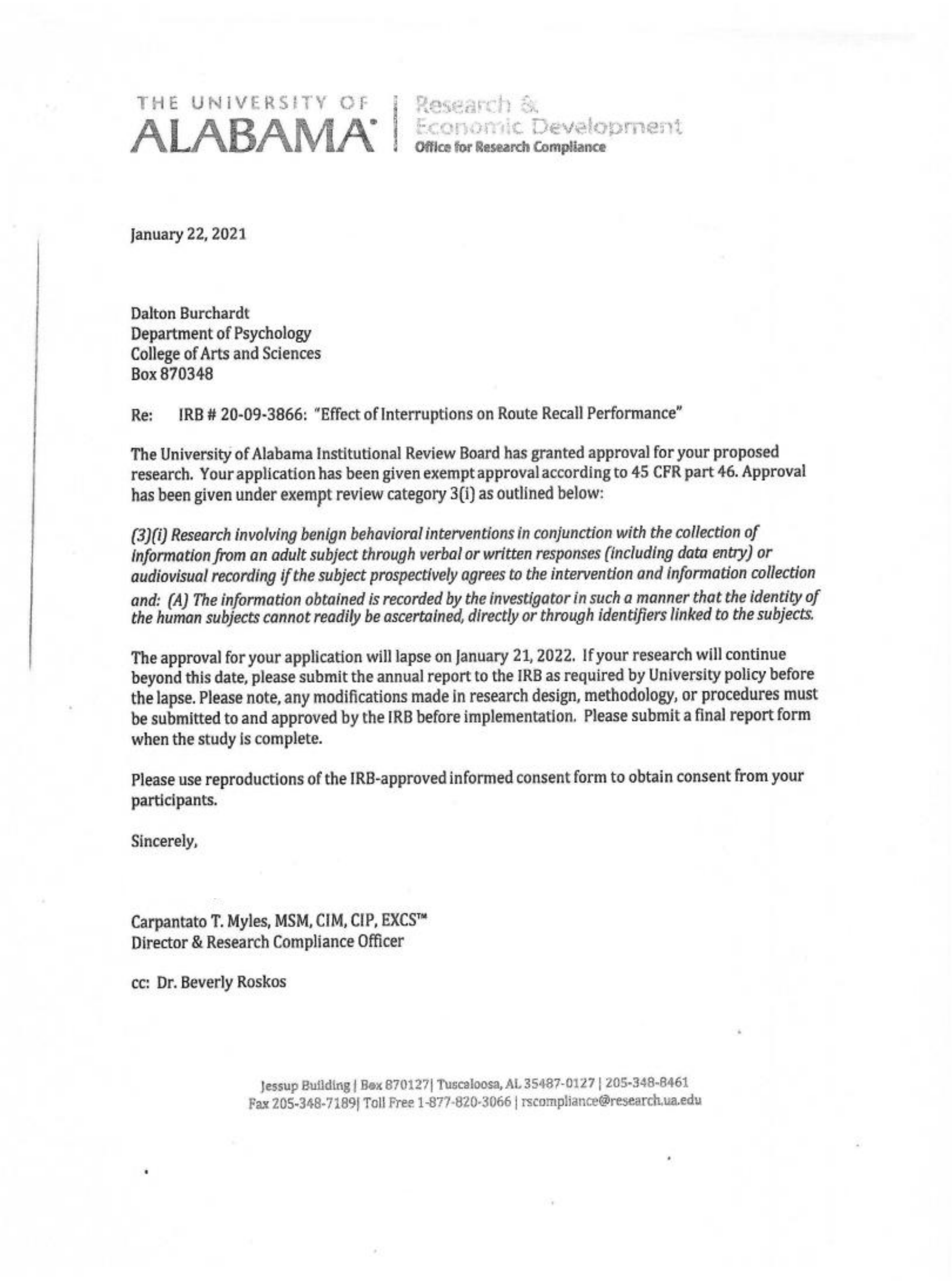
Table 22
ANOVA – Object Recognition

Cases	Sum of Squares	df	Mean Square	F	p
condition	15.017	3	5.006	0.599	0.620
Residuals	300.883	36	8.358		

Note. Type III Sum of Squares

Table 23
Descriptives – Object Recognition

Condition	Mean	SD	N
Control	14.182	1.834	11
Early	14.286	2.928	7
Late	12.909	3.300	11
Middle	13.091	3.270	11



THE UNIVERSITY OF ALABAMA | Research & Economic Development
Office for Research Compliance

January 22, 2021

Dalton Burchardt
Department of Psychology
College of Arts and Sciences
Box 870348

Re: IRB # 20-09-3866: "Effect of Interruptions on Route Recall Performance"

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval according to 45 CFR part 46. Approval has been given under exempt review category 3(i) as outlined below:

(3)(i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and: (A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

The approval for your application will lapse on January 21, 2022. If your research will continue beyond this date, please submit the annual report to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

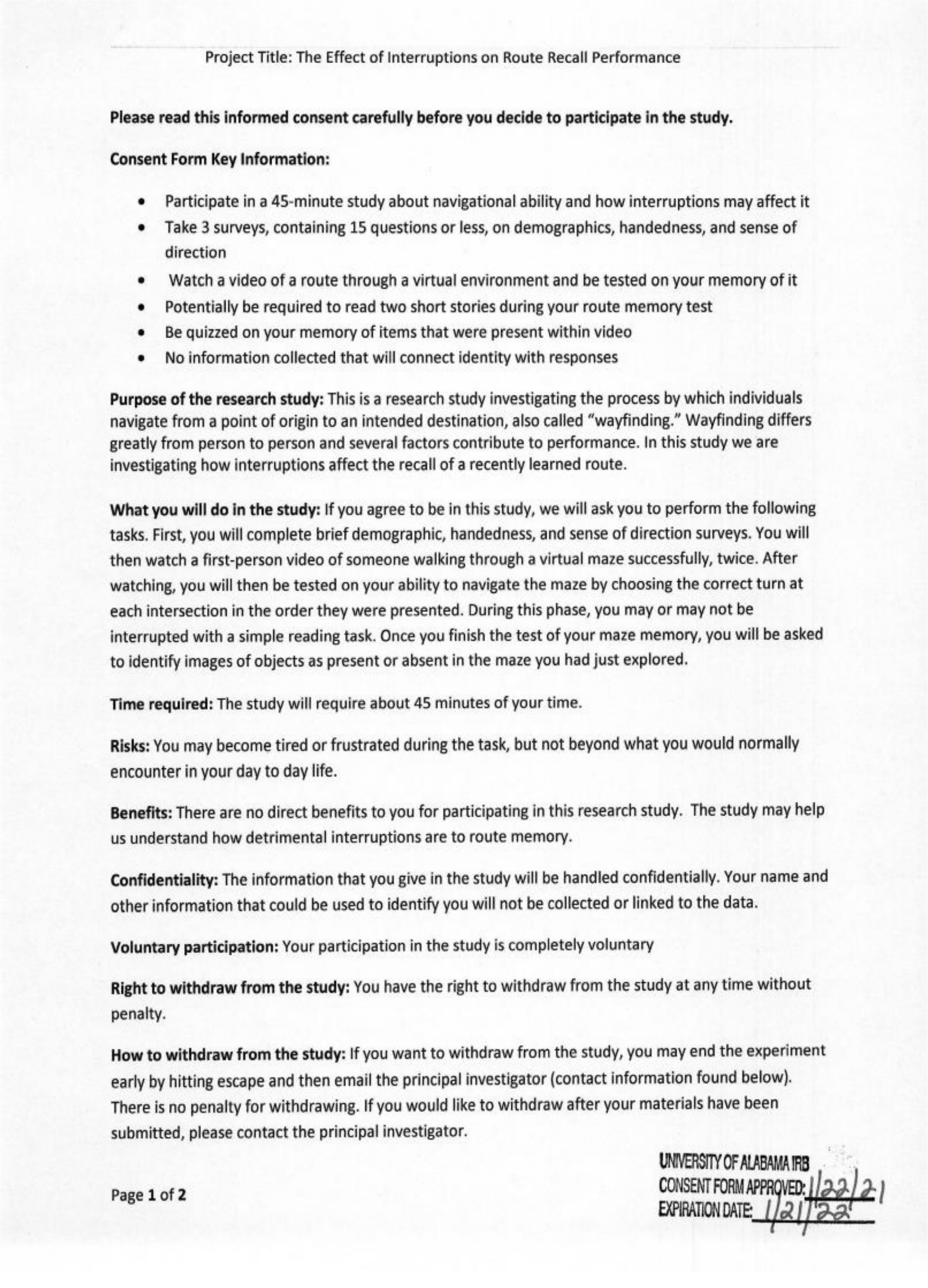
Please use reproductions of the IRB-approved informed consent form to obtain consent from your participants.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP, EXCS™
Director & Research Compliance Officer

cc: Dr. Beverly Roskos

Jessup Building | Box 870127| Tuscaloosa, AL 35487-0127 | 205-348-8461
Fax 205-348-7189| Toll Free 1-877-820-3066 | rscompliance@research.ua.edu



Project Title: The Effect of Interruptions on Route Recall Performance

Please read this informed consent carefully before you decide to participate in the study.

Consent Form Key Information:

- Participate in a 45-minute study about navigational ability and how interruptions may affect it
- Take 3 surveys, containing 15 questions or less, on demographics, handedness, and sense of direction
- Watch a video of a route through a virtual environment and be tested on your memory of it
- Potentially be required to read two short stories during your route memory test
- Be quizzed on your memory of items that were present within video
- No information collected that will connect identity with responses

Purpose of the research study: This is a research study investigating the process by which individuals navigate from a point of origin to an intended destination, also called "wayfinding." Wayfinding differs greatly from person to person and several factors contribute to performance. In this study we are investigating how interruptions affect the recall of a recently learned route.

What you will do in the study: If you agree to be in this study, we will ask you to perform the following tasks. First, you will complete brief demographic, handedness, and sense of direction surveys. You will then watch a first-person video of someone walking through a virtual maze successfully, twice. After watching, you will then be tested on your ability to navigate the maze by choosing the correct turn at each intersection in the order they were presented. During this phase, you may or may not be interrupted with a simple reading task. Once you finish the test of your maze memory, you will be asked to identify images of objects as present or absent in the maze you had just explored.

Time required: The study will require about 45 minutes of your time.

Risks: You may become tired or frustrated during the task, but not beyond what you would normally encounter in your day to day life.

Benefits: There are no direct benefits to you for participating in this research study. The study may help us understand how detrimental interruptions are to route memory.

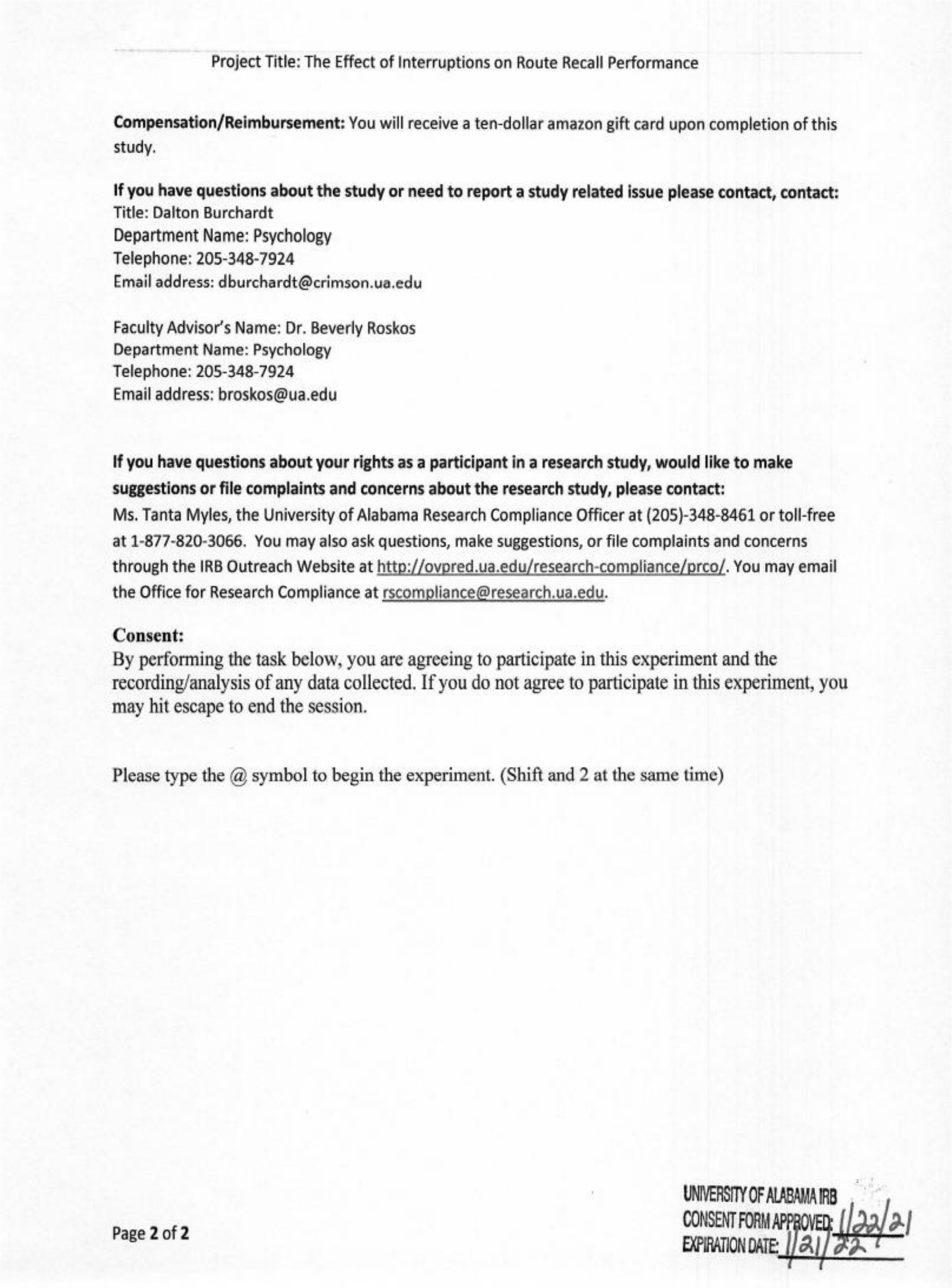
Confidentiality: The information that you give in the study will be handled confidentially. Your name and other information that could be used to identify you will not be collected or linked to the data.

Voluntary participation: Your participation in the study is completely voluntary

Right to withdraw from the study: You have the right to withdraw from the study at any time without penalty.

How to withdraw from the study: If you want to withdraw from the study, you may end the experiment early by hitting escape and then email the principal investigator (contact information found below). There is no penalty for withdrawing. If you would like to withdraw after your materials have been submitted, please contact the principal investigator.

UNIVERSITY OF ALABAMA IRB
CONSENT FORM APPROVED: 1/22/21
EXPIRATION DATE: 1/21/22



Project Title: The Effect of Interruptions on Route Recall Performance

Compensation/Reimbursement: You will receive a ten-dollar amazon gift card upon completion of this study.

If you have questions about the study or need to report a study related issue please contact, contact:
Title: Dalton Burchardt
Department Name: Psychology
Telephone: 205-348-7924
Email address: dburchardt@crimson.ua.edu

Faculty Advisor's Name: Dr. Beverly Roskos
Department Name: Psychology
Telephone: 205-348-7924
Email address: broskos@ua.edu

If you have questions about your rights as a participant in a research study, would like to make suggestions or file complaints and concerns about the research study, please contact:
Ms. Tanta Myles, the University of Alabama Research Compliance Officer at (205)-348-8461 or toll-free at 1-877-820-3066. You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach Website at http://ovpred.ua.edu/research-compliance/prco/. You may email the Office for Research Compliance at rscompliance@research.ua.edu.

Consent:
By performing the task below, you are agreeing to participate in this experiment and the recording/analysis of any data collected. If you do not agree to participate in this experiment, you may hit escape to end the session.

Please type the @ symbol to begin the experiment. (Shift and 2 at the same time)

UNIVERSITY OF ALABAMA IRB
CONSENT FORM APPROVED: 1/22/21
EXPIRATION DATE: 1/21/22

Page **2** of **2**