Navigating Through Virtual Spaces

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Spatial navigation is the ability to maneuver within the environment. This ability to use new and old information about one's surroundings to get to and from a location is a daily requirement. Successfully navigating a space is a complex phenomenon, using a variety of neural structures. There have been many ways to study spatial navigation. Many studies use a hedge maze or variations of it, wherein the participant must find their way down a series of virtual corridors, like hedges, tunnels, hallways, or city streets (Maïano, Therme, & Mestre, 2011;Nowak, Murali, & Driscoll, 2015; Jacobs, 2010; van der Ham, van Zandvoort, Meilinger, Bosch, Kant, & Postma, 2010). This maze is particularly useful within EEG studies, because due to the simplicity of the task (go down the hall and turn right or left) there are few distractions for the participant or reasons to excessively move their head or eyes around the screen. (Bischof & Boulanger, 2003; Gramann et al, 2009; Kober & Neuper, 2010). Additionally, a task used to study spatial navigation is the Morris water maze (Morris, 1984). The original article has been cited over 6000 times since 1984, and it has been used in both humans and animals (de Bruin, Sànchez-Santed, Heinsbroek, Donker, & Postmes, 1994; Livingstone-Lee et al., 2014; Livingstone-Lee Zeman, Gillingham, & Skelton, 2011; Padilla, Creem-Regehr, Stefanucci, &Cashdan, 2017; van Gerven, Schneider, Wuitchik, & Skelton, 2012).

The original water maze was developed for rats. The researcher would place a rat in a circular pool of water with full visibility to objects located within the lab. The rat would search for a platform just below the surface to get out of the water, using the cues around the lab as a reference. Typically developing rats would remember where the platform was, based on its location in the room and return there during each trial, usually getting faster and taking a more direct path. The water maze is a useful method of evaluating spatial navigation abilities, because it has the ability to distinguish proximal (close) cues from distal (far away) cues. This has proven to be important, as one of the common uses of the water maze is studying gender differences in spatial navigation (de Bruin, Sànchez-Santed, Heinsbroek, Donker, & Postmes, 1994; Livingstone-Lee et al., 2014; Livingstone-Lee Zeman, Gillingham, & Skelton, 2011; Padilla, Creem-Regehr, Stefanucci, & Cashdan, 2017; van Gerven, Schneider, Wuitchik, & Skelton, 2012). And some research is finding that gender differences – in humans and rodents – only exist in distal environments (D'Hooge & De Deyn, 2001; Padilla et al., 2017).

The water maze was later adapted for human research in virtual reality (Livingstone-Lee et al., 2014; Livingstone-Lee Zeman, Gillingham, & Skelton, 2011; Padilla, Creem-Regehr, Stefanucci, & Cashdan, 2017; van Gerven, Schneider, Wuitchik, & Skelton, 2012). Many researchers adapted the environment to be more natural. For example, instead of virtually swimming in a pool, the participant would navigate through a field (Padilla et al., 2017). And similar to the animal research, individual differences were studied to better understand what makes some more or less successful within the maze.

Research shows that gender plays a critical role in spatial navigation, such that males typically outperform females on the same spatial navigation task (Nowak, Murali, & Driscoll, 2015; Padilla, Creem-Regehr, Stefanucci, & Cashdan, 2017; van Gerven, Schneider, Wuitchik, & Skelton, 2012). Livingstone-Lee Zeman, Gillingham, & Skelton (2011) found that when participants are randomly assigned and trained to use an allocentric (a typically distal cue-based strategy; navigating with respect to an object's proximity to another object) or egocentric (a typically proximal cue-based strategy; navigating with respect to an objects proximity to one's self) strategy, sex differences disappear. But when a choice of strategy is given, men choose to use an allocentric strategy more often than egocentric; the researchers found given a choice and no training these men navigate with better accuracy than women using the same strategy (van

Gerven, Schneider, Wuitchik, & Skelton, 2012). Nowak, Murali, & Driscoll (2015) found similar results to van Gerven et al. (2012) and implied that that this is because men and women naturally apply navigation strategies differently. However, most virtual navigation research studies humans in a small environment. Little is understood about the abilities of humans in a large scale environment and how distal or proximal cues may influence their spatial navigation abilities. Padilla et al. (2017) studied just this, and they found that gender differences were only present when given the chance to navigate using distal cues in a large environment; males made fewer navigation errors than females. In this study we isolated the environments to distal only and proximal only to address the possible differences between proximal and distal cues for different genders.

One method of studying individual differences in spatial navigation that has been unique to humans is mobility experience. The average American man drives 63% more miles per year than the average woman (U.S. Department of Transportation, 2018). And there is evidence to suggest that those who have more navigation experience perform better on large scale navigational tasks than those with less navigation experience (Padilla, Creem-Regehr, Stefanucci, & Cashdan, 2017). Research indicates that men and women do not differ in their ability to learn navigation tasks (Chai & Jacobs, 2009), but men still perform better given no training (Nowak, Murali, & Driscoll, 2015; Padilla et al., 2017; van Gerven, Schneider, Wuitchik, & Skelton, 2012). Furthermore when participants are trained to use an allocentric or egocentric strategy, sex differences disappear (Livingston-Lee et al., 2011). Together these results suggests that more experience and practice in navigation tasks may result in an advantage in spatial navigation ability. The measures of navigation experience in this study are two novel surveys. The specifics of the surveys are discussed in the methods.

The two main types of navigation strategies are allocentric and egocentric. As previously stated, allocentric strategies use the relationship of the objects to one another in the environment as a reference for navigation. Egocentric strategies use the relationship of the self to objects in the environments as a reference for navigation. It is unclear if one strategy is better, but rather that some individuals apply egocentric and allocentric navigation strategies differently. Some data suggest that navigation strategy contributes to observed gender differences, but when controlling for gender have no effect on spatial navigation success (Livingstone-Lee et al., 2014).

Some research suggests that spatial navigation abilities may relate to an individual's likelihood of being cautious while navigating (Gagon, Cashdan, Stefanucci, & Creem-Regehr, 2016). This may relate to the person's predisposition to act in such a way due to their temperament or personality. A traditional method of evaluating personality is the Big-5 Personality scale (Goldberg, 1993). One researcher found marginal significance correlating a higher extraversion score to better spatial navigation performance (Shoenfeld, Foreman, & Leplow, 2014). Furthermore, Pickering, Diaz, and Gray, (1994) found that those high in neuroticism and anxiety were not as fast at successful maze completion. And those who were high in extraversion successfully completed the maze faster.

One influential approach to understanding the relationship between temperament and spatial navigation is Grey's reinforcement sensitivity theory (Gray & McNaughton, 2000). Some people are more introverted and prefer solitude, while others are more extroverted and enjoy being outgoing. Growing research is attempting to understand ways in which these types of individual differences are biologically different between groups and how these potential differences may affect spatial navigation. Personality types briefly described above like introversion and extroversion generally correlate with what Grey and McNaughton call the Behavioral Inhibition System (BIS) and Behavioral Approach System (BAS), respectively. Those who test high in BIS are highly receptive to punishment as a motivation while those high in BAS are highly receptive to rewards. The two systems are orthogonal in that an individual can be high or low in both (Carver & White, 1994). While they operate independently of each other, one does tend to be higher than the other, such that an individual would prioritize either avoiding a punishment over pursuing a reward, or vice versa. These systems can affect the way individuals live their lives (Carver & White, 1994; Gray & McNaughton, 2000). For example, those high in BIS are prone to anxiety and neuroticism, which is correlated with poor spatial navigation performance (Pickering, Diaz, & Gray, 1994).

Levels of BIS and BAS have been found to be associated with a difference in neural activity. Such that those high in BAS are documented to have greater activity in the left frontal cortex than the right, and those high in BIS have greater resting activity in the right midfrontal cortex (Coan & Allen, 2003; Sutton & Davidson, 1997). However, the relationship between BIS and right frontal asymmetry is only partially supported. Findings have not been constant in determining if BIS is correlated to right frontal asymmetry, only right midfrontal asymmetry, or no asymmetry at all (Harmon-Jones & Allen, 1997). One of the goals of the present study is to investigate this relationship between frontal asymmetry and spatial navigation as an alternative to measuring temperament.

This then becomes a question of how neural asymmetry can relate to spatial navigation. Eynseck and Calvo (1992) proposed Processing Efficiency Theory, which states that there is a limited capacity in working memory. Researchers find that the neural processes of spatial navigation are majorly in the right hemisphere (Jacobs et al., 2010; van der Ham et al., 2010).

This would suggest that spatial navigation being processed in a person who is already high in BIS, and therefor high in right hemispheric activity, may not be able to allot enough of their neural resources for successful spatial navigation. Processing Efficiency Theory states that only so much can be processed at once, so if a person is too worried about being punished by making a wrong turn or not finding what they should, they may be processing the anxiety over thecognitions required for spatial navigation. Perhaps while self-reported BIS and spatial navigation are not related, a stronger relationship may exist between the neural processes behind temperament. Therefor our lab also aims to investigate if a correlation between neural asymmetry and BIS may be present, and because of processing efficiency theory, can neural asymmetry predict navigation ability?

EEG research on spatial navigation typically focuses on theta oscillations (EEG activity in the 4-8 Hz range) in specific brain locations. Theta oscillations have been found to indicate the ability to focus and encode new information (Wolfgang, 1999). Bischof and Boulanger (2003) found that theta power and maze difficulty were positively correlated. In addition, they found that, similar to rodents, theta episodes may indicate encoding and retrieving spatial information; for example, when a new hallway was discovered or a mistake was made and needed correcting. Kober and Neuper (2011) found that men with more theta oscillations were more likely to do poorly on a spatial navigation task, while in women the same patterns indicated better performance. Overall, women showed stronger theta oscillations than men during the task, despite no difference in resting theta. The researchers suggest that women are more driven by landmarks, as these theta oscillations are more likely to occur when a searched for landmark becomes visible. Gramann et al. (2010) found that only 5 of 30 independent component clusters showed a difference from egocentric to allocentric navigation. Egocentric navigation correlated with stronger alpha (EEG activity in the 8-13 Hz range) desynchronization in or near the right inferior occipital gyrus. Alpha desynchronization is positively correlated with long-term memory performance (Wolfgang, 19999). Those navigating using an allocentric frame had stronger alpha blocking preceding and during changes in or near bilateral occipital-temporal cortex. Allocentric navigators had more activity in bilateral parietal cortex as well, likely due to the reliance on visual imagery as opposed to a mental representation. In addition, researchers found differences in inferior parietal cortex.

In this study, we aimed to better understand individual differences in spatial navigation performance in a proximal only and a distal only maze, specifically gender, temperament, experiences, and neural asymmetry, because the documented relationships between these constructs is extremely limited. The specific goals of the present study are as follows:

1. Examine individual differences in spatial navigation ability in a distal only and proximal only virtual water maze
2. Examine the difference in EEG activity between initial exploration of the water maze and being testing on returning to a location in the environment
3. Examine frontal asymmetrical neural activity
4. Test the validity of two navigation experience measures, Lifetime Mobility and Types of Navigation

Methods

Participants

We recruited individuals in the city of Laramie, WY who self-identify as either very good or very poor navigators to participate in this study. They were compensated $50 cash. Participants were also recruited through the University of Wyoming's online participant pool, SONA Systems. All 30 participants signed a written consent form when arriving at the lab. Two participants did not participate in the EEG portion of the study because of system crashing and comfort, but their survey data were still collected. Thirty participants had an average age of 22 with a range of 18 to 56. Twelve identified as male and eighteen as female.

Electroencephalograph (EEG)

Participants were fitted with an EEG cap containing 128 electrodes covering the scalp. Independent Component Analysis (ICA) was performed using these data. While wearing the cap, participants were instructed to blink and move only as much as necessary before every task.

Apparatus

The participants viewed the paradigms on three ASUS VZ249H Frameless 23.8" 5 ms (GTG) IPS Widescreen LCD/LED monitors which were mounted on a monitor stand so that one monitor was centered with the other two angled on the left and right to give a more immersive experience. The display was wrapped across all the monitors. A joystick was used to control movements within the maze.

Resting Asymmetry. An average cortical EEG activity was measured while participants sat quietly in a dark room for six one-minute blocks to determine their resting cortical asymmetry. Participants were told open or close their eyes for one minute while staring or facing toward a white cross on a black screen. The task started when the participant heard one high tone and ended with two low tones along with the changing of the screen. They were given 45 seconds to rest between the end of a block and the beginning of another. The researcher clicked through the screens while the participant performed the task.

Virtual Morris Water Maze. A traditional water maze demands participants search for a hidden platform in a small pool of water. The paradigm in this study used a virtual landscape, as this is a more realistic environment to navigate. The virtual maze was created using video game software (Unity Technologies, 2015) by the University of Wyoming. In this task, they explored an open field surrounded by either only distal cues (mountains, hills, and trees; Figure 1) or only proximal cues (flowers, bushes, and shrubs; Figure 2) to find a flock of birds resting in the field. The field is 146.4 unity meters in diameter, and in the distal condition the cues are at least 100 m away from the boundary. The boundary of the maze is invisible, but the participants cannot pass through. However, for the purpose of visualization, a boundary has been drawn in red around the maze in the figures below. The participants navigated the environment using the joystick to look around, move about, and indicate they found the birds and were ready to continue. As the participant is closer to the finding the hidden birds, they are considered more successful.

Figure 1: A bird's eye view of the distal maze, showing hills, trees, and mountains to the west, north, and east respectively. These distal cues are outside of the boundary and can only be seen but not reached.

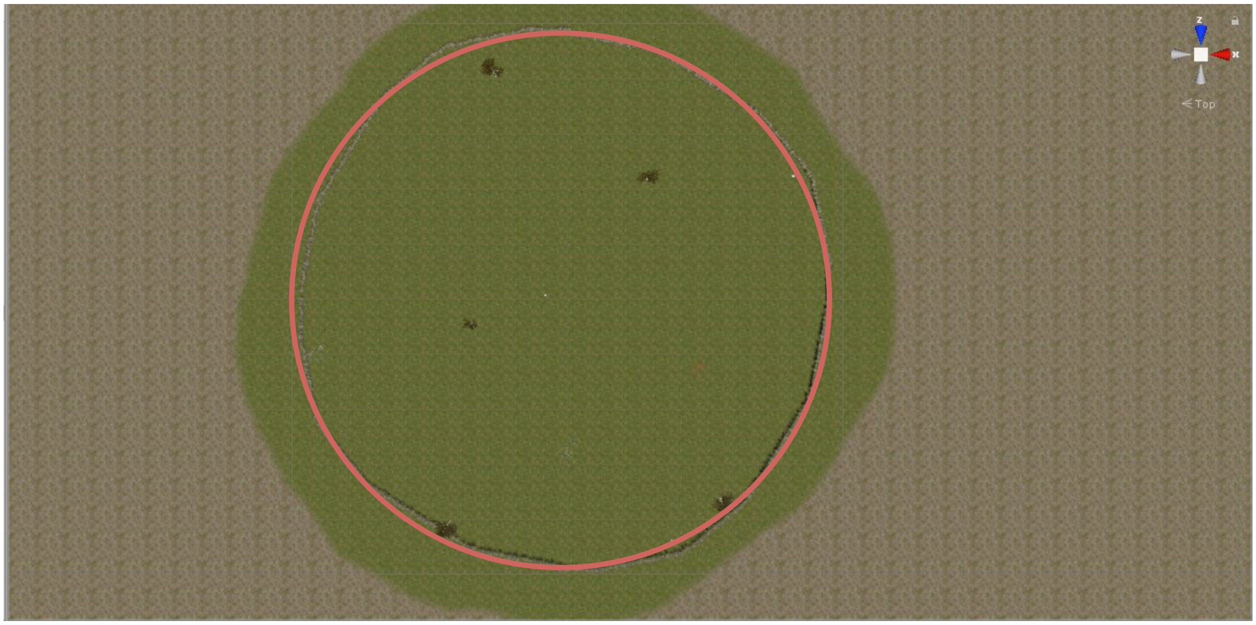

Figure 2: A bird's eye view of the proximal maze. These proximal cues are within of the boundary and can be seen and reached.

Paper Measures

All paper measures were giving online via Qualtrics, excluding the Topographic Map Assessment. This assessment could not be giving in the same format as the others because it involved drawing.

BIS/BAS. BIS orthogonally relates to BAS, as they are comprised of different criterion (Carver & White, 1994); this scale is therefore divided into 2 parts – the BIS scale and the BAS subscales: drive, fun-seeking, and reward responsiveness. The Drive scale evaluates desired goals. There are 4 items. For example, "I do everything to get the thing that I want." The Fun Seeking scale focuses on willingness to spontaneously participate in rewarding and/or new events. There are 4 items. For example, "I am always willing to try something new when I think it will be fun." And the Reward Responsiveness scale evaluates how positive a response is when experiencing or anticipating a reward. There are 5 items. For example, "When I am doing well at something, I like to keep doing this." BIS only has one 7-item scale. It evaluates how sensitive the participant is to punishment and how likely they are to avoid it. For example, “I usually get tense when I think something unpleasant is going to happen.” All scales use a four-point Likert scale ranging from “1=not true of me” to “4=very true of me.” A higher score in BAS determines more drive, sensation seeking, and susceptibility to reward in the individual. A higher score in BIS determines a higher susceptibility to punishment in the individual.

Big 5 Personality Inventory. Participants are instructed to rate on a scale of 1-5 whether a characteristic applies to them (Goldberg, 1993). Where in, 1 is disagree strongly, 2 is disagree a little, 3 is neutral or no opinion, 4 is agree a little, and 5 is agree strongly. The individual is scored on 5 personality types – extraversion (“is talkative”), agreeableness (“tends to find fault with others” - reverse coded), conscientiousness (“does a thorough job”), negative emotions (is depressed, blue”), and open-mindedness (“is original, comes up with new ideas”). A higher score in a particular personality indicated more of that trait in the individual. The fiver personalities that were evaluated were extraversion (8 items), agreeableness (9 items), conscientiousness (9 items), negative emotions (8 items), and open-mindedness (10 items).

Spatial Anxiety Survey. Participants are instructed to indicate how anxious (Lawton, 1994) they would be in each situation from 1 (not anxious at all) to 5 (very anxious). There were 9 items. For example, the participant are instructed to determine how anxious they would be if they were “finding [their] way to an appointment in an unfamiliar area of the city or town.” A higher score indicates more spatial anxiety.

Santa Barbara Sense of Direction Scale. Participants are instructed (Hearty et al., 2002) to indicate how much they agree or disagree with statements about their spatial and navigation abilities, preferences, and experiences from 1 (strongly agree) to 7 (strongly disagree). There were 15 items. For example, the participant is instructed to determine how much they agree or disagree with "My 'sense of direction' is very good." A higher score indicates a better sense of direction.

Way-finding Strategies Questionnaire. Participants are instructed to indicate how much they use the following strategies in a situation in the past where they have driven to a location in a town or city that is somewhat familiar, but they have not been to a specific location in that city before (Lawton, 1994). There were 14 items. For example, the participant is instructed to determine how typical it would be for them to "keep track of the direction (north, south, east or west) in which [they were] going," from 1 (not typical of me) to 5 (extremely typical of me). A higher score indicates better way-finding abilities.

General Anxiety 7-item Scale. Participants (Spitzer, Kroenke, Williams, & Löwe, 2006) are instructed to indicate on how many days they have been bothered by the following problems on a scale 0-3. Where in, 0 is "not at all," 1 is "several days," 2 is "over half the days," and 3 is "nearly every day." There were 7 items. For example, the participant is asked to indicate how many days they have been bothered by "worrying too much about different things."

Lifetime Mobility. This is one measure of navigation experience. This measure separates local mobility from national mobility. The lifetime mobility measure in this study is a version of the Padilla et al. (2017) lifetime mobility measure that has been adapted to Wyoming and neighboring landmarks to reflect the place of research. This survey measured an individuals' navigation experience by measuring the amount of locations in which they have visited. The local mobility measure, like the original, is composed of 41 significant towns, parks, and landmarks around the state and neighboring states. Their average distance from the University of Wyoming is 248.7 miles. The national mobility is the same as the original, which divided the US into 13 distinct regions down state lines. On both the local and national measure, the participant is asked to mark a box if they have been to the location or region. The more boxes that are checked indicates the participant is more mobile and therefor has more navigation experience.

Types of Navigation. This is the second measure of navigation experience. This measure was created in the University of Wyoming Spatial Cognition Lab as a means of understanding the ways in which people navigate. This survey measured an individuals' navigation experience by measuring the amount of activities in which they participate. Participants are asked to make how often they do a particular activity. Where in, 1 is "never participated," 2 is "participated less than 4 times," 3 is "participated from 5-15 times," 4 is "participated about once a month," 5 is "participated about once a week, and 6 is "participated more than once a week." Participants were asked if they participated in a variety of activities, like orienteering, hunting, being in the military, driving an Uber/Lyft/taxi, giving directions, playing map-based video games, and playing real-world fantasy games (LARP).

Topographic Map Assessment. Participants were instructed to answer 18 questions (some with multiple parts) using a topographic map (Newcombe et al., 2015) to assess their topographic map reading abilities. Each part is worth 1 point, for a total of 28 points. Participants were asked to use logic and the maps provided to do the following: draw a path or river, determine if a location is higher than another, determine the altitude of a location, assess for steepness, determine contour intervals, imagine a top down 2D map in 3D or from the side, and combinations of these tasks. For example, one of the questions is "The contour interval for this map is 40 feet. What is the elevation at point A?" Where in, a picture shows "A" on a topographic map between 6000 and 7400 feet, the most extreme points.

Procedure

When participants arrived at the lab, they read and signed a written consent form. After, the research assistant measured the participants' head circumference and determined the net size. The RA soaked the EEG net in electrolyte solutions while the participant filled out all the surveys except for demographics. When they were done with the packet and the net was done soaking, the RA placed the net on the participants' head. The RA led the participant to the EEG room where an average cortical EEG activity was measured to determine resting asymmetry, as described above. After, the participant started the Water Maze. The proximal and distal conditions alternated as the first condition. When the participant finished one, they would move on to the other. Between the resting asymmetry paradigm and each water maze condition, the RA would re-wet the electrodes with a pipette and measure net impedances. After the second Water Maze, the participant was done with the EEG portion of the study. The net was removed, and they were asked to fill out the demographics form. Participants who were recruited by SONA system were told they would be receiving course credit very soon, and those who were recruited by the flyers were paid $50 for participation in the study.

Results

Because the scope of this study is vast and our research team has not completed our analyses of the date, not all of the results will be discussed. Instead the survey measures and the navigation ability will be briefly discussed, and this paper will conclude with a description and explanation of the future of this research and the planned analyses as we go into the spring 2019 semester. In addition, please note that all results discussed in this paper are preliminary and much more data will need to be collected before results can be generalized. A one way ANOVA was used to analyze all behavioral data unless gender was involved; when analyzing gender, we used an independent sample t-test.

Behavioral Preliminary Results

Table 1
Behavioral Correlations

		1	2	3	4	5	6	7	8	9	10	11
1. Gender	Pearson Correlation	-	-	-	-	-	-	-	-	-	-	-
	Sig. (2-tailed)	1	-	-	-	-	-	-	-	-	-	-
2. BIS	Pearson Correlation	.401*	1	-	-	-	-	-	-	-	-	-
	Sig. (2-tailed)	0.028		-	-	-	-	-	-	-	-	-
3. Spatial Anxiety	Pearson Correlation	.361*	.543**	1	-	-	-	-	-	-	-	-
	Sig. (2-tailed)	0.050	0.002		-	-	-	-	-	-	-	-
4. GAD-7	Pearson Correlation	.427*	.591**	.509**	1	-	-	-	-	-	-	-
	Sig. (2-tailed)	0.019	0.001	0.004		-	-	-	-	-	-	-
5. SB Sense of Direction	Pearson Correlation	-0.303	-.457*	-.710**	-.713**	1	-	-	-	-	-	-
	Sig. (2-tailed)	0.103	0.011	0.000	0.000		-	-	-	-	-	-
6. B5 Neuroticism	Pearson Correlation	0.340	.763**	.537**	.726**	-.631**	1	-	-	-	-	-
	Sig. (2-tailed)	0.066	0.000	0.002	0.000	0.000		-	-	-	-	-
7. WM Distal Average	Pearson Correlation	0.150	0.347	0.158	0.151	0.001	0.082	1	-	-	-	-
	Sig. (2-tailed)	0.446	0.070	0.421	0.444	0.997	0.678		-	-	-	-
8. WM Proximal Average	Pearson Correlation	0.068	0.339	0.222	0.308	-0.196	0.265	.529**	1	-	-	-
	Sig. (2-tailed)	0.733	0.077	0.256	0.111	0.318	0.173	0.004		-	-	-
9. Lifetime Mobility	Pearson Correlation	-0.272	-0.072	-0.340	-0.110	0.291	-0.078	-0.188	-0.186	1	-	-
	Sig. (2-tailed)	0.146	0.705	0.066	0.562	0.119	0.682	0.339	0.344		-	-
10. Types of Navigation	Pearson Correlation	-.450*	-0.262	-.409*	-0.207	.371*	-0.239	-.376*	-0.030	.760**	1	-
	Sig. (2-tailed)	0.013	0.161	0.025	0.273	0.043	0.204	0.049	0.879	0.000		-
11. Topographic Assessment	Pearson Correlation	-0.142	-0.255	-.367*	-0.225	.564**	-0.122	-0.110	-.418*	0.359	0.282	1
	Sig. (2-tailed)	0.455	0.173	0.046	0.231	0.001	0.522	0.576	0.027	0.051	0.130	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Navigation Error. The error in the proximal maze (*M*=17.21, *SD*=10.44) was correlated with distal maze error (*M*=22.20, *SD*=8.25); the relationship was significant (*r*=.529, *p*=.004). There were no significant gender differences in either maze. And although there was no significant relationship between BIS and mazer error in the proximal (*r*=.339, *p*=.077) or distal (*r*=.347, *p*=.070) condition, it is unclear if with a higher sample this relationship will become stronger. The proximal error also correlated negatively (*r*=-.418, *p*=.027) with the topographic assessment (*M*= 19.20, *SD*=4.69). The error in the distal maze correlated negatively with the types of navigation measure (*M*=107.97, *SD*=26.50); this was significant (*r*=-.376, *p*=.049). However, there were no other significant relationships with navigation error. The individuals' self-reported lifetime mobility, sense of direction, and spatial anxiety had no bearing on whether the participant did well at the task or not.

Gender, BIS, Generalized & Spatial Anxiety. There was a significant difference in BIS for men (*M*=18.67, *SD*=3.92) and women *(M*=21.78, *SD*=3.39*); t* (28)=-2.32, *p*=.028 There was a significant difference in spatial anxiety for men (*M*=13.75, *SD*=3.86) and women *(M*=17.00,*SD*=4.49*); t* (28)=-2.05, *p*=.05. There was a significant difference in generalized anxiety disorder (GAD) for men (*M*=10.33, *SD*=2.67) and women *(M*=15.00, *SD*=6.06*); t* (28)=-2.50, *p*=.019. BIS, GAD, and spatial anxiety were all significantly correlated as shown in Table 2. Again, there was no correlation between gender and spatial navigation error.

Table 2
Independent sample t-tests of gender significant measures

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
BIS	-2.316	28	0.028	-3.111*	1.343	-5.863	-0.359
Spatial Anxiety	-2.051	28	0.050	-3.250*	1.585	-6.496	-0.004
GAD-7	-2.500	28	0.019	-4.667*	1.867	-8.491	-0.842

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Navigation Experience. We found that while the lifetime mobility measure (*M*=22.73, *SD*=10.23) did not correlate to maze error, it still had a significant relationship to the types of navigation measure (*M*=107.97, *SD*=26.50; *r*=.760, *p*=.000). In addition, a relationship between gender and types of navigation was found, such that men *(M*=122.33, *SD*=29.09*)* were more likely than women *(M*=98.39, *SD*=20.20*)* to participate in activities which required navigation of some kind *(t* (28)=2.67*, p*=.013). Future analyses of the types of navigation survey will create groups to understand if one type of navigation experience is driving the connection between this measurement and distal maze error.

EEG Preliminary Results

Preprocessing. The data were filtered with a band pass filter from a lower end of 1 Hz to an upper end of 40 Hz in EEG Lab. The data were then re-referenced. The data were trimmed to remove any data 200 ms before the study started or after it ended. Data were manually rejected if there were large movement impacting multiple channels. Channels were rejected manually if they were poorly connected. Channels were then automatically rejected using Kurtosis at a threshold of five. The data were again re-referenced. Lastly an ICA was run to determine artifact rejection, primarily eye blinks and movements.

Analysis. While much research uses the water maze to study spatial navigation, little research has been done using this method and EEG, partially because EEG data is so challenging to interpret from a water maze. In a free roaming spatial navigation task, such as the water maze, determining what is an artifact and what is a signal of value, is a challenge. Because of this reason, most EEG and spatial navigation research is done using hedge mazes, where the only visual decision comes from deciding to move left or right. It involves little movement in the program and on the part of the participant. Whereas, in the water maze people are more likely to move their head and eyes around to take in as much information as possible. But if it were possible to remove artifacts like eye blinks, head turning, and random activity, then the water maze may be a very beneficial tool for understanding spatial navigation using EEG. Furthermore, the biggest concern with EEG data is the poor spatial resolution. While a signal may come from a single location, there is not a simple method using an EEG cap to measure exactly from where that signal is coming. For example, there may be activity in the prefrontal cortex, but the actual source within the prefrontal cortex may be unclear because the signal is spread across the skull and scalp. The signal may be coming from one or many sources. The present study will use ICA to analyze EEG data and address the concerns of spatial resolution.

Discussion

The results of this study are preliminary; data collection and EEG analysis should continue for clarity. There was a marginal relationship between BIS and spatial navigation in both mazes. Furthermore, the relationship between gender, spatial anxiety, and BIS, disappeared when controlling for spatial anxiety. A relationship may exists such that one's perception of their spatial navigation abilities has no bearing over how successfully they navigate. Women typically are more likely to perform poorly on spatial navigation tasks when compared to men. This relationship has gone unexplained by self-reported measured of temperament, spatial anxiety, or sense of direction. Future analysis will continue to examin these constructs and examine asymmetrical neural activity as an explanation. Preliminary findings have found theta waves present during spatial navigation, although the analyses are not far enough along to determine if they are more than baseline, significantly different from trial to trial, or consistent across participants.

A strong influence on this study was Padilla, Creem-Regehr, Stefanucci, & Cashdan, (2017). The water mazes created for this study were designed based on the large mazes used in that study. Both studies used a joystick to move and adjusted the high of the monitor so the participants eyes were centered to the middle monitor by adjusting its height. The present study used a three monitor set up to create a periphery, which Padilla et al. did not use. In their study participants moved throughout the environment at a fixed rate of 1m/s (similar to a slow walk) and instructions were always at the bottom of the screen. In an attempt to limit frustrations with slow movement and distractions, our participants moved at a faster rate more representative of jogging and could bring the instructions up at will any time as a reminder. In addition, in their study, participants could not move to the next trial if they had not reached a close proximity to the target. It is unclear exactly what made the difference between the results in their study and ours, but we suspect it is a combination of many differences. Furthermore, the ecological validity of the study may have bearings on the interpretability of the results. While searching around a field is more realistic than swimming in a pool looking for a platform, we hypothesize that the act of looking for stationary birds is also unrealistic with respect to things one might search for in a field. The environment might be realistic but the task might not.

In conclusion, the results of this study are inconclusive due to the sample size and lack of time for EEG analysis. More data will be collected to draw more complete conclusions. The navigation experience measures will continue to develop different options for clustering and be analyzed for validity. These preliminary results have still provided us with future directions for research. The current findings suggest a positive relationship between BIS, spatial anxiety, and gender and a negative relationship between theses constructs and spatial navigation ability. Further EEG analysis should be considered in future water maze research using ICA.

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