PREDICTING GPS USAGE: THE RELATIVE IMPORTANCE OF WAYFINDING ABILITY, OBJECT-BASED SPATIAL ABILITY, WORKING MEMORY CAPACITY, ANXIETY, AND OVERALL TECHNOLOGY USAGE

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ABSTRACT

Based on what is known about spatial skills and the popularity of GPS technology, one could make the argument that the more an individual relies on that technology, the less likely they are to actually remember the features and layout of their environment. Not knowing the features and layout of one’s environment can be very detrimental and have serious consequences. The main objective of this study was to investigate the possible predictors of GPS usage and to test different models of how these predictors may be related.

Path analyses were conducted to determine a best fitting model for the data. After testing all of the models, we found one model that fit the data nicely. In the final model, we found that wayfinding ability mediated the relationship between anxiety, object-based spatial ability and GPS usage. This study has important implications that could allow researchers to develop lessons to help people learn their environments, be able to judge when their GPS device is in error, and recover from its erroneous instructions. In short, this project has important practical implications and lays the groundwork for future research.
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<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>GPS</td>
<td>Global Positioning Satellite</td>
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<tr>
<td>SOD</td>
<td>Sense of Direction</td>
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<td>MR</td>
<td>Mental Rotation</td>
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<td>PF</td>
<td>Paper-Folding</td>
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<td>OBSA</td>
<td>Object-Based Spatial Ability</td>
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<tr>
<td>WMC</td>
<td>Working Memory Capacity</td>
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<tr>
<td>$M$</td>
<td>Mean: arithmetic average</td>
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<tr>
<td>$SD$</td>
<td>Standard deviation: value of variation from the mean</td>
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<tr>
<td>$r$</td>
<td>Pearson product-moment correlation</td>
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<tr>
<td>$p$</td>
<td>Probability</td>
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<tr>
<td>$N$</td>
<td>Sample size</td>
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<tr>
<td>$&lt;$</td>
<td>Less than</td>
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<td>$&gt;$</td>
<td>Greater than</td>
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<tr>
<td>$=$</td>
<td>Equal to</td>
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<tr>
<td>SEM</td>
<td>Structural Equation Modeling</td>
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<tr>
<td>$X^2$</td>
<td>Chi Square Value</td>
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<tr>
<td>CFI</td>
<td>Comparative Fit index</td>
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<tr>
<td>BIC</td>
<td>Bayesian Information Criteria</td>
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<td>RMSEA</td>
<td>Root Mean Square Error of Approximation</td>
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ACKNOWLEDGMENTS

I feel very fortunate to be surrounded by very kind and supportive people. First and foremost, I could not have completed this dissertation without the advice and guidance of my advisor, Beverly Roskos. She has taught me a great deal while working on this project. I would also like to thank my other committee members Dr. Edward Merrill, Dr. Theodore Tomeny, Dr. Thomas Ward and Dr. Joseph Weber for their feedback and support. I would also like to acknowledge the research assistants in my lab who spent countless hours running participants. Furthermore, I could not have made it through graduate school without the love and support of my family and friends. They might have been a few hundred miles away; however, there support was always there. Additionally, the friends I have made in Tuscaloosa have supported me in so many ways. In short, I would like to thank everyone who has been involved with this project as well as all those who supported me along the way. This dissertation took years to complete, and I can say this is the first time in my life I truly accomplished something. Thank you again to my family, friends and colleagues who helped me get to where I am today.
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1. INTRODUCTION

Global Positioning Satellite (GPS) devices are the most popular navigation tool today (Li, Ma & Chang, 2010). They are generally defined as any portable device that keeps track of one’s current location to aid in navigation (Mace & Steele, 2010). Reports have shown that global shipments of GPS devices reached an impressive 560 million units in 2012 (Li, Zhu, Zhang, Wang, Wu & Zhang, 2014). It is clear that GPS technology has become a common accessory for automobile drivers as well as pedestrians to improve their mobility. It comes as no surprise as to why they are so popular. GPS devices tend to have useful features such as informing the user of current traffic conditions, locating nearby facilities as well as identifying routes based on the users preference. Although they are considered to be the most popular navigation tool, current research suggests that using them to learn a new environment may not be very effective.

One study found that wayfinding with GPS devices actually results in less spatial knowledge about the environment than paper maps (Ishikawa, Fujiwara, Imai, & Okabe, 2008). Ishikawa and colleagues (2008) examined the effectiveness of a GPS-based mobile navigation system in comparison to paper maps by focusing on the user's wayfinding behavior and acquired spatial knowledge. Participants navigated in a novel environment using a GPS or a paper map. Results showed that GPS users traveled longer distances and made more stops during the walk than regular map users. Also, GPS users traveled more slowly, were less accurate in drawing maps of the environment, and rated the wayfinding task as more difficult than the regular map participants.
In another study, a driving simulator was used to examine the effects of GPS Usage on the development of spatial cognitive maps (Burnett & Lee, 2005). The participants used a turn-by-turn voice guidance system or a paper map with highlighted routes to navigate an environment. The results indicated that those who used voice guidance remembered fewer scenes, were less accurate in their ordering of images seen along routes and drew simpler maps that included a smaller number of landmarks, compared to map users.

Yet another study examined the influence of GPS display scales (single-scale vs. dual-scale) using simulated driving tasks in a virtual environment (Li et al., 2014). The single-scale GPS was similar to the regular GPS view with a simple map and turn-by-turn directions. The dual-scale GPS aid was a two-screen navigation tool that provided two levels of detail, including both detailed information (i.e. landmarks) and an overview of the environment. The results of their study demonstrated that the dual-scale GPS allowed the participants to retain more knowledge about the environment than the traditional single scale design. However, the authors cautioned that the dual screen might cause the user to consistently focus their attention on more than one screen for navigation information and thus it might become a distraction while driving.

Although research has identified a potential way to improve the GPS systems, most research still suggests that GPS’s are not an effective tool if the goal is to learn the environment.

One could ask the question, how important is it for people to know their environment? There are two sides to this question. First, is this concern due to the idea of technology replacing human thinking? Take, for instance, calculators. Hembree & Dessart (1986) found that calculator usage had a negative effect on mathematical computational skills. Does this mean that we should stop using calculators? The answer is probably no, because calculators can be found almost anywhere, and they allow us to conduct more complicated computations compared to other ways
(e.g., pencil and paper). The same argument can be made about GPS devices. Most people have access to a GPS device, and they have become tools that allow us to travel more and with higher confidence, in part because they provide more specific information compared to maps.

The flip side of the question is, what are the consequences for not learning the basic skills? For calculators, there are usually no serious consequences to not knowing how to multiply and divide numbers. The main consequence is not understanding what the results mean or not being able to judge whether the outcome makes sense. The consequences of not knowing one’s environment due to GPS reliance can be more serious. Lack of environmental knowledge could hinder one’s independence, affect one’s decision to go outdoors, impede the ability to develop or retain a social network, or even affect one’s ability to navigate somewhere in an emergency. Therefore, while reliance on some forms of technology may be useful, reliance on GPS devices might be more detrimental for the user.

Because the consequences of not knowing one’s environment are possibly dangerous, it is important to teach people how to learn their environment independently of, or perhaps in addition to, GPS devices. Wayfinding should be more about understanding where we are in an environment as we move through it, than just following specific directions. Similarly, learning to use GPS devices should include learning how to judge whether the GPS instructions make sense within the environmental context.

One way to think about this problem would be to think about the negative effects of drug usage. There is good reason to want to understand the factors related to (i.e., predictive of) drug usage since it can lead to negative consequences. Similarly, this project aims to understand the factors related to (i.e., predictive of) GPS usage, since there is literature to support that these
devices might be detrimental to the user, especially if the goal is to learn the environment (Burnett & Lee, 2005).

The current study investigates the variables that predict individual differences in GPS usage. Specifically, different possible models of the relations among these variables for predicting GPS usage are tested. The results could inform educational programs designed to increase a person’s knowledge of their environment.

**Possible Correlates of GPS Usage**

There are four possible types of cognitive-related correlates of GPS usage identified from the literature: wayfinding ability, anxiety, object-based spatial ability, and working memory capacity. This section describes each cognitive correlate and then considers the relations among them. A fifth non-cognitive correlate is overall technology use.

**Cognitive Correlates of GPS Usage**

**Wayfinding Ability.** Wayfinding is typically defined as one’s ability to navigate an environment successfully (Lawton, 1994). It is only logical that wayfinding ability would be related to GPS usage since the GPS acts as an aid to the user. However, there is no direct evidence of this based on a search of the literature. There are several different measures one could use for wayfinding ability. One measure is sense of direction. Sense of direction is typically referred to as one’s confidence in navigating an environment and is correlated with wayfinding ability (i.e., the accuracy with which a person knows where they are in an environment; Prestopnik & Roskos-Ewoldsen, 2000; Hund & Nazarczuk, 2009). Sense of direction can be assessed with a simple survey and is a common measure in the spatial cognition literature.
A second measure of wayfinding ability is the extent to which a person uses survey strategies when wayfinding. Survey strategies typically involve a bird’s eye perspective of an environment whereas a route strategy typically involves a set of instructions on how to navigate based on landmarks (Lawton, 1994). Prestopnik and Roskos-Ewoldsen (2001) found that relying on survey strategies to complete an environment-based wayfinding task was predictive of stronger wayfinding performance. In another study, Prestopnik (2000) looked at the relationship between sense of direction and preferred wayfinding strategy (survey vs. route). The results of this study found that those reporting high sense of direction also reported a preference for survey wayfinding strategies compared to those reporting low sense of direction.

One last measure of wayfinding ability used in the current study involves participants actually completing a wayfinding task. There are several different kinds of wayfinding tasks. For instance, some researchers rely on driving simulators to measure wayfinding ability (Gugerty, 1997). Other researchers ask participants to navigate a pre-determined real-world environment. This environment might be outside or indoors. However, for these tasks, participants are asked to actually move around the environment and navigate to a destination (Malinowski, 2001). Some researchers make use of model buildings, whereby participants need to move an object through a model building to a destination (Hund & Nazarczuk, 2009). The wayfinding task used in the current study utilized a more simulated approach, whereby participants had to mentally navigate a familiar college campus.

Overall, the literature suggests that high sense of direction and higher use of survey strategies seem to be strongly linked to better wayfinding ability, and that wayfinding ability in general could be predictive of GPS usage.
Anxiety. According to recent research, one correlate of GPS device usage is spatial anxiety (Mace & Steele, 2010). Spatial anxiety is typically defined as anxiety one experiences when completing spatial tasks such as navigation. In the Mace and Steele (2010) study, participants completed a spatial anxiety measure (Lawton, 1994) and a GPS Usage survey, which was specifically designed for the study. The GPS Usage survey had questions such as, “I use a GPS daily” or “I use a GPS in unfamiliar areas,” and participants rated their agreement with the statements on a scale ranging from 1 to 5. The spatial anxiety survey had questions such as, “Rate your anxiety on a scale of 1 to 5 for the following question: Leaving a store that you have been to for the first time and deciding which way to turn to get to a new destination.” Mace and Steele (2010) found that those reporting high GPS Usage also reported high spatial anxiety. Furthermore, Lawton & Kallai (2002) found that anxiety was negatively correlated to survey strategy usage.

Spatial anxiety has also been shown to be a subset of trait anxiety (McKeen, 2011). Trait anxiety is typically defined as a complex state that comprises cognitive, behavioral and bodily responses (Sarason, 1984). Some research shows that overall trait anxiety is a better predictor of a navigation-related activity--willingness to ask for directions--than spatial anxiety (McKeen, 2011). McKeen (2011) also found that general anxiety was negatively correlated with sense of direction. Therefore, since anxiety has been linked to sense of direction and survey strategy usage, it might also be linked to wayfinding ability, which in turn could predict GPS usage.

It may seem odd that anxiety is included as a cognitive correlate; it is true that anxiety is not a cognitive phenomenon. However, anxiety has been shown to reduce working memory capacity. So, although anxiety is not a cognitive process per se, research suggests that it directly
impacts cognitive processes. We will discuss more about the relationship between anxiety and other cognitive predictors in the upcoming section, Relationships among Cognitive Correlates.

Object-Based Spatial Ability. A third cognitive correlate of GPS usage could be object-based spatial ability, which can be thought of as the mental assembly and disassembly of objects. One measure of this ability is mental rotation. Mental rotation is generally one’s ability to rotate a two- or three-dimensional figure using imagination and make judgments in relation to a comparison (Voyer, Voyer & Bryden, 1995). For instance, in a typical mental rotation task, participants are shown a figure on the left hand side of a page. They are then shown four other figures that have been rotated to varying degrees. Only two of these figures match the original one. The participant has to identify which of the rotated figures matches the original image. Another typical measure is a paper-folding task. Paper-folding is considered to be a spatial visualization task and typically is considered the ability to manipulate complex spatial information (Voyer et al., 1995). For example, in a typical paper-folding task, participants view a simulation of a piece of paper being folded. After the last fold, they are shown a hole punched through a portion of the paper. The participant must then determine from a set of options what the piece of paper would look like once it is unfolded.

Mace & Steele (2010) found a strong negative correlation between mental rotation performance and GPS usage. In another study, mental rotation performance was strongly correlated with wayfinding ability (Malinowski, 2001). Malinowski asked participants to navigate in a wooded area to find markers. Performance was measured by how many targets participants found in the woods as well as time to complete the task. The researcher also had participants complete a mental rotation task. The results showed that those who had high performance on the mental rotation task also completed the wayfinding task with fewer errors.
than those with poor mental rotation skills. Therefore, since object-based spatial ability has been linked to wayfinding, it might also be linked to GPS usage.

Furthermore, there is some evidence that the different object-based spatial skills are related. Miyake, Friedman, Shah, Rettinger and Hegarty (2001) had participants complete several object-based spatial tasks and found that mental rotation ability was highly correlated with spatial visualization ability. Therefore, it is likely that both mental rotation and spatial visualization abilities are linked to wayfinding and might be contributing factors to GPS usage.

**Working Memory Capacity.** A fourth possible cognitive correlate of GPS usage is working memory capacity. Working memory is essentially one’s ability to keep information “online” and available for a limited amount of time and it relies heavily on memory and attentional processes (Li et al., 2014). There are a variety of tasks that have been used as measures of working memory capacity, but some of the most widely used measures within cognitive psychology are span tasks: rotation span, operation span, symmetry span, amongst others. For span tasks, participants are generally given a task in which they have to make a decision and hold something in mind for later recall. For example, in an operation span task, participants determine whether a math problem is correct or not. They are then shown a letter shortly after their decision. After a set of math problems are completed, each with a to-be-remembered letter, participants are asked to report back the letters they saw in the order they saw them. The maximum number of letters recalled in the correct order is considered as the capacity of one’s working memory.

Evidence that wayfinding requires memory and attention is from Li and colleagues (2014), who conducted a study comparing two digital navigational aids. They compared a single scale versus dual scale GPS unit to determine which format was best for the user while
navigating, with the dual scale GPS containing two screens with more information about the environment. They argued further that popular navigation aids such as GPS devices reduce the demand on attention and memory and thus reduce the overall cognitive workload.

Another study investigating the role of memory and attention in wayfinding utilized a PC based simulated driving task to evaluate drivers’ knowledge of the environment (Gugerty, 1997). Participants were asked to drive around a three-dimensional scene and were subsequently asked to remember where certain cars were around them. Gugerty concluded that navigating requires situational awareness, which he defines as maintaining a complex set of information in real time. Furthermore, Gugerty argues that higher levels of situational awareness predicts higher working memory capacity. Thus, high working memory capacity may be needed for unaided wayfinding to be performed successfully.

A third study investigated the relationship between working memory capacity and wayfinding ability (Nori, Grandicelli & Giusberti, 2009). Nori and colleagues (2009) asked participants to navigate around an unfamiliar botanical garden as well as complete several measures of working memory. Their results showed that those with lower working memory capacity made more errors navigating the unfamiliar botanical garden than those with higher working memory capacity.

In sum, the literature suggests that higher working memory capacity seems to be related to better wayfinding. Thus, one could suggest that those who have lower working memory capacity would also report higher GPS usage.

**Relationships among Cognitive Correlates of GPS Usage**

The current research suggest that the four variables described above are the full range of cognitive factors that could possibly predict GPS usage; however, no study has actually
investigated each variable independently, let alone each variable’s relative importance. Fortunately, there is some research that we can use to help create testable models to determine how these variables work together to predict GPS usage.

Lawton (1994) conducted a study that looked at the relationship between anxiety and object-based spatial ability. Participants were asked to complete a mental rotation task as well as a spatial anxiety scale. The results of this study suggested a strong negative correlation between these two variables. However, these results are only correlational and do not suggest a direct cause and effect relationship.

Another study looked at the relations between object-based spatial ability and working memory capacity (Kauffman, 2007). This study asked participants to complete a variety of spatial tasks such as a mental rotation test and a DAT spatial relations test, as well as several measures of working memory capacity. The results showed strong positive correlations between performance on a mental rotation task and working memory capacity. Kauffman (2007) argued that object-based spatial skill requires the ability to maintain an active representation of all the parts, and the interrelations of all the parts, while simultaneously rotating an image in the mind. This complex processing of information requires higher working memory capacity than other less complex tasks.

Additionally, working memory capacity has been linked to performance on spatial visualization tasks. One study looked at performance on a paper-folding task and two working memory capacity tasks, namely a dot matrix task as well as a letter rotation task (Miyake et al., 2001). A dot matrix task asks participants to view a math equation and determine if it is true or false. They then view a grid with a dot inside of it. After a series of equations and grids, they indicate in a blank answer grid where the dots from all the grids were located. The letter rotation
task involved participants viewing a series of letters rotated in different orientations and having to determine if each letter is normal or mirrored. After all the letters, they indicate in an answer grid where the top of each letter was located. Miyake and colleagues (2001) found that performance on a paper-folding task was strongly positively correlated to performance on the working memory measures. Therefore, it can be concluded that working memory is linked to object-based spatial ability; however, the relation is not documented as a cause and effect relationship.

There is also research that has investigated the relationship between anxiety and working memory capacity. Sarason (1984) proposed a cognitive interference theory, suggesting that worrisome thoughts disrupt attentional control, which is an important function of the working memory system. One study recently examined the relationship between anxiety and working memory capacity during a math test (Ganley & Vasilyeva, 2014). For this study, participants completed a math test. Afterward, the researchers measured the participants’ working memory capacity and anxiety levels. They found a strong negative relationship between working memory capacity and anxiety. They also found that working memory capacity and anxiety were linked to poor performance on the math exam.

Non-Cognitive Correlate of GPS Usage

Overall Technology Usage. Another possible correlate of GPS usage that is not related to cognitive processing directly, but could be related to GPS usage, is overall technology usage. Overall technology usage may be defined as one’s combined usage of technology such as computers, televisions, cell phones, and so on. Research suggests that people who own one form of technology typically own other forms of technology as well (Brasel & Gips, 2011). Therefore, one predictor of GPS usage might be one’s usage of technology in general. Though this variable
does not seem to be related to any of the other variables, it is included because it may be the case that the GPS usage is not related to aspects of cognition, but to “geekiness”—a fondness for all things electronic.

The results of these studies help to form the basis of the possible models to test for the current study. It is also important to note that the predictor variables used in this study focus on individual differences instead of aspects of the environment itself in predicting GPS usage. Looking into environmental factors that predict GPS usage is beyond the scope of this investigation.

**Purpose of Proposed Study**

Based on what is known about spatial skills and the popularity of GPS technology, one could make the argument that the more an individual relies on that technology, the less likely they are to actually remember the features and layout of their environment. As stated previously, not knowing the features and layout of one’s environment can have serious consequences. The main objective of this study was to investigate the possible predictors of GPS usage and to test different models of how these predictors may be related. If this study can identify the relative importance of the predictors of GPS usage, researchers might be able to develop lessons to help people learn their environments, be able to judge when their GPS device is in error, and recover from its erroneous instructions. In short, this project has important practical implications.

**Proposed Hypotheses**

The main purpose of this study was to identify the relations among the possible correlates of GPS usage so that spatial learning can be developed. However, there are known correlations among these correlates that we wanted to replicate. The hypotheses below (H1 and H2) are based on these known relations. The research question (RQ1) describes various models of the relations
among the variables for predicting GPS Usage. More specifically, the models represent different scenarios of the ordering of precursors (variables) in predicting GPS Usage.

**H1:** There will be a negative relationship between GPS Usage and Wayfinding Ability, Object-Based Spatial Ability and Working Memory Capacity.

**H2:** There will be a positive relationship between GPS Usage and Anxiety and Overall Technology Usage

**RQ1:** What is the relative importance of Wayfinding Ability, Object-Based Spatial ability, Working Memory Capacity and Anxiety predicting GPS Usage?

Several different models of possible relations among predictor variables will be tested.

**Overall Model (Figure 1).** This model includes all individual-differences measures as well as the latent constructs. This information should be the set-up for understanding the 19 parameters that are in the model.

**Model 1 (Figure 2).** The reasoning behind this model is that object-based spatial ability, wayfinding ability, working memory capacity, and anxiety are separate processes that have unique, independent influences on GPS Usage. Thus, in the model, each latent variable is an independent predictor of GPS Usage.

**Model 2 (Figure 3).** The reasoning behind this model is that high anxiety and low working memory capacity might narrow attentional focus and may hinder ones object-based spatial ability, which can hinder wayfinding ability, which in turn might predict GPS Usage. Thus, in this model, anxiety and working memory capacity will predict object-based spatial ability, which will turn predict wayfinding ability and thus GPS Usage.

**Model 3 (Figure 4).** The reasoning behind this model is that doing a wayfinding task may lead someone to feel more anxiety. Anxiety level in turn might use part of one’s working
memory capacity, leaving less capacity available for other cognitive tasks. Simultaneously, higher anxiety levels would narrow attentional focus, which would hinder the processing of the objects in one’s environment (i.e., object-based spatial ability). In turn, lower levels of working memory capacity and object-based spatial performance may cause a higher reliance on GPS devices. Thus, in this model, wayfinding ability predicts level of anxiety, anxiety level predicts working memory capacity and object-based spatial performance, which separately predicts GPS Usage.

**Model 4 (Figure 5).** The reasoning behind this model is that having high anxiety, low working memory capacity and poor object-based spatial ability may extremely narrow your attentional focus and lead to poor wayfinding ability, which might predict GPS Usage. Thus, in this model, the relationship between anxiety, working memory capacity, object-based spatial ability and GPS Usage will be mediated by wayfinding ability.

**Model 5 (Figure 6).** The reasoning behind this model is that already having high anxiety could lead to limited working memory resources, which could then lead to poor object-based spatial ability, which in turn could predict poor wayfinding ability. This decrease in wayfinding ability might predict GPS Usage.
Figure 1—Overall Model. The full model.

Figure 2: Model 1. All Latent variables are independent predictors of GPS Usage.
Figure 3-Model 2. Anxiety and working memory capacity will predict object-based spatial ability, which will in turn predict wayfinding ability and thus predict GPS Usage.

Figure 4-Model 3. In this model, wayfinding ability predicts level of anxiety, anxiety level predicts working memory capacity and object-based spatial performance, which separately predicts GPS Usage.
Figure 5-Model 4. Wayfinding ability will mediate the relationship between anxiety, working memory capacity, object-based spatial ability and GPS Usage, with anxiety, working memory capacity, and object-based spatial ability independently predicting wayfinding ability.

Figure 6- Model 5. Anxiety will predict working memory capacity, which will predict object-based spatial ability, which will then predict wayfinding ability, which in turn will predict GPS Usage.
2. METHOD

Participants

187 undergraduate students (71 men and 116 women) were recruited using the online sign-up method implemented by the psychology department. The age of the participants ranged from 17 to 23 years old ($M = 18.7, SD = .98$). Participants received credit toward an introduction to psychology course requirement for participating in this study. There was minimal risk to participants and no deception was involved. Participants cannot be identified on any forms or in any data files.

Measures

Self-Report Surveys

Demographic Survey-Appendix B. This demographic form asked participants their sex/gender, race/ethnicity, year in school and age. This form took approximately 1 minute to complete.

GPS Usage Survey (Mace & Steele, 2010) -Appendix C. This 10 item likert-scale survey is a relatively new measure designed to assess GPS Usage in a variety of setting, such as in your car, familiar areas or unfamiliar areas. Scores on each item ranged from 1 to 5, with a total minimum score of 10 and a maximum score of 50. The original scale had 7 likert scale items. However, for purposes of this study, we included 3 additional questions, as well as open-ended questions. An example question is “What features of a GPS do you use?” A high score on this survey indicates high GPS Usage, whereas a low score indicates low GPS Usage. Internal
consistency reports show a Cronbach’s alpha of .90 (Mace & Steele, 2010). This task took approximately 2 minutes to complete.

**Media and Technology Usage and Attitudes Scale** - (Rosen, Whaling, Carrier, Cheever, Rokkum, 2013)-Appendix D. Participants completed a 60 item likert-scale questionnaire designed to examine technology usage and attitudes across different domains. It was comprised of Usage and Attitude subscales. The Usage subscales were: Smartphone Usage (9 items), General Social Media Usage (9 items), Internet Searching (4 items), E-Mailing (4 items), Media Sharing (4 items), Text Messaging (3 items), Video Gaming (3 items), Online Friendships (2 items), Facebook Friendships (2 items), Phone Calling (2 items) and TV Viewing (2 items). Scores one each item ranged from 1-10 (for questions 1-40) with a minimum score of 40 and maximum score of 400. Scores for questions 41-44 were based on a 1-9 likert scale with a minimum score of 4 to a maximum score of 36. The Attitudes subscales are Positive Attitudes toward Technology (6 items), Anxiety about Being without Technology or Dependence on Technology (3 items), Negative Attitudes toward Technology (3 items), and Preference for Task Switching (4 items). Scores on each item ranged from 1 to 5, with a total minimum score of 16 and a maximum score of 80. Scores from both subscales were combined to create a single composite score. The measure is considered to be internally reliable with all of the subscales having a Cronbach’s alpha of at least .61 (Rosen et al., 2013). This task took approximately 5 minutes to complete.

**Santa Barbara Sense of Direction Survey** (Hegarty, Richardson, Montello, Lovelace & Subbiah, 2002)-Appendix E. Participants completed a 15-item likert-scale questionnaire designed to assess their sense of direction. Each item was on a 1-7 likert scale, with a minimum score of 15 and a maximum score of 105. This measure had 8 items that were reverse coded. The
higher the score on this questionnaire, the higher the reported sense of direction. This measure has high internal consistency with a Cronbach’s alpha of .88 (Hegarty et al., 2002). This task took approximately 2 minutes to complete.

**Spatial Anxiety Survey (Lawton, 1994)-Appendix F.** Participants completed an 8-item questionnaire designed to assess spatial anxiety in a variety of wayfinding situations (e.g., “Rate the level of anxiety you think you would feel when finding your way around an unfamiliar mall”). Each item was on a 1-5 likert scale, with an overall minimum score of 8 and a maximum score of 40. A high number on this survey indicates high spatial anxiety. This measure has high reliability with a reported Cronbach’s alpha of .80 (Lawton, 1994). This task took approximately 2 minutes to complete.

**Neuroticism Scale from Big Five Personality Inventory (John & Srivastava, 1999) - Appendix G.** This personality inventory was composed of 5 subscales (Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness). The subscale this project used is the Neuroticism scale, because this scale is considered to be a measure of general trait anxiety. The scale was composed of 8 likert items, using a 1-5 scale, how much the statement is like them. The range of scores for the neuroticism scale is 8-40. The higher the score, the higher the neuroticism (anxiety). The neuroticism subscale has high internal reliability, with a Cronbach’s alpha of .72 (Hee, 2014). This task took approximately 2 minutes to complete.

**Wayfinding Strategy Survey (Lawton, 1994) –Appendix H.** Participants completed a 14-item questionnaire designed to assess the types of wayfinding strategies they typically use. Each item was rated on a 1-6 scale, with higher numbers indicating higher usage of that type of strategy. It included two subscales: Route and Survey. The Route subscale had 5 items and its scores ranged from 5 to 30. The Survey subscale had 9 items and its score ranged from 9 to 54.
The Cronbach’s alpha coefficient was .73 for the survey strategies and .65 for the route strategies (Lawton, 1994). This task took approximately 2 minutes to complete.

Spatial Performance Tasks

Mental Rotation Task (Peters, Laeng, Latham, Johnson, Zaiyouna & Richardson, 1995) – Appendix I. This was a paper and pencil test where participants were to imagine a three dimensional figure that were rotated at varying degrees. In each problem there was a standard picture and four alternatives showing the standard picture rotated to various degrees. Two of the alternatives correctly represented the standard rotated to that degree, and two are impossible rotations of the standard figure. Participants checked the correctly rotated alternatives. There were 24 problems in this test. Participants earned 1 point for each item they got correct. This task has a minimum score of 0 and a maximum score of 48. This task has a reported Cronbach’s alpha of .92 (Caissie, Vigneau & Bors, 2009). This task took approximately 10 minutes to complete.

Paper-Folding Task (Ekstrom, French, Harman, Derman, 1976) – Appendix I. This was a paper and pencil test where participants were to imagine the folding and unfolding of pieces of paper. On each problem there was a series of drawings depicting the folding of a piece of paper, one fold at a time. The number of folds varied from 1 to 4. The last figure depicted a hole being punched in the folded paper. There were 5 alternatives depicting what the pattern of punched holes would look like if the paper were unfolded. Participants were to decide which one of the alternatives was correct and draw an X through that figure. There were 20 problems in this test, each worth 1 point. The scores on this task ranged from 0 to 20. This task has a Kuder-Richardson coefficient of .68 (Study, 2012). This task took approximately 10 minutes to complete.
Wayfinding Task (Prestopnik, 2001) – Appendix J. The wayfinding task was a computer based mental navigation task using SuperLab 4.0. In this task, participants mentally navigate through areas of Tuscaloosa as well as the University of Alabama by following directions that appear on a computer screen. There are 13 trials. On each trial the participants imagine that they are at the starting location, facing in a particular direction. Then they mentally follow a 4-segment route, ending at a target location, facing in a particular direction. Finally, they are asked to indicate the direction of the starting location, using the numeric keypad on the keyboard. The numbers on the numeric keypad correspond to the 45-degree angles surrounding them. The numeric keypad we used had 1-2-3 on the bottom row, 4-5-6 in the middle row, and 7-8-9 on the top row. The 5 key represents the current (mental) location of the participant. In this case, the 8 key represents a location directly in front of them, and 6 would be directly to their right. Participants were first familiarized with using the numeric keypad to respond. After becoming familiar with the keypad participants continued to the mental navigation task. The dependent variable for this measure was percent correct. This task took approximately 15 minutes to complete.

Working Memory Capacity Tasks

Rotation Span (Foster, Shipstead, Harrison, Hicks, Redick, & Engle, 2014) – Appendix K. Participants were shown a letter on a screen. They were then presented with an arrow pointing in one of eight directions. Participants were then shown another letter and were asked to identify if a rotated letter is presented correctly, or is a mirrored image of the letter. The to-be-remembered items are arrows of either short or long length, pointing in one of eight different directions. The rotation-arrow sequence is repeated from two to five times per trial. Scores were calculated by summing the number of arrows correctly recalled in the correct order.
The dependent variable was percent correct. This program was run on E-prime 2.0.10 software. This task has a reported Cronbach’s alpha of .86 (Oswald, McAbee, Redick & Hambrick, 2014). This task took approximately 10 minutes to complete.

**Operation Span (Foster, Shipstead, Harrison, Hicks, Redick, & Engle, 2014) – Appendix K.** Participants were presented with a set of arithmetic operations and asked to judge whether each equation is true or false (approximately half are true). After each arithmetic operation, participants were presented with an element (a letter) for recall at the end of the set. Six trials were presented (2 each of list lengths 4, 5, & 6). The dependent variable was percent correct. This program was run on E-prime 2.0.10 software. This task has a reported Cronbach’s alpha of .86 (Oswald et al., 2014). This task took approximately 10 minutes to complete.

**Symmetry Span (Foster, Shipstead, Harrison, Hicks, Redick, & Engle, 2014) – Appendix K.** In this task, participants are presented with a set of 8 × 8 matrices of black and white squares and asked to make a judgment as to whether the matrices are symmetrical down the vertical axis (approximately half of the matrices are symmetrical). After each matrix, participants see a red square positioned in a 4 × 4 matrix; they are to remember the position(s) of the red square for recall at the end of the set. Recall consists of a blank 4 x 4 matrix into which participants click on the remembered locations of the red squares. Set sizes range from 2–5 symmetry judgments, with three administrations for each set size. The dependent variable is percent correct. This program was run on E-prime 2.0.10 software. This task has a reported Cronbach’s alpha of .80 (Oswald et al., 2014). This task took approximately 10 minutes to complete.

**Procedure**

Participants entered the lab and were greeted by the experimenter. They then read an information sheet about the study. Participants then completed the demographic form and 6 self-
report surveys in a randomized order. Participants then completed the Mental Rotation and Paper-Folding task with paper and pencil. Participants then were asked to move to the computers in the lab to complete the Wayfinding and Working Memory Capacity tasks. After all surveys and tasks were completed, participants received a debriefing sheet and were thanked for participating in the study. The entire study took approximately 1.5 hours to complete.
3. RESULTS

Before the data were analyzed, all data were screened for outliers and normality. There were no outliers and all variables were normally distributed, with kurtosis and skewness within acceptable ranges (i.e., -3 to +3 for kurtosis and -1 to +1 for skewness). Once deemed normal, descriptive statistics were calculated (Table 1, Mean, SD, Minimum, and Maximum). All descriptive statistics, correlational analyses, and factor analyses were conducted using SPSS version 23.

Correlations for Individual Measures

A correlation matrix was created for each individual task/measure (Table 1). A few patterns emerged from these data. First, the individual measures associated with each latent variable are correlated significantly (Table 1, correlations within boxes). For example, the measures of the latent variable Wayfinding Ability (Wayfinding Task, Sense of Direction, Survey Strategy Use) are all positively correlated ($r = .23, .36, .50$). Second, the measures of the three types of cognitive processes are all positively correlated. That is, the measures of Object-Based Spatial Ability (Table 1, columns 1, 2) are positively correlated with the measures of Wayfinding Ability (Table 1, rows 3, 4, 5) and measures of Working Memory (Table 1, rows 6, 7, 8). Further, the measures of cognitive processes (Table 1, columns 1-8) are generally negatively correlated, if correlated at all, with the non-cognitive measures of Anxiety (Table 1, rows 9, 10), Technology Usage (Table 1, row 11), and GPS Usage (Table 1, row 12).
Although we did not have specific hypotheses regarding individual correlations, they seem to be in the direction that the literature suggests, and they preview the factor analyses. In terms of individual correlations and GPS usage we see a few patterns emerge. First, GPS usage was negatively correlated with only one measure of object-based spatial ability, all three of the wayfinding ability measures and only one of the working memory capacity measures. Second, GPS usage was positively correlated with both measures of anxiety as well as overall technology usage. Some other, interesting correlations also appeared in the data analysis. For instance, the results generally showed a negative correlation between Overall Technology usage and Object-Based Spatial Ability. This interesting finding will be examined more closely in the discussion section.
Table 1

Means, SD, and Bivariate Correlations for Individual Variables

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<td>38</td>
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<td>447</td>
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Note: *p<.05, **p<.01, n=187
Exploratory Factor Analysis

An exploratory factor analysis was completed to determine whether the different types of tasks (e.g. object-based spatial ability tasks) formed separate factors. We originally expected 5 factors, representing Wayfinding Ability, Object-Based Spatial Ability, Anxiety, Working Memory Capacity, and Technology Usage. The criteria for acceptable factors was an Eigenvalue greater than 1. Also, each individual measure needed to have a factor weighting of at least .40 on one factor and less than .40 on the second factor. The analysis yielded 2 factors and not the expected 5 (Table 2). Factor 1 had an Eigenvalue of 3.32 and Factor 2 had an Eigenvalue of 1.72, with both factors combined to explain 50.47% of the variance for the entered set of variables. No other factors reached criterion. The factor analysis essentially split the data into tasks that used self-reported scales and tasks that involved performance. Since this breakdown reflected the method of measurement rather than the content of the measure, we decided to pursue confirmatory factor analyses of each construct (e.g. object-based spatial ability).

Table 2
Factor Solution for Exploratory Analysis

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<tr>
<th>Task Performance</th>
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<th>Factor 2</th>
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<tr>
<td>Paper-Folding</td>
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<td>Mental Rotation</td>
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<td>Wayfinding</td>
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<td>Rotation Span</td>
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<td>Symmetry Span</td>
<td>.514</td>
<td>.285</td>
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<td>Operation Span</td>
<td>.414</td>
<td>.176</td>
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<table>
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<tr>
<th>Self-Report Surveys</th>
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<td>Sense of Direction</td>
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<td>Survey Strategy Use</td>
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<td>.455</td>
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Confirmatory Factor Analyses

Four confirmatory factor analyses were conducted to determine if the relevant measures loaded onto the predetermined latent variables (Wayfinding Ability, Object-Based Spatial Ability, Working Memory Capacity, and Anxiety). Criteria for the analyses required eigenvalues greater than 1.0 and factor loadings greater than .40. Each variables loaded properly onto each predetermined construct. The results of these analyses are in Table 3.

The three measures related to wayfinding ability (Survey Strategy Usage, Wayfinding Performance, and Sense of Direction Scale) yielded one factor with an eigenvalue greater than 1.0, explaining a total of 42.79% of the variance for the entered set of variables. The factor loadings ranged from .40 to .89. Based on these factor loadings, the three variables were combined into a single composite score to represent wayfinding ability.

The two tasks related to Object-Based Spatial Ability (Mental Rotation and Paper-Folding Task) also yielded 1 factor with an eigenvalue greater than 1.0, explaining a total of 58.82% of the variance for the entered set of variables. The factor loadings were both .77. Based on the factor loadings, the two variables were combined into a single composite score to represent Object-Based Spatial Ability.

The three tasks related to Working Memory Capacity (Rotation Span, Symmetry Span and Operation Span Task) yielded 1 factor with an eigenvalue greater than 1.0, explaining a total of 34.91% of the variance for the entered set of variables. The factor loadings ranged from .44 to .67. Based on these factor loadings, the three variables were combined into a single composite score to represent Working Memory Capacity.

A final factor analysis used the two tasks that were related to overall anxiety (Big 5 Neuroticism Subscale and Spatial Anxiety Scale). The analysis yielded 1 factor with an eigenvalue greater than 1.0, explaining 49.93% of the variance for the entered set of variables.
The factor loadings all were .71. Based on these factor loadings, the two variables were combined into a single composite score to represent Overall Anxiety.

**Latent Variables**

There were a total of 4 latent variables that were calculated based on a composite score. The five latent variables were as follows: Wayfinding Ability, Object-Based Spatial Ability, Working Memory Capacity, and Anxiety. A fifth latent variable had only one measure (Overall Technology Usage) and so a composite score was not necessary.

**Wayfinding Ability.** Overall wayfinding ability was a composite score of performance on the wayfinding task, responses to the Sense of Direction Scale (Hegarty et al., 2002) and responses to the Survey Strategy usage scale (Lawton, 1994). The variables were standardized and an average composite score was calculated.

**Object-Based Spatial Ability.** Object-Based spatial ability was a composite score of percent correct on a Mental Rotation task (Peters et al., 1995) and a Paper-Folding task (Ekstrom et al., 1976). Scores between these two tasks were averaged together.

**Working Memory Capacity.** Working memory capacity was a composite score of the rotation, operation, and symmetry working memory tasks (Foster et al., 2014). Scores on all these tasks were averaged together to form the composite score. Since they were all on the same scale, they were not standardized first.

**Anxiety.** Anxiety was composed of scores on the Spatial Anxiety survey (Lawton, 1994) and the neuroticism scale from the Big Five Personality Inventory (John & Srivastava, 1999). The variables were standardized and then averaged together to form the composite score.

**Overall Technology Usage.** Overall technology usage was the total score from the Media and Technology Usage and Attitudes Scale (Rosen et al., 2013).
The correlations among the latent variables (Table 4) follow the same patterns as those found in the individual-variable analyses, namely, GPS Usage was largely negatively related to the cognitive measures of Wayfinding Ability, Object-Based Spatial Ability and Working Memory Capacity, and positively correlated with Anxiety and Technology Usage. In addition, all of the cognitive measures were positively correlated with each other, and there was a negative relationship between the cognitive measures and Anxiety. It is important to note that Anxiety and

Table 3
Factor Solution for Latent Variables

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<th>1 Factor Loading</th>
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<td>Sense of Direction</td>
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<td>Eigenvalue</td>
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<td><strong>Object-Based Spatial Ability</strong></td>
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<tr>
<td>Eigenvalue</td>
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<td>Eigenvalue</td>
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Latent Variable Correlations

The correlations among the latent variables (Table 4) follow the same patterns as those found in the individual-variable analyses, namely, GPS Usage was largely negatively related to the cognitive measures of Wayfinding Ability, Object-Based Spatial Ability and Working Memory Capacity, and positively correlated with Anxiety and Technology Usage. In addition, all of the cognitive measures were positively correlated with each other, and there was a negative relationship between the cognitive measures and Anxiety. It is important to note that Anxiety and
Technology use were not correlated, suggesting that these are indeed separate constructs even though they have the same directional relationships with the other latent variables. This latent variable correlation matrix was used to test Hypotheses 1 and 2.

Table 4
Means, SD and correlations for latent variables

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<td>5-Anxiety</td>
<td>.31**</td>
<td>-.48**</td>
<td>-.12</td>
<td>-.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-Tech Total</td>
<td>.23**</td>
<td>-.16*</td>
<td>-.31**</td>
<td>-.12</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>28.19</td>
<td>.00</td>
<td>71.0</td>
<td>69.10</td>
<td>.00</td>
<td>306.1</td>
</tr>
<tr>
<td>SD</td>
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<td>.75</td>
<td>17.32</td>
<td>15.54</td>
<td>.86</td>
<td>48.9</td>
</tr>
<tr>
<td>Min</td>
<td>10</td>
<td>-1.69</td>
<td>33</td>
<td>21</td>
<td>-1.97</td>
<td>160</td>
</tr>
<tr>
<td>Max</td>
<td>50</td>
<td>2.06</td>
<td>100</td>
<td>100</td>
<td>2.21</td>
<td>447</td>
</tr>
</tbody>
</table>
Hypothesis Testing

**H1:** Hypothesis 1 stated that there would be a negative correlation between GPS Usage and Wayfinding Ability, Object-Based Spatial Ability, and Working Memory Capacity. Results confirmed that there was a strong negative correlation between GPS Usage and Wayfinding Ability, $r = -.42, p < .01$, and GPS Usage and Object-Based Spatial Ability, $r = -.20, p < .01$. The correlation between GPS Usage and Working Memory Capacity did not reach statistical significance; however, it was in the expected direction, $r = -.15, p = .06$. Therefore, Hypothesis 1 was partially supported by the data.

**H2:** Hypothesis 2 stated that there would be a positive correlation between GPS Usage and Anxiety and Overall Technology usage. Results confirmed a strong positive correlation between GPS Usage and Anxiety, $r = .31, p < .01$; and GPS Usage and Overall Technology Usage, $r = .23, p < .01$. Therefore, Hypothesis 2 was supported by the data.

**RQ1: Path Analyses**

We used the Lavaan package in R Studio to conduct path analyses to test the hypothesized models and evaluate the likelihood of competing models (Figures 1-A8) for goodness of fit. Latent variables in the models were also reversed to test other possible pathways in the models. SEM provides four basic indices of fit: Chi-Square, Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA) and Bayesian Information Criteria (BIC). Models that were deemed to have a good fit had to have a CFI of .95 or higher, a RMSEA score of less than .08 and a non-significant Chi-Square value (Schreiber, Stage, King, Nora, & Barlow, 2006). However, Chi-Square values are sometimes poor indicators of good models; therefore, the Chi-Square values were interpreted with caution. If the models met these criteria, the model with the lower BIC score was considered to be the best fit for the data. The BIC is commonly used for
model comparisons (Schreiber et al., 2006). The fit indices for all models are in Table 5. All of the models had an \( n = 187 \).

The Overall Model (Figure 1) met the criteria for a good fitting model. However, it is important to note that when you have a large amount of parameters, it is likely that the model will be an excellent fit. Therefore, we used Model 1 as our base comparison model.

In Model 1 (Figure 2), all latent variables were expected to predict the DV separately. Model 1 was a good fit to the data \( X^2(4) < 0.01, p > .05 \) with CFI of 1.0, RMSEA \( \leq .01 \), and a BIC of 2496.2. All of the other models were compared to this BIC to determine whether they had a better fit to the data. Model 1A (Appendix A, Figure A1) was created by removing the insignificant pathways from Model 1 and thus it appears as the best fitting model. However, we stayed with our original Model 1 as the main comparison model because all of the other models included all four latent variables, and we wanted to compare them with a similar model that included all four latent variables.

Model 2 (Figure 3), which hypothesized that both Anxiety and Working Memory Capacity would predict Object-Based Spatial Ability which would predict Wayfinding Ability and thus GPS Usage was tested and was considered not be a good fit. We then switched the order of Object-Based Spatial Ability and Wayfinding Ability and created Model 2A (Appendix A, Figure A2). We determined that this model was also not a good fit for the data, according to the fit indices. However, after taking Anxiety out of the model, and instead having Working Memory Capacity predicting Object-Based Spatial Ability which in turn predicted Wayfinding Ability and thus GPS Usage, model 2B (Appendix A, Figure A3) was considered a better fit than Model 2 and Model 2A with CFI = .99 and RMSEA = .04 and \( X^2(3) = 4.2, p = .25 \).
Model 3 (Figure 4), which had Wayfinding Ability predicting Anxiety and Working Memory Capacity and Object-Based Spatial Ability acting as mediators between Anxiety and GPS Usage, was also not considered to be a good fit for the data, with CFI = .34 and RMSEA = .34. We then switched Anxiety and Wayfinding and had Working Memory Capacity and Object-Based Spatial Ability act as mediators between Wayfinding and GPS Usage to create Model 3A (Appendix A, Figure A4). Model 3A was not also not considered to be a good fit for the data. We decided to then take Working Memory Capacity out of the model to create Model 3B (Appendix A, Figure A5), which had Wayfinding Ability predicting Anxiety, which in turn predicted Object-Based Spatial Ability, and thus GPS Usage. This model was also not considered to be a good fit of the data.

Model 4 (Figure 5) had Anxiety, Working Memory Capacity and Object-Based Spatial Ability predicting Wayfinding Ability, which is turn predicted GPS Usage. This was considered an acceptable model with CFI = .99, RMSEA = .03 and $X^2(3) = 3.65$, $p > .05$. We also reversed the order of latent variables in Model 4 and used Anxiety, Working Memory Capacity, and Object-Based Spatial Ability as mediating variables between Wayfinding Ability and GPS Usage and created Model 4A (Appendix A, Figure A6). This was not considered to be an acceptable model, according to fit indices. In an effort to improve Model 4, working memory capacity was taken out to create model 4B. In Model 4B (Appendix A, Figure A7), Wayfinding Ability acted as a mediating variable between Anxiety, Object-Based Spatial Ability and GPS Usage. Model 4B was considered to be a good fit for the data with CFI = .99 and RMSEA = .06, $X^2(4) < 0.0$, $p = .16$. We reversed the latent variables to see if the model could be improved by having Anxiety and Object-Based Spatial Ability act as mediating variables between GPS Usage and Wayfinding Ability. This model was not a good fit for the data.
The final model tested was Model 5 (Figure 6) which suggested a linear relationship between all predictor variables. This was not considered a good fit for the data, according to the fit indices. We reversed the order of the latent variables and again found that Model 5A (Appendix A, Figure A8) was not an acceptable model for the data.

After testing all the models, we concluded that models 2B, 4 and 4B met the criteria for acceptable models, according to CFI, RMSEA and $X^2$. The next step was to compare them using the BIC fit index. As a reminder, the full model (Model 1) had a BIC of 2496.2. Furthermore, a BIC difference greater than 6 indicates a strong difference between models (Kass & Raftery, 1995). Model 2B had a BIC of 2027.5, Model 4 had a BIC of 2505.2 and Model 4B had a BIC of 2021.9. Therefore, Model 4B is considered to be the best fitting model for this set of data.

<table>
<thead>
<tr>
<th>Model</th>
<th>Pathway</th>
<th>$X^2$</th>
<th>Model Parameters</th>
<th>CFI</th>
<th>RMSEA</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>WF &amp; SA &amp; WM &amp; AX - ALL</td>
<td>&lt; .00</td>
<td>19</td>
<td>1.00</td>
<td>&lt; .01</td>
<td>1319.5</td>
</tr>
<tr>
<td>1</td>
<td>WF &amp; SA &amp; WM &amp; AX</td>
<td>&lt; .00</td>
<td>5</td>
<td>1.00</td>
<td>&lt; .01</td>
<td>2496.2</td>
</tr>
<tr>
<td>1A</td>
<td>WF &amp; AX</td>
<td>&lt; .00</td>
<td>3</td>
<td>1.00</td>
<td>&lt; .01</td>
<td>1519.3</td>
</tr>
<tr>
<td>2</td>
<td>(AX &amp; WM) – SA – WF</td>
<td>50.65**</td>
<td>7</td>
<td>.72</td>
<td>.22</td>
<td>2557.3</td>
</tr>
<tr>
<td>2A</td>
<td>(AX &amp; WM) – WF – SA</td>
<td>63.73**</td>
<td>7</td>
<td>.65</td>
<td>.25</td>
<td>2570.3</td>
</tr>
<tr>
<td>3</td>
<td>WF – AX – (WM &amp; SA)</td>
<td>115.74**</td>
<td>9</td>
<td>.34</td>
<td>.34</td>
<td>2632.8</td>
</tr>
<tr>
<td>3A</td>
<td>AX – WF – (WM &amp; SA)</td>
<td>63.07**</td>
<td>9</td>
<td>.65</td>
<td>.24</td>
<td>2580.2</td>
</tr>
<tr>
<td>3B</td>
<td>WF – AX – SA</td>
<td>68.50**</td>
<td>6</td>
<td>.45</td>
<td>.34</td>
<td>2092.2</td>
</tr>
<tr>
<td>4</td>
<td>(AX &amp; WM &amp; SA) - WF</td>
<td>3.65</td>
<td>6</td>
<td>.99</td>
<td>.03</td>
<td>2505.2</td>
</tr>
<tr>
<td>4A</td>
<td>WF – (AX &amp; WM &amp; SA)</td>
<td>47.83**</td>
<td>10</td>
<td>.74</td>
<td>.24</td>
<td>2570.2</td>
</tr>
<tr>
<td>4B</td>
<td>(AX &amp; SA) – WF</td>
<td>3.65</td>
<td>5</td>
<td>.99</td>
<td>.06</td>
<td>2021.9</td>
</tr>
<tr>
<td>4C</td>
<td>WF – (AX &amp; SA)</td>
<td>16.92**</td>
<td>7</td>
<td>.88</td>
<td>.20</td>
<td>2045.6</td>
</tr>
<tr>
<td>5</td>
<td>AX – WM – SA – WF</td>
<td>51.88**</td>
<td>8</td>
<td>.73</td>
<td>.20</td>
<td>2563.7</td>
</tr>
<tr>
<td>5A</td>
<td>WF – SA – WM – AX</td>
<td>69.23**</td>
<td>8</td>
<td>.62</td>
<td>.24</td>
<td>2581.1</td>
</tr>
</tbody>
</table>
Sex Differences

After conducting the main analyses, we turned our attention to possible sex differences (Table 6) because they are ubiquitous in many spatial tasks (Prestopnik & Roskos, 2001). We found sex differences in most of the latent variables except for working memory capacity. The results suggest that women reported higher GPS usage, anxiety and technology usage than men whereas men had higher wayfinding ability and object-based spatial ability compared to women. Though the differences in working memory capacity were not significant, they were in the same direction as the other variables in that men had higher capacity than women.

Table 6:
Sex Differences For All Latent Variables

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M/ SD</td>
<td>M/SD</td>
</tr>
<tr>
<td>n=71</td>
<td>n=116</td>
<td></td>
</tr>
<tr>
<td>GPS Usage*</td>
<td>25.44/6.21</td>
<td>29.88/6.95</td>
</tr>
<tr>
<td>Wayfinding Ability*</td>
<td>.51/.64</td>
<td>-.31/.64</td>
</tr>
<tr>
<td>Anxiety*</td>
<td>-.33/.74</td>
<td>.23/.74</td>
</tr>
<tr>
<td>OBSA*</td>
<td>78.10/15.71</td>
<td>66.65/16.9</td>
</tr>
<tr>
<td>WMC</td>
<td>71.82/13.67</td>
<td>67.4/16.44</td>
</tr>
<tr>
<td>Technology Usage*</td>
<td>289.01/47.48</td>
<td>316.41/47.05</td>
</tr>
</tbody>
</table>

Note: * = sex differences p < .05, OBSA=Object Based Spatial Ability, WMC=Working Memory Capacity

We then looked at the latent variable correlations separately for men and women (Tables 7 and 8). For both men and women, a) anxiety correlated positively with GPS usage, b) working memory was positively correlated with object based spatial ability, c) wayfinding ability was negatively related to anxiety and positively related to object-based spatial ability and working memory capacity. The only difference was that the relationship between GPS Usage and wayfinding ability was significant for females only.
Table 7
*Correlations Among Latent Variables for Men Only*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GPS Usage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Wayfinding Ability</td>
<td>-.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Anxiety</td>
<td>.28*</td>
<td>-.41*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. OBSA</td>
<td>-.10</td>
<td>.31*</td>
<td>-.19</td>
<td></td>
</tr>
<tr>
<td>5. Working Memory</td>
<td>-.09</td>
<td>.28*</td>
<td>.22</td>
<td>.42*</td>
</tr>
</tbody>
</table>

Note: * = p < .05

Table 8
*Correlations Among Latent Variables for Women Only*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. GPS Usage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Wayfinding Ability</td>
<td>-.38*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Anxiety</td>
<td>.18*</td>
<td>-.33*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. OBSA</td>
<td>-.12</td>
<td>.34*</td>
<td>-.06</td>
<td></td>
</tr>
<tr>
<td>5. Working Memory</td>
<td>-.12</td>
<td>.31*</td>
<td>.04</td>
<td>.48*</td>
</tr>
</tbody>
</table>

Note: * = p < .05

After looking at the correlations separately, we compared Models 1 and 4B (i.e., the initial and best fitting models) separately for men and women. As a reminder, Model 1 had all four latent variables independently predicting GPS usage, and in Model 4B, wayfinding ability mediated the relationship between anxiety, object-based spatial ability and GPS Usage. The results (Table 9) showed that Model 1 was a good fitting model for both men and women, and Model 4B had a better fit than Model 1. These results are the same as our previous conclusions and indicate that the same variables predict GPS usage in the same way for both men and women, despite the sex differences on most of the tasks. If anything, the models are a much better fit for men than for women.
Table 9:
*Model Fit for Path Analyses-Sex Differences*

<table>
<thead>
<tr>
<th>Model</th>
<th>Pathway</th>
<th>$X^2$</th>
<th>Model Parameters</th>
<th>CFI</th>
<th>RMSEA</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WF &amp; SA &amp; WM &amp; AX</td>
<td>&lt; .00</td>
<td>5</td>
<td>1.00</td>
<td>&lt;.01</td>
<td>2496.2</td>
</tr>
<tr>
<td>4B</td>
<td>(AX &amp; SA) – WF</td>
<td>3.65</td>
<td>5</td>
<td>.99</td>
<td>.06</td>
<td>2021.9</td>
</tr>
</tbody>
</table>

Sex Differences

| Men Model 1 | WF & SA & WM & AX | <.00 | 5 | 1.00 | <.01 | 980.17 |
| Women Model 1 | WF & SA & WM & AX | <.00 | 5 | 1.00 | <.01 | 1579.96 |
| Men Model 4B | (AX & SA) – WF | 3.92 | 5 | .90 | .12 | 800.29 |
| Women Model 4B | (AX & SA) – WF | .45 | 5 | 1.00 | <.01 | 1286.36 |
4. DISCUSSION

This study aimed to identify possible predictors of GPS usage using correlations and path analyses. The reason for this emphasis was to show that, just as in predicting drug usage to develop interventions, it would also be useful to predict GPS usage, as the literature has shown the detrimental effects of using this technology (Burnett & Lee, 2005). The results of this study demonstrated that factors we thought would be related to GPS usage based on the literature, actually were related and in the expected directions.

The first hypothesis that GPS usage would be negatively related to wayfinding ability, object-based spatial ability and working memory capacity was partially supported. There was a negative correlation between GPS usage and wayfinding ability. This is consistent with previous research that has argued that using a GPS is strongly related to poor spatial knowledge (Burnett & Lee, 2005). The negative correlation between GPS usage and object-based spatial ability replicates an earlier study (Mace & Steele, 2010). However, the relationship between working memory capacity and GPS usage was only trending towards significance in the expected direction. This contrasts with research that has shown working memory capacity as an important component of wayfinding performance (Nori et al., 2009). It is possible we did not have enough power to detect a relationship or there really was no relationship, more research is needed in this area.

The second hypothesis was that GPS usage would be positively correlated with anxiety and overall technology usage. The correlation between GPS usage and anxiety replicated results
from the Mace and Steele (2010) study. This relation fits with the idea that GPS usage causes a lower level of anxiety while navigating. But of course, it is a correlation and we cannot say definitively. We also found a positive correlation between GPS usage and overall technology usage. Therefore, our second hypothesis was supported.

The last finding is consistent with previous literature that suggests that people generally use or have more than one form of technology on a daily basis. This leads to the idea that those who use this technology might be “techies” who own a variety of technological devices. However, the results indicate that people who use technology often actually have lower wayfinding performance. This might be because people might be using technology to help them with other areas of cognition. More research is still needed in this area.

Aside from looking at correlations between GPS usage and its predictors, it is also important to look at correlations amongst the measures themselves to see how they relate to previous literature. In terms of measures of wayfinding ability, we found correlations consistent with the literature. For instance, survey strategy usage and sense of direction were positively correlated with performance on the wayfinding task. These results are similar to results in Prestopnik and Roskos-Ewoldsen (2001). Finally, our data show that sense of direction and survey strategy usage were positively correlated with each other, which is also consistent with previous literature (Prestopnik, 2000).

For the composite measure of anxiety, we used a spatial anxiety measure as well as an overall anxiety measure from the Big Five Inventory of personality traits. We found both of these measures to be positively correlated (.50) with each other. This relationship fits nicely with previous research that found similar results (McKeen, 2011).
For measuring object-based spatial ability, we used two common measures in the literature: Mental Rotation and Paper-Folding. Our research shows that performance on these two tasks was positively correlated. This finding is consistent with work from Miyake et al. (2001) that found a correlation of .49 between similar measures. This indicates that mental rotation and paper-folding tasks might rely on similar cognitive processes.

It is also important to compare the relationships among the latent variables to previous research. First, our data showed no significant relationship between anxiety and object-based spatial ability; however, it was still in the expected negative direction. This finding is somewhat inconsistent with Lawton (1994), who found a negative correlation between the two. It is possible we did not have enough power to detect this relationship. More research in regards to this finding.

We also did not find a relationship between anxiety and working memory capacity as previous research has shown fairly consistently; however, it was in the expected direction (Sarason, 1984). Previous correlations have been close to -.50, whereas our correlations was -.13. Although this was not a significant correlation, that does not necessarily mean there is no relationship between these variables.

Finally, our work did show a positive relationship between working memory capacity and object-based spatial ability. This finding was consistent with previous literature that found a relationship between performance on a mental rotation task and working memory tasks (Kauffman, 2007). This might be because object-based spatial tasks generally require someone to actively hold information while manipulating it at the same time. This process would need to take up working memory resources to be completed successfully.
One interesting result that we found was a negative relationship between overall technology usage and object-based spatial ability. No previous research has identified this relationship; therefore, there is not much we can compare this particular result to. In terms of explaining why this relationship exists, it could be that those who have poor object-based spatial ability might also have poor cognition in other areas as well and thus rely on different forms of technology to aid them on a frequent basis.

The most important aspect of this study involved the path analyses. The analyses were conducted to determine the combination and order of the factors that best predicted GPS usage. After testing all of the models, we found one model that fit the data best, based on several indicators, including a Bayesian comparison. In the best-fitting model, anxiety and object-based spatial ability have indirect effects on GPS usage via wayfinding ability. This begs the question: What is it about object-based spatial ability and anxiety that predicts wayfinding performance? It might be that there is a connection between these underlying object-based spatial abilities and performance in larger scale settings, such as navigation. In terms of anxiety, it might be related to the feeling of personal safety during navigation. Previous research suggests that worrisome or intrusive thoughts can hinder cognitive abilities (Sarason, 1984). Therefore, these intrusive thoughts might hinder wayfinding ability.

It should be worth noting that although it may seem GPS is bad for learning an environment, it could still potentially be helpful to those with high levels of anxiety to help them explore their environments. People who are highly anxious might not go anywhere without the help from a GPS, so therefore, they do serve a useful purpose to calm someone down while navigating. However, caution must be kept if the intended purpose is to learn the environment.
Although not an original objective, we chose to look at sex differences on the latent variables and in the model testing. We found sex differences for GPS usage, wayfinding ability, object-based spatial ability, anxiety and technology usage. All of the sex differences we found were consistent with previous literature with men having better wayfinding ability (Malinowski, 2001) and object-based spatial ability (Kauffman, 2007), and women reporting higher anxiety (Lawton, 1994). When looking at the correlations amongst the latent variables, they were very similar in terms of strength and direction across men and women.

The one sex difference we did not find was in working memory capacity. Previous research has found sex differences in working memory capacity, while others have not. For instance, Kauffman (2007) had participants complete a variety of spatial ability and spatial working memory test. He found that there were no significant differences between men and women in the working memory tasks. However, Voyer (2016) found a sex difference in working capacity between men and women. Therefore, more research is need in this area.

Finally, we conducted separate path analyses for both men and women separately. Our results showed that the final model (model 4B) whereby wayfinding ability acted as a mediator between object-based spatial ability, anxiety and GPS usage, was the best fitting model for both men and women compared to the overall/comparison model. Therefore, our conclusions that Model 4B was the best fitting model is still valid.

Implications

This research has some important implications to consider. Previous research has linked GPS usage to poor spatial knowledge of the environment (Burnett & Lee, 2005). Poor spatial knowledge of an environment could have some potentially negative consequences, such as not knowing where to navigate in an emergency. The potential negative consequences are important
to consider as they could be dangerous to individuals. By identifying variables that have known relationships with GPS usage we can potentially design intervention programs to help people learn their environment even as they use their GPS system for navigation.

In terms of interventions, we could try to target variables such as anxiety and object-based spatial ability. Some research suggests that simply providing reassuring statements can help people cope with their anxiety (Sarason, 1984). In addition, we might be able to design an intervention that can improve these underlying object-based spatial skills. It would be of great use to possibly design a 2 (object-based spatial ability training vs none) x 2 (soothing words vs none) manipulation to test their effects on wayfinding. We could implement a pre and post wayfinding test as well as a GPS usage survey to see if there are any differences after the intervention. In terms of who would be the best target for an intervention, it would be best to try it on a similar sample first, since the data was collected from college students.

Another implication for this research was that working memory capacity did not contribute heavily to the models tested. It is possible, with using other measures of working memory, we might have found different results. However, the results regarding working memory for this particular study suggest that working memory capacity is not as important as one might think in navigation. This result goes against the general consensus in the literature and further research is needed in this area.

Limitations

There are some limitations to this study. First, this sample was composed of college students, most of whom probably have access to GPS technology. Therefore, the results might not be generalizable to other age groups. Another limitation is the size of the sample itself. There might have been an issue of power. It is possible that if we had more participants, we might have
found a significant relationship between working memory capacity and GPS usage. A further limitation was that this research was conducted in a lab, and may not be to have high external validity.

**Future Directions**

The results from this project are a great starting point for investigating further the relation between GPS usage and spatial skill. It would also be of interest to identify which factors in the environment itself are related to GPS usage, instead of using an individual differences approach. For example, is GPS usage more common in urban or rural areas? This might be able to tell us whether individual differences or environmental factors are more predictive of GPS Usage. Additionally, it would also be interesting to see how consumers are using these products. Are they using them to walk around or drive? Do they use other features from the GPS besides just navigation? A more qualitative approach might be able to address these questions. By gaining a more detailed understanding of how people use this technology, we might be able to generate more detailed models that can predict GPS usage.

**Conclusions**

This study found support for the notion that there are both cognitive and non-cognitive correlates of GPS usage. This project identified a model that suggests that object-based spatial ability and anxiety predict wayfinding ability and in turn wayfinding ability predicts GPS usage. With this knowledge researchers can create lessons to help people learn their environments, be able to evaluate when their GPS device is in error, and recover from its incorrect instructions. The results from this study have far reaching implications that could help people become better navigators that do not need to rely on GPS technology. The results could lead to interventions that could target variables such as object-based spatial ability and anxiety to reduce reliance on
GPS technology. Or, at least to help people learn the environment in addition to using GPS technology.

Time will tell how GPS technology will affect our cognition. For example, will our current understanding of navigation strategies be a thing of the past? Will people still learn and use both route and survey strategies? Or simply not use survey strategies anymore because of this technology? There is plenty more research needed in this area that can help the scientific community understand the potential long-term effects of this technology as well as studying ways to improve GPS technology to help the user potentially learn their environment better. Overall, this study provides a solid framework for understanding correlates of GPS usage, as well how people are using this technology.
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Appendix A

Figure A1: Model 1A

Figure A2: Model 2A

Figure A3. Model 2B

Figure A4: Model 3A

Figure A5: Model 3B
Figure A6: Model 4A

Figure A7: Model 4B

Figure A8: Model 5A
Appendix B

Demographic Form

Instructions: Please fill out this form with the information that describes you the most.

Age:
How old are you?________

Sex/Gender:
__Female
__Male
__Transgender
__Prefer not to respond

Race/Ethnicity:
__White
__African American/Black
__Asian/Pacific Islander
__Hispanic/Latino
__Native American/American Indian
__Multiracial
__Not Listed (please specify)
__Prefer not to respond

Class status:
__Freshman
__Sophomore
__Junior
__Senior
Below are several statements regarding Global Positioning Satellite (GPS) usage. A GPS is defined as any portable technological device that keeps track of your current location to help you navigate an environment. For each statement, rate on a scale from 1 (not like me) to 5 (most like me), which represents you the most, generally speaking.

1. I use a GPS in my car most of the time I am driving.
   Not like me 1 2 3 4 5 Most like me

2. I use a GPS in unfamiliar areas.
   Not like me 1 2 3 4 5 Most like me

3. I use a GPS at least once a month.
   Not like me 1 2 3 4 5 Most like me

4. I use a GPS at least once a week.
   Not like me 1 2 3 4 5 Most like me

5. If traveling more than one hour away I use a GPS.
   Not like me 1 2 3 4 5 Most like me

6. I use a GPS daily.
   Not like me 1 2 3 4 5 Most like me

7. I use a GPS in familiar areas.
   Not like me 1 2 3 4 5 Most like me

8. I prefer to use a GPS if I am navigating alone.
   Not like me 1 2 3 4 5 Most like me

9. I use a GPS as a back up to paper maps/directions while navigating.
   Not like me 1 2 3 4 5 Most like me

10. I use a GPS while walking and/or biking around campus
    Not like me 1 2 3 4 5 Most like me

1. If you do own a GPS, why do you use a GPS?

2. If you do use a GPS, what features of the GPS do you use?

3. How much navigating/traveling have you done on your own?
Appendix D

Overall Technology Survey

This survey is designed to assess general technology usage. Please use the following 1-10 scale below to answer questions 1-40. Write your number on the blank spaces provided.

Never (1)
Once a month (2)
Several times a month (3)
Once a week (4)
Several times a week (5)
Once a day (6)
Several times a day (7)
Once an hour (8)
Several times an hour (9)
All the time (10)

Please indicate how often you do each of the following e-mail activities on any device (mobile phone, laptop, desktop, etc.)

___ 1. Send, receive and read e-mails (not including spam or junk mail)
___ 2. Check your personal e-mail
___ 3. Check your work or school e-mail
___ 4. Send or receive files via e-mail

Please indicate how often you do each of the following activities on your mobile phone.

___ 5. Send and receive text messages on a mobile phone
___ 6. Make and receive mobile phone calls
___ 7. Check for text messages on a mobile phone
___ 8. Check for voice calls on a mobile phone
___ 9. Read e-mail on a mobile phone
___10. Get directions or use GPS on a mobile phone
___11. Browse the web on a mobile phone
___12. Listen to music on a mobile phone
___13. Take pictures using a mobile phone
___14. Check the news on a mobile phone
___15. Record video on a mobile phone
___16. Use apps (for any purpose) on a mobile phone
___17. Search for information with a mobile phone
___18. Use your mobile phone during class or work time

How often do you do each of the following activities?

___19. Watch TV shows, movies, etc. on a TV set
___20. Watch video clips on a TV set
___21. Watch TV shows, movies, etc. on a computer
___22. Watch video clips on a computer
___23. Download media files from other people on a computer
24. Share your own media files on a computer
25. Search the Internet for news on any device
26. Search the Internet for information on any device
27. Search the Internet for videos on any device
28. Search the Internet for images or photos on any device
29. Play games on a computer, video game console or smartphone BY YOURSELF
30. Play games on a computer, video game console or smartphone WITH OTHER PEOPLE IN THE SAME ROOM
31. Play games on a computer, video game console or smartphone WITH OTHER PEOPLE ONLINE

Do you have a Facebook account? If the answer is “yes,” continue with item 32; if “no” skip to the Attitudes Subscale Scale items (next page).

Use the scale below (same as before) to indicate how often you do each of the following activities on social networking sites such as Facebook (questions 32-40)?

Never (1)
Once a month (2)
Several times a month (3)
Once a week (4)
Several times a week (5)
Once a day (6)
Several times a day (7)
Once an hour (8)
Several times an hour (9)
All the time (10)

32. Check your Facebook page or other social networks
33. Check your Facebook page from your smartphone
34. Check Facebook at work or school
35. Post status updates
36. Post photos
37. Browse profiles and photos
38. Read postings
39. Comment on postings, status updates, photos, etc.
40. Click "Like" to a posting, photo, etc.
Please answer the following questions about your Facebook and other online friends. For questions 41-44. Please use the 1-9 scale below.

0 (1)
1-50 (2)
51-100 (3)
101-175 (4)
176-250 (5)
251-375 (6)
376-500 (7)
501-750 (8)
751 or more (9)

____41. How many friends do you have on Facebook?
____42. How many of your Facebook friends do you know in person?
____43. How many people have you met online that you have never met in person?
____44. How many people do you regularly interact with online that you have never met in person?

ATTITUDES SUBSCALES
This scale is designed to assess your attitude towards technology. Please rate questions 1-16 using the scale below.

Strongly Agree (5)
Agree (4)
Neither Agree nor Disagree (3)
Disagree (2)
Strongly Disagree (1)

____1. I feel it is important to be able to find any information whenever I want online.
____2. I feel it is important to be able to access the Internet any time I want.
____3. I think it is important to keep up with the latest trends in technology.
____4. I get anxious when I don't have my cell phone.
____5. I get anxious when I don't have the Internet available to me.
____6. I am dependent on my technology.
____7. Technology will provide solutions to many of our problems.
____8. With technology anything is possible.
____9. I feel that I get more accomplished because of technology.
____10. New technology makes people waste too much time.
____11. New technology makes life more complicated.
____12. New technology makes people more isolated.
____13. I prefer to work on several projects in a day, rather than completing one project and then switching to another.
____14. When doing a number of assignments, I like to switch back and forth between them rather than do one at a time.
____15. I like to finish one task completely before focusing on anything else.
____16. I have a task to complete, I like to break it up by switching to other tasks intermittently
Appendix E
SANTA BARBARA SENSE-OF-DIRECTION SCALE
This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. Circle "1" if you strongly disagree that the statement applies to you, "7" if you strongly agree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

Questions to reverse code in bold.

1. I am very good at giving directions.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

2. I have a poor memory for where I left things.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

3. I am very good at judging distances.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

4. My "sense of direction" is very good.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).
   strongly disagree 1 2 3 4 5 6 7 strongly agree

6. I very easily get lost in a new city.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

7. I enjoy reading maps.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

8. I have trouble understanding directions.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

9. I am very good at reading maps.
   strongly disagree 1 2 3 4 5 6 7 strongly agree

10. I don't remember routes very well while riding as a passenger in a car.
    strongly disagree 1 2 3 4 5 6 7 strongly agree

11. I don't enjoy giving directions.
    strongly disagree 1 2 3 4 5 6 7 strongly agree

12. It's not important to me to know where I am.
    strongly disagree 1 2 3 4 5 6 7 strongly agree
13. I usually let someone else do the navigational planning for long trips.  
strongly disagree 1 2 3 4 5 6 7 strongly agree

14. I can usually remember a new route after I have traveled it only once.  
strongly disagree 1 2 3 4 5 6 7 strongly agree

15. I don't have a very good "mental map" of my environment.  
strongly disagree 1 2 3 4 5 6 7 strongly agree
INSTRUCTIONS: Rate the level of anxiety you would experience for each context.

1. Leaving a store that you have been to for the first time and deciding which way to turn to get to a new destination.
   None at all 1 2 3 4 5 Very Much

2. Finding your way out of a complex arrangement of offices that you have visited for the first time.
   None at all 1 2 3 4 5 Very Much

3. Pointing in the direction of a place outside that someone wants to get to and has asked you for directions, when you are in windowless room.
   None at all 1 2 3 4 5 Very Much

4. Locating your car in a very large parking lot or parking garage.
   None at all 1 2 3 4 5 Very Much

5. Trying a new route that you will think will be a shortcut without the benefit of a map.
   None at all 1 2 3 4 5 Very Much

6. Finding your way back to a familiar area after realizing you have made a wrong turn and become lost while driving.
   None at all 1 2 3 4 5 Very Much

7. Finding your way around an unfamiliar mall.
   None at all 1 2 3 4 5 Very Much

8. Finding your way to an appointment in an area of a city of town with which you are not familiar.
   None at all 1 2 3 4 5 Very Much
Appendix G
BFI-Overall Anxiety

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. For this scale a 1 means you strongly disagree and 5 means you strongly agree.

Disagree strongly  Disagree a little  neither agree nor disagree  Agree a little  Agree Strongly
1  2  3  4  5

I see myself as someone who...

_____1. Is emotionally stable, not easily upset
_____2. Is depressed, blue
_____3. Can be moody
_____4. Is relaxed, handles stress well
_____5. Remains calm in tense situations
_____6. Can be tense
_____7. Gets nervous easily
_____8. Worries a lot

Scoring:

Bold Items are reverse coded
Appendix H
Wayfinding Strategy Scale

Think of a time when you traveled to a particular location within a city or town. You had visited the city a few times before, but you had never been to your particular destination within the city before. Rate how typical it is for you to have used each particular strategy. Use the scale below. Write in the left hand column the number from the scale that best represents how typical it is for you to have used this strategy.

1  2  3  4  5  6
Not at all typical of me  Very typical of me

1. As I drove, I made a mental note of the number of streets I passed before making each turn.

2. Before starting I asked directions telling me whether to go east, west, north or south at particular streets or landmarks.

3. I made a mental note of landmarks, such as buildings or natural features that I passed along the way.

4. Before starting, I asked for directions telling me how far to go in terms of mileage.

5. I kept track of the relationship between where I was and the center of town.

6. I kept track of where I was in relationship to the sun (or moon) in the sky as I went.

7. I visualized a map or a layout of the area in my mind as I drove.

8. Before starting I asked for directions telling me whether to turn right or left particular streets or landmarks.

9. Before starting, I asked for directions telling me how many streets to pass before making each turn.

10. I kept track of the direction (north, south, east or west) in which I was going.

11. I kept track of the relationship between where I was and the next place where I had to change direction.

12. Before starting, I asked for a drawn map of the area.

13. As I drove, I made a mental note of the mileage I traveled on different roads.

14. I referred to a published road map.
Appendix I

Spatial Task Examples

Mental Rotation Task

2.a

![Image of mental rotation task options]

The answer here is the 2\textsuperscript{nd} and 3\textsuperscript{rd} option. Participants will select the correct answers by marking them with an X.

Paper-Folding Task

![Image of paper-folding task options]

The correct answer to the sample problem above is C. Participants will indicate the correct answer by marking it with an X.
Appendix J

Example Wayfinding Test Trial

1. You are on Hackberry with the Science and Engineering library on your right. Turn right onto Campus Drive.

2. Continue on Campus drive to the ramp for McFarland Blvd. Turn right onto McFarland Blvd.

3. Take McFarland to University Blvd. Turn right onto Hackberry Lane.

4. Russell Hall is on your right.

5. In which direction is the Science and Engineering Library? Answer: Front/8 on keypad
Appendix K
Working Memory Capacity Tasks

**Operation Span**
- Distractor: $(2 \times 2) - 1 = 3$
- Memory: $F$
- Time: $(6 \times 3) + 5 = 21$
- Recall: F H J K L N P O R S T Y

**Symmetry Span**
- Distractor: 
- Memory: 
- Time: 
- Recall: 

**Rotation Span**
- Distractor: 
- Memory: 
- Time: 
- Recall:
Appendix L
IRB Approval

September 22, 2015

Beverly Roskos, PhD
Dept. of Psychology
College of Arts & Sciences
Box 870348

Re: IRB#: 15-OR-287 “Predicting GPS Usage: The Relative Importance of Wayfinding Performance, Object-Based Spatial Ability, Working Memory Capacity, Anxiety, and Overall Technology Usage”

Dear Dr. Roskos:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given expedited approval according to 45 CFR part 46. You have also been granted the requested waivers of informed consent/resent and parental permission. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

Your application will expire on September 20, 2016. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Request for Study Closure Form.

Please use reproductions of the IRB approved stamped information sheets to provide to your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

[Signature]

Calandra T. Myles, MSM; CICM, CIP
Director R & Research Compliance Officer