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Exploring Cognitive Maps through Sketching

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Abstract

Periodic testing has been found to improve the accuracy of participants' cognitive maps when an onscreen map is provided, however, it is unclear whether the same results would occur without the onscreen map. The current study investigated whether drawing a map periodically while exploring the virtual environment Silcton would improve cognitive map accuracy. Participants explored Silcton and were stopped every 4 minutes to either sketch a map of Silcton, identify items seen in Silcton, or colour an unrelated picture, and a baseline group was not stopped. All groups drew a final sketch map and completed a direction estimation task. Results indicated that periodic testing using sketching led to significantly more accurate final sketch maps when compared to periodic testing using identified items but did not result in more accurate sketches across other groups or improved direction estimation scores. Accurate and inaccurate mappers demonstrated improved, but differing, accuracy across sketch development.

Keywords

Cognitive map, navigation, sketching, sketch maps, periodic testing, virtual reality, memory, attention, individual differences

Summary for Lay Audience

Accurate navigation is important for everyday tasks such as driving home from work, and we often create a map layout of our environment in our head called a cognitive map. Although most people use cognitive maps on a daily basis, we still do not understand how to make them better or how they develop. One technique that has been shown to improve cognitive maps is called periodic testing, in which an individual is stopped at various times during learning and asked to recall information. Previous research using periodic testing and cognitive maps used a virtual town on a computer and provided an onscreen map of the entire town for people while they were quizzed on where they thought they were located. Although periodic testing resulted in more accurate cognitive map development, it was difficult to determine the role that the onscreen map played in performance. The current study used periodic testing in a virtual town to measure cognitive map accuracy, but without the onscreen map. Participants walked around a virtual town and tried to find eight buildings within a specified amount of time. Four different groups of participants each completed one of the following tasks during their periodic testing: draw their current understanding of the layout of the town as a quick sketch map; check off items already seen in the town on a checklist; colour an unrelated picture; or they were not asked to do any periodic testing. All participants completed a final sketch map of the environment and a task that tested their understanding of the directions between the eight buildings. When we looked at the final sketch maps, we only found a significant difference in sketch map accuracy between the group that sketched throughout and the group that used the checklists, but no differences between the other groups. There were no differences between how the groups performed on the directions task. We looked at the periodic testing sketches and found that all individuals in that group showed improvement in performance from their first sketch to their last sketch.

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List of Abbreviations

Abbreviation	Meaning
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
CanOrg	Canonical Organization
cm	Centimetre
F	F distribution value
GMDA	Gardony Map Drawing Analyzer
M	Mean
MRI	Magnetic Resonance Imaging
N	Number of participants
η_p^2	Measure of strength of relationship (partial eta squared)
p	Probability
r	Correlation coefficient
SD	Standard deviation
SE	Standard error

Introduction

The ability to navigate is a complex task that relies on multiple sensory and cognitive processes (Wolbers & Hegarty, 2010) and is crucial for functioning in both humans and animals. Without the ability to navigate, we would not be able to complete everyday tasks such as going to the grocery store or driving back home for the night. Although navigation is a daily task, the development and implementation of this ability is still not fully understood. When traveling in a new place, the mental representations individuals create are thought to consist of at least two forms: an allocentric map-like memory of the layout of important landmarks in a survey representation, also called a *cognitive map* and egocentric route knowledge based on the sequence of turns and landmarks along a path in the environment (Gallistel, 1990; Tolman, 1948, O'Keefe & Nadel, 1978, Siegel & White, 1975). Allocentric navigation, or a cognitive map, requires a strong understanding of the connections between landmarks in the environment and allows for impromptu navigation down a never-before-seen route (Aguirre & D'Esposito, 1999; Gallistel, 1990). Whereas relying only on route knowledge limits a traveler to specific paths, an accurate cognitive map is flexible and enables novel short cuts and detours (Bennett, 1996; O'Keefe & Nadel, 1978; Tolman, 1948).

There are two recognized theories that have built the foundation of our understanding of human cognitive map development. First, Siegel and White (1975) proposed a theory in which individuals acquire spatial knowledge through three stages. The first stage consisted of landmark knowledge which might include physical features and possibly names of the landmarks but no understanding of how they relate to one another spatially. Next was route knowledge, which consisted of an understanding of directions of turns and the order that landmarks appear in. The third and final stage consisted of survey knowledge (or a cognitive map), which allowed the individual to bring together their landmark and route knowledge and build an understanding of how they all relate to one another. Siegel and White's theory specifically stated that an individual must pass through each individual stage before moving on to the next one, although not all individuals would reach the survey knowledge or final stage. In another theory, Montello

(1998) suggested an alternative framework which proposed that individuals can acquire some form of route and survey knowledge within minutes of exposure to a novel environment and that all three stages are essentially acquired simultaneously. Montello's theory suggested that the development of cognitive maps could vary quite drastically among individuals depending on the type of information that they initially acquire. Together, these two frameworks both predict the individual differences seen in cognitive map formation.

Robust individual differences exist in the ability to form an accurate cognitive map of a new environment (Ishikawa & Montello, 2006, Newcombe & Shipley, 2015, Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2017, Weisberg, Schinazi, Newcombe, Shipley, & Epstein, 2014). For instance, Ishikawa and Montello (2006) found that individual differences in cognitive map accuracy are found in real-world route-learning tasks. They conducted a study across a 10-week period during which they drove participants once per week on two different routes that had no common segments and were in an unfamiliar setting. They asked participants to pay attention to eight specific landmarks, many of which could not be seen from any one location due to the hilly landscape of the routes. Four weeks into the study, they added a connecting route between both routes that was meant to help participants integrate both routes into a common representation. During each session, a battery of varied spatial tasks was administered to understand the development of participants' mental representations. The spatial tasks included a pointing task where participants were asked to estimate directions between landmarks that were either on the same or different routes, and the drawing of a sketch map of the travelled routes. Accurate direction estimation between unseen landmarks would suggest that an individual had developed an accurate cognitive map of the environment. Ishikawa and Montello found large differences in how individuals performed across the 10 weeks of testing with accurate mappers showing consistently precise maps from the initial assessment, inaccurate mappers showing little to no improvements, some participants showing only minor improvements, and a few participants even showing deterioration of accuracy by the end of the study. Ishikawa and Montello's findings support the existence of widespread individual differences in cognitive map formation and development, with little evidence of change in accuracy across time for both accurate and inaccurate mappers.

It is important to consider, however, that Ishikawa and Montello used passive learning, in which participants were not physically in control of the navigation process, a method that influences the learning process and is limited in ecological validity. To investigate how active learning, where participants determine how they navigate, affected cognitive map development, Schinazi, Nardi, Newcombe, Shipley, and Epstein (2013) had participants walk in a real-world environment once per week over the course of three weeks. Participants were first exposed to two main routes and then to two connecting routes. They used a number of different spatial measures, including onsite (conducted in the environment) and offsite (conducted in the lab) direction estimation tasks and sketch maps, combined with MRI scans and determined that underlying neuroanatomical differences appeared to exist that might explain the individual differences seen in mapping abilities. Weisberg et al. (2014) used a non-immersive desktop environment called Silcton to further build on the findings of Ishikawa and Montello and Schinazi et al. Weisberg et al. had participants travel through four specific routes within the Silcton environment: two separate main routes and two connecting routes. Participants were asked to remember the names and locations of eight buildings along each of the main routes. Participants also completed spatial tasks that measured their memory for the environment including a direction estimation task that was very similar to Schinazi et al.'s direction estimation tasks. In contrast to Schinazi et al's active, real-world immersion, Weisberg et al.'s participants performed all tasks virtually on the desktop and incorporated both between-route and within-route direction estimation tests. Between-route trials consisted of estimating the direction of buildings located on different routes. This required navigators to integrate information from the two separate main routes. Within-route trials consisted of buildings that were located on the same route. Based on their between-route and within-route performances on the direction estimation task, Weisberg et al. classified individuals who were accurate at both between-route and within-route trials as those with the most accurate cognitive map representations. This ability provides a substantial advantage for accurate navigation yet, much like the findings of Ishikawa and Montello (2006), a wide range of individual differences in accurate and inaccurate mappers were observed.

Differences in cognitive map accuracy across individuals may be explained in the way that individuals encode spatial knowledge. Wolbers and Hegarty (2010) conducted a review and proposed the importance of executive function and working memory, specifically when it comes to the ability to transform spatial cues into spatial representations. Wen, Ishikawa, & Sato (2013) proposed that spatial information about an environment is first encoded egocentrically and is then transformed into an allocentric representation. They examined individuals with good and poor senses of direction and used interference tasks to demonstrate that both verbal and spatial working memory play critical roles in the development of egocentric survey knowledge (which they defined as self-to-object relations tied to a specific viewpoint) and egocentric and allocentric direction and distance estimation. In addition, they found that visual and spatial working memory were crucial for the development of allocentric survey knowledge suggesting that directions are first encoded egocentrically through verbal and spatial working memory, and then allocentrically through visual and spatial working memory. Additional research by Weisberg and Newcombe (2016) further examined these individual differences in mapping ability and working memory. Specifically, Weisberg and Newcombe used route integration (participants are exposed to two separate routes and two connecting routes and must incorporate them together to form an accurate representation) and tests that examined spatial, verbal, and working memory capacities and showed that less precise navigators had lower spatial working memory capacity. After a two-step cluster analyses on between-route pointing and within-route pointing performance, participants were divided into three different groups based on their performance: integrators (performed well on between-route and within-route judgements), non-integrators (performed well on within-route judgements), and imprecise navigators (did not perform well on between-route or within-route judgements). They found that imprecise navigators showed lower recall accuracy and lower working memory capacity on tasks that measured both spatial and verbal working memory. In addition, Weisberg and Newcombe found that imprecise navigators were not able to learn critical identifying information of landmarks, such as a building's name and physical features, as a function of lower working memory. It seems likely that this inability to identify key landmark features would certainly make it difficult for these individuals to understand and measure the relationship between landmarks. This suggests that these individual differences may occur when people encode the spatial properties of an environment during the exploration period, or when they are learning an environment for the first time**.**

There is evidence from Parush et al. (2007) that periodic testing can improve the accuracy of cognitive maps when implemented during encoding of the environment throughout the exploration process. Participants freely explored a virtual environment with the goal of finding specified targets in the environments. Participants were placed in one of two conditions, which each included two different levels. The two conditions consisted of: continuous onscreen map display of an aerial perspective of the virtual environment with current position indication or current position display by request, and the two levels involved the inclusion or exclusion of random orientation quizzes where participants were asked to stop at random times across trials and indicate their current position using an onscreen map of the environment before returning to exploring. Participants who completed these orientation quizzes, or periodic tests, showed more accurate spatial knowledge of the environment on a later judgment of relative direction task than those who did not take the tests. Additionally, when position indication, was removed but orientation quizzes remained, researchers saw no detrimental effect on performance. When orientation quizzes were removed however, there was a clear degradation in performance. These findings suggest that periodic testing, through the retrieval of current knowledge of an environment during the exploration process, improves how accurately individuals develop their mental representation of a novel environment during the exploration process.

Periodic testing has been shown to be beneficial for learning in other domains, such as written recall. Retrieval-based learning strategies can be used to enhance memory during the learning phase. The '*testing effect*' or '*retrieval-based learning*', involves the act of using free recall during the learning process (Karpicke, 2012; McDaniel & Einstein, 2000; Roediger & Karpicke, 2006, Wheeler & Roediger, 1992). A number of studies have indicated that using recall tests during learning is a powerful way to increase learning and can decrease the rate of misremembering (Blunt & Karpicke, 2014; Karpicke & Grimaldi, 2012; Lechuga, Ortega- Tudela, & Gomez-Ariza, 2015; Roediger & Butler, 2011; Roediger & Karpicke, 2006; Rowland, 2014). There have been multiple attempts at explaining why retrieval-based learning is effective. One approach is the *transfer-appropriate-processing view* which suggested that the greater the similarity between the cognitive processes used during the intervening test and final memory test, the better the overall test performance (Morris, Bransford, & Franks, 1977; McDaniel, Friedman & Bourne, 1978, Kolers & Roediger, 1984; Roediger, Guynn, 1996; Marsh, Edelman, & Bower, 2001; Roediger & Karpicke, 2006a, 2006b). These findings highlight the importance of similarity between retrieval cues and the final test however they do not identify the mechanisms that underlie retrieval-based learning.

To further understand how retrieval-based learning enhances memory, a more comprehensive approach has emerged called the *episodic context account* (Karpicke, Lehman, & Aue, 2014). This account operates on the idea that successful retrieval occurs as a result of context updating (the idea that each time an item is retrieved, the representation stored with that item is updated leading to easier recall in the future) during the encoding process which then allows individuals to recall a stricter, more refined memory for that item when they are asked to recall it again. Context updating can facilitate future context reinstatement during later testing. Based on the episodic context account, Parush et al.'s (2007) use of periodic testing during the exploration process should have allowed participants to create a more refined, more accurate version of the virtual environment each time they were tested and ultimately resulted in better performance on judgment of relative direction task. This, along with the additional retrieval-based learning benefits mentioned above, help to explain why Parush et al. found that their periodic testing yielded more accurate acquisition of spatial knowledge. However, the exact effects of their periodic testing on spatial mental representations are unclear because of their inclusion of an onscreen map.

It is important to note that Parush et al. provided their participants with the entire map of the environment during their periodic tests. This meant that participants were being tested on their current position in the environment, but with the aid of an onscreen map that did not require them to answer the questions solely based on their own mental representation of the environment. Therefore, it is impossible to infer how participants' own cognitive maps developed across the learning period and how the course of this development differed for accurate versus inaccurate cognitive mappers.

One way to test the accuracy of participants' representations while exploring in the Parush et al. (2007) study would be to have participants draw a map of their current mental representation of the environment during the periodic tests. Drawing has been shown to be an effective method of enhancing memory through recall (Wammes, Meade & Fernandes, 2016; Wammes, Meade & Fernandes, 2017; Fernandes, Wammes & Meade, 2018; Meade, Wammes & Fernances, 2018; Wammes, Meade & Fernandes, 2018; Wammes, Roberts, & Fernandes, 2018; Meade, Wammes, & Fernandes, 2019; Wammes, Jonker, & Fernandes, 2019). Individuals consistently show more accurate memory when drawing is used during the encoding process as compared to other interventions such as writing. For example, Wammes et al., (2016) found that there was a significant verbal recall advantage when participants drew an object referred to by a word during the encoding phase rather than when they wrote out, visualized, or looked at the word. Over the course of seven experiments, Wammes et al. asked participants to either illustrate a word, write it out plainly, visualize the word, or simply view it. Across all seven experiments, Wammes et al. consistently found that individuals who illustrated the words performed better on a verbal recall task compared to those who wrote them out. They hypothesized that this may be partially explained as a result of drawing's emphasis on the integration of semantic, visual, and motor memory. Sketch maps are a drawing measure that are often used to assess cognitive map accuracy in spatial research and have been found to be a reliable measure of an individual's internal cognitive map (e.g., Blades, 1990; Billinghurst & Weghorst, 1995; Kitchin, 2015). Wen et al. (2013) concluded that drawing an accurate sketch map requires the ability to combine directions and distances and comprehend landmark relationships beyond egocentric knowledge.

Therefore, sketch maps are an accurate measure to gain insight into an individual's allocentric survey knowledge. If drawing during the encoding process enhances memory, and sketch maps are a reliable drawing measure, then including the drawing of sketch maps should allow for the assessment of an individual's current representations of the virtual environment without the inclusion of any onscreen maps or aids.

In the current study, periodic testing using sketching without the use of onscreen aids was implemented while participants explored a novel virtual environment to determine whether it could improve cognitive map accuracy, allow for a better measure of the participant's current representation, and document the development of cognitive maps in strong and weak navigators. Participants freely explored the virtual environment Silcton (Weisberg et al., 2014), and were instructed to remember the names and locations of eight buildings situated throughout the town. During exploration, participants were randomly assigned to one of four groups: the Sketch group, which stopped every 4 minutes to sketch a map of their current knowledge of the environment, the Silcton Task group, which stopped every 4 minutes to identify non-building-related items seen in the environment, the Non-Silcton Task group, which stopped every 4 minutes to colour an unrelated picture, and a Baseline group which was not stopped during exploration. After exploration, all groups drew a final sketch map and completed an onsite direction estimation task that assessed their spatial memory for Silcton.

It was predicted that the Silcton Sketch group would yield the most accurate results on both the onsite direction estimation task (i.e., have the lowest error scores) and overall sketch map accuracy compared to the other groups. It was also predicted that if any type of thinking about Silcton during the break was helpful, then the Silcton Task group should perform as well as the Sketch Map group, and better than both the Non-Silcton Task and Baseline groups. However, if interruptions that do not include testing that is specific to the target buildings prove to be detrimental, then the Baseline group should perform as well as the Sketch group, and better than both the Silcton Task and Non-Silcton task groups.

Sketch map accuracy was expected to be correlated with direction estimation performance. For the Sketch Map group, it was unclear whether accurate mappers would draw accurate, though incomplete at first, sketch maps throughout the exploration period and inaccurate mappers would show consistent inaccuracy, or if those differences would not be observed until their final sketch maps. Also of interest was whether there would be a clear trend of improvement across the sketch maps.

Method

Participants

Participants were recruited for this study via the Department of Psychology SONA research participation pool website and posters displayed at the University of Western Ontario's campus. Of the 172 participants who were tested, five were removed as outliers (any participants whose scores fell two standard deviations above or below the group mean), two participants preferred not to disclose their gender and could not be included in the analyses, and one participant was removed due to researcher error bringing the total number of participants to 164 (age $M = 21.21$, $SD = 6.44$). Block randomization was used to randomly assign participants to one of the four groups. The Sketch group initially consisted of 45 participants however three outliers (defined as those having scores that fell more than two standard deviations beyond the mean of the group) fell within this group, so the final group consisted of 42 participants in total. Of the 164 participants whose data were analyzed, 75 were male and 89 were female. There were 42 participants in the Sketch group, with 19 males and 23 females, 42 participants in the Silcton Task group (Checklist), with 19 males and 23 females, 40 participants in the Non-Silcton group (Colouring), with 18 males and 22 females, and 40 participants in the Baseline group, with 19 males and 21 females. Participants recruited through SONA received 1.0 course credits as compensation for participating and participants recruited through posters each received $15. The study was approved by the University of Western Ontario Non-Medical Research Ethics Board.

Materials and Procedure

After providing written informed consent, participants completed a paper demographic questionnaire. Silcton and the onsite direction estimation task were then presented on either a 19” Samsung LCD monitor which sat approximately 70 centimetres in front of the participant and was run on a PC desktop computer operating Windows 10 and an external mouse and keyboard or on a 22” Samsung LCD monitor connected to a Samsung Laptop (Samsung R525, Samsung Electronics, Suwon, South Korea) running Windows 8 with an external mouse and keyboard. Precautions were taken to ensure that Silcton was always presented in the same dimensions and resolution on both monitors. Participants sketched their mental representations in a pre-set 13.5 cm by 13.5 cm square on paper. Each experimental session lasted approximately one and a half hours.

Demographic questionnaire. Participants completed a three-item paper-based demographic questionnaire. On this questionnaire they provided their age, gender, how frequently they played video games, and the types of video games played. Video game playing frequency was classified on a five-point Likert-type scale ranging from zero (less than once per week) to four (more than six times per week) however these data were not analyzed for the purposes of this study.

Silcton exploration task. Participants moved through Silcton using the up, down, left, and right arrows keys on the keyboard, along with the mouse, which, when used simultaneously, guided participant's visual field as well as direction of travel. Before the task began, participants were able to practice “walking” in Silcton to ensure they were comfortable with the controls. All participants freely explored the town for 16 minutes. In the exploration phase, all participants were instructed to find and remember the locations of eight landmarks in the Silcton virtual environment. All participants were informed that they would be drawing a sketch map of the entire virtual environment after the exploration period. In the Sketch group, participants were stopped and asked to draw a map of Silcton using their current knowledge of the environment for one minute after every four minutes during exploration. Participants continued sketching on the same map at each break. A photo of the participant’s map was taken after each stop. Sketching at each four-minute interval, plus completing the sketch map immediately after the end of exploration, resulted in four photos of sketch maps across the exploration period.

Participants in the Silcton Task group followed the same procedure as those in the Sketch group above, except that instead of drawing a map after each four-minute interval, they indicated items they had seen in Silcton using a checklist that included a mixture of objects and foils that they may have observed in the environment. A new checklist was provided at each interval and participants were specifically told that they did not need to find any items that they had not found in the environment but were included on previous lists. Immediately after the end of the exploration period, they completed a final sketch map instead of the checklist. In the Non-Silcton Task group, participants followed the same format as those in the Sketch and Silcton Task groups, however after each four-minute interval, they had one minute to work on an unrelated colouring page that featured various designs and shapes such as buildings, animals, flowers etc. They continued working on the same colouring page during each break in the exploration period. They then completed a final sketch map immediately after the end of the exploration period. Finally, in the No Breaks (Baseline) group, participants explored the Silcton environment for 16 minutes without any breaks. They completed a final sketch map immediately after the exploration period. All Silcton sketch maps were analyzed using Gardony Map Drawing Analyzer (GMDA) software.

After producing their final sketch maps, all participants completed an on-site pointing task. In the on-site task, they were virtually placed in front of one of the eight buildings in Silcton and asked to point in the direction of one of the other seven buildings using the computer mouse. Free exploration mode in Silcton allows the participant to walk around the environment without any specific routes or directions. Participants were instructed to remember the names and locations of eight buildings (Batty House, Lynch Station, Harris Hall, Tobler Museum, Sauer Centre, Snow Church, Golledge Hall, and Harvey House). Each building was marked with a blue diamond that hovered over the path and directly in front of the building. There was a sign located in the front of each building that clearly identified the building’s name and participants were also given a list of all eight

buildings. This list was removed from participants in all groups when they drew their final sketch maps. Figure 1 shows the layout of the eight target buildings in Silcton.

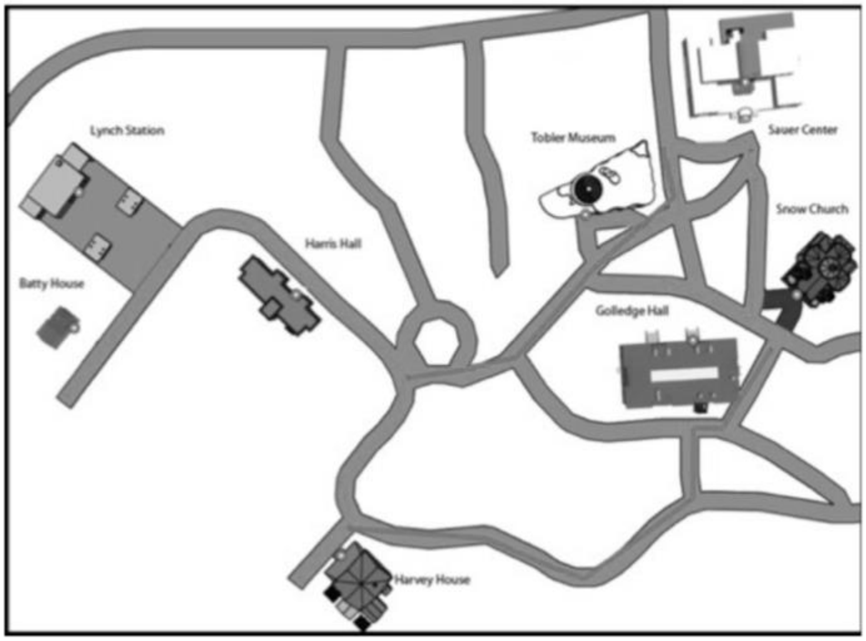

Figure 1: Overhead view of the eight target buildings located in Silcton. From "Variations in Cognitive Maps: Understanding Individual Differences in Navigation," by S. M. Weisberg, V. R. Schinazi, N. S. Newcombe, T. F. Shipley, and R. A. Epstein, 2014, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 671. Copyright 2013 by the American Psychological Association.

On-site pointing direction estimation task. After completing the final sketch map following exploration period, all participants completed the on-site pointing direction estimation task. This was a direction estimation task that used the eight buildings located in Silcton. Participants were placed in front of one of the eight buildings, and then asked to point a crosshair located in the centre of the screen in the direction of one of the other Silcton buildings using a prompt at the top of the screen. Participants were asked to point towards the front door of the target building. There were 56 trials total and no set time limit. Absolute error (in degrees) between participant's estimated direction and the true direction was used to evaluate their accuracy.

Analysis of Sketch Map Data

Sketch map analyses were performed using the Gardony Map Drawing Analyzer (GMDA) (Gardony, Taylor, & Brunyé, 2016). The GMDA involved uploading a map of Silcton which was used to input the coordinates of the target environment, Silcton. The coordinates were used to compare the difference between the actual building location and the location drawn by the participant. Each participant's sketch map was scored by uploading it into GMDA and comparing the buildings they drew with the previously entered coordinates of the target buildings. Not all of the participants drew all 8 buildings, so missing buildings needed to be taken into account when calculating map accuracy. GMDA includes a number of different measures that could be used to analyze sketch maps. The Canonical Organization (CanOrg) measure is recommended for analyzing maps containing missing landmarks, as it scores missing landmarks with a lower accuracy score. CanOrg calculated participants' scores by comparing canonical (N, S, E, W) placements between each individual location of the hand-drawn buildings with the coordinates of the corresponding target environment buildings. The closer a building was drawn to the correct coordinates, the higher the score that it received. The resulting CanOrg accuracy score ranged from 0 to 1 with 1 being the most accurate. Sketch maps that contained one or fewer buildings could not be accurately scored with the CanOrg equation so it was determined that these maps would receive an automatic score of zero.

Statistical Analyses

Overview of Analyses. The final data set consisted of 164 participants, 75 males and 89 females. All participants were given a list of buildings during the exploration period and asked to check off a building if they found it during that period. Not all participants found all eight Silcton buildings. Therefore, initial correlations of number of buildings checked off on the list, final sketch map accuracy, and onsite direction estimation error, were conducted to investigate whether or not the number of buildings that a participant found was related to their performance on both the onsite task and sketch map accuracy. To further examine the relation of the number of buildings reported as found and performance, a one-way ANOVA was conducted on the number of buildings reported across exploration groups. The main analyses of interest were Exploration Group (Sketch Group, Silcton Task Group, Non-Silcton Group, and Baseline Group) x Sex (male, female) between-subjects ANOVAS on final sketch map accuracy and Silcton onsite direction estimation error. The initial correlations showed that number of buildings checked off on the list was significantly correlated with both final sketch map accuracy and onsite direction estimation task, so number of buildings reported was included as a covariate in the Exploration Group x Sex analyses to create two ANCOVAs. A mixed ANOVA was also conducted to examine the development of sketch map accuracy within the Sketch group by comparing the four sketch maps drawn within each participant's exploration period.

Results

Correlations. Two-tailed Pearson correlation analyses were conducted on number of buildings checked off on the list and final sketch map accuracy, and number of buildings checked off on the list and onsite direction estimation absolute error. Number of buildings checked off on the list showed a significant, weak relationship with both the sketch maps, $r(162) = .26$, $p = .002$,and a significant, moderate relationship with the absolute error scores $r(169) = -.40$, $p < .001$. Analyses indicated that most participants reported that they found all or almost all eight buildings ($M = 7.54$, $SD = .87$), drew moderately accurate sketch maps ($M = .68$, $SD = .21$), and had moderately low absolute error scores ($M = 31.99$, $SD = 12.94$).

Number of Buildings Reported as Found x Exploration Group One-Way ANOVA. To ensure that exploration group did not affect the number of buildings found by participants, a one-way ANOVA was conducted examining the number of buildings reported as found across exploration groups. There was no significant relationship found between the number of buildings reported as found and exploration group, $F(3, 160) = .221$, $p = .881$.

Sex x Exploration Group ANCOVA for Final Sketch Map. Since number of buildings checked off on the list was found to be significantly correlated with final map accuracy, it was possible that the number of buildings reported as found by a participant was related to their ability to produce an accurate sketch. To account for this, we conducted a Sex (male, female) x Exploration Group (Sketch Group, Silcton Task Group, Non-Silcton Task Group, Baseline Group) between-subjects ANCOVA, with number of buildings checked off on the list as the covariate, for final sketch map accuracy (Figure 2). Based on adjusted means from the ANCOVA, number of buildings checked off on the list was significantly associated with final sketch map accuracy in the ANCOVA, $F(1, 155) = 8.10$, $p = .005$, $\eta_p^2 = .05$. Controlling for number of buildings reported, the main effect of Sex (males: $M = .69$, $SE = .02$, females: $M = .67$, $SE = .02$) was not significant, $F(1, 155) = .110$, $p = .74$, $\eta_p^2 = .00$. The main effect of exploration group (Sketch Group: $M = .76$, $SE = .03$, Silcton Task Group: $M = .62$, $SE = .03$, Non-Silcton Group: $M = .66$, $SE = .03$, Baseline Group: $M = .65$, $SE = .03$), however, was significant, $F(3, 155) = 3.92$, $p = .01$, $\eta_p^2 = .07$, indicating that group membership affected sketch map accuracy. Post hoc pairwise comparisons using a Bonferroni correction on the main effect of exploration group were used to compare final sketch map accuracy across exploration groups. Posthocs showed a significant difference between the Sketch Group and the Silcton Task Group (Checklist) with the Sketch Group performing more accurately, $p = .001$. There were no significant differences found between Sketch Group and Non-Silcton Task or Baseline Group, or Silcton Task and Non-Silcton Task or Baseline, all *p*s > .05.

The Sex x Exploration Group interaction was not significant for final sketch map accuracy scores (Sketch Group, males: $M = .76$, $SE = .05$, females: $M = .77$, $SE = .04$, Silcton Task Group, males: $M = .64$, $SE = .05$, females: $M = .61$, $SE = .04$, Non-Silcton Group, males: $M = .65$, $SE = .05$, females: $M = .72$, $SE = .04$, Baseline Group, males: $M = .70$, $SE = .05$, females: $M = .60$, $SE = .04$), $F(3, 155) = 1.41$, $p = .24$, $\eta_p^2 = .03$, indicating that males and females did not perform differently in the exploration groups. Therefore, individuals in the Sketch Group created significantly more accurate maps that those in the Silcton Task Group but did not create more accurate maps than those in the other exploration groups. Sex also was not related to performance overall or performance in any of the exploration groups.

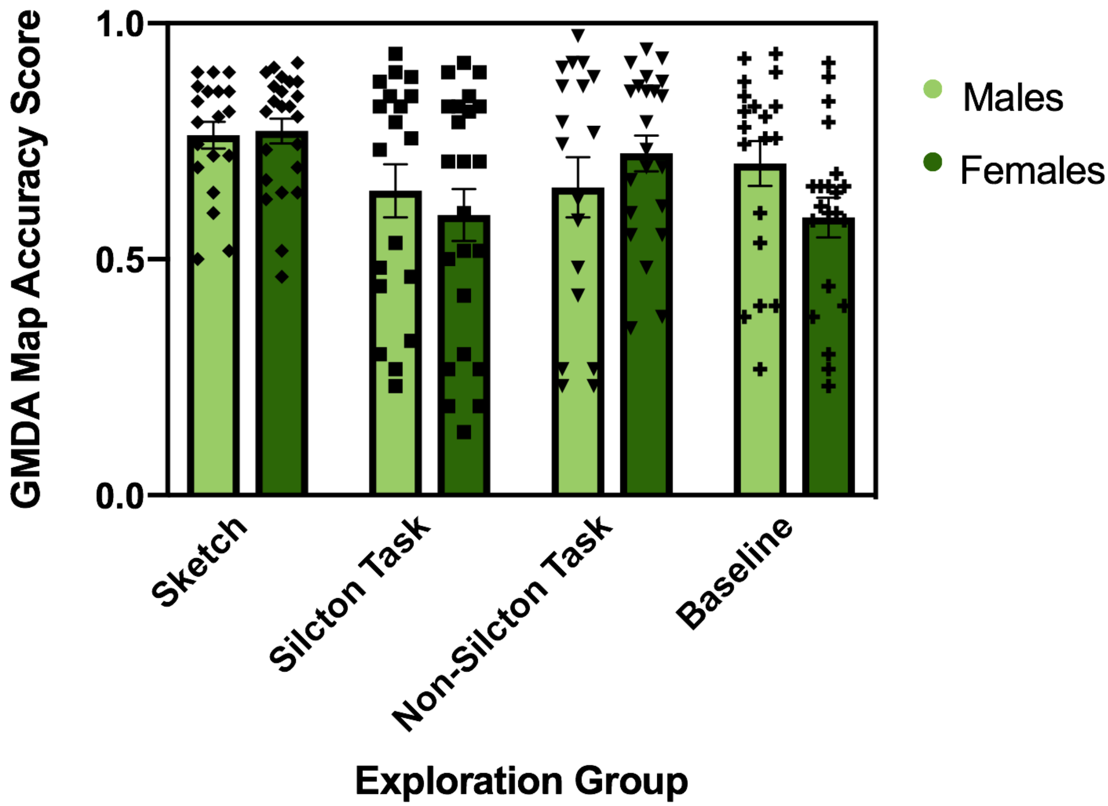

Figure 2: The unadjusted means for final sketch map accuracy across exploration groups. Error bars indicate standard error.

It should be noted that the Levene's Test for Homogeneity of Variance was found to be significant. Frequency histograms were created for each condition of the Exploration Group at each level of Sex in order to investigate the cause of the significant Levene's test. Figure 3 shows the frequency histograms for each exploration group for both males and females. Observations showed less variation in the Sketch Group compared to the three other exploration groups, with the Sketch group participants showing more accurate scores overall. This decrease in variation might be expected given the more accurate overall performance by participants in the Sketch group. Given the small difference between group sizes and the fact that sketching improved scores, the analysis was continued.

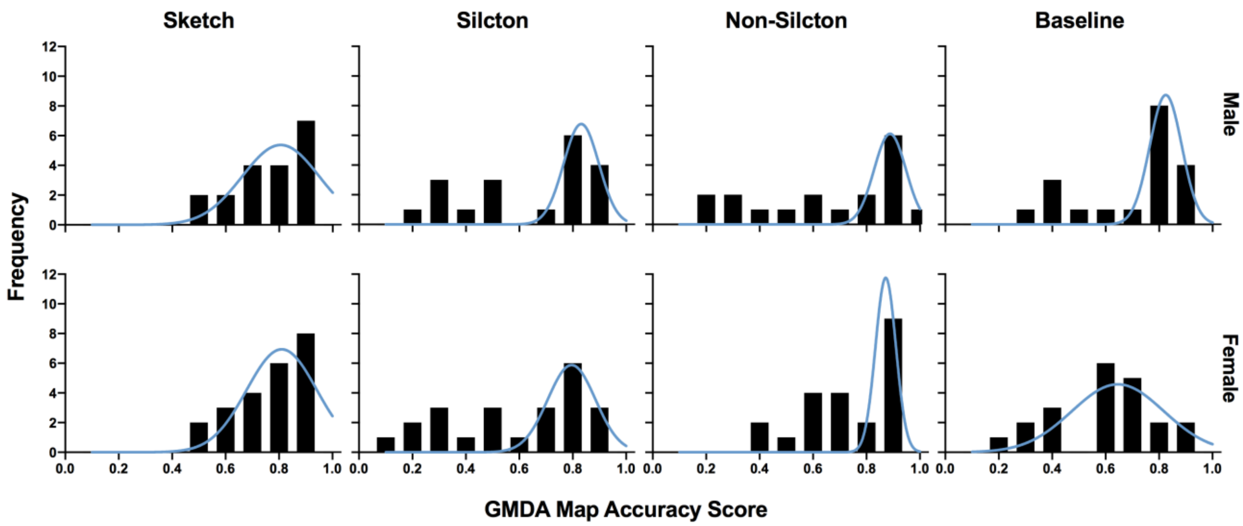

Figure 3: Frequency histograms showing Gaussian distributions for each Exploration Group at the level of Sex. The distributions peak at the mean.

Sex x Exploration Group ANCOVA for Onsite Direction Estimation. Because number of buildings checked off on the list by participants was found to be significantly correlated with onsite direction estimation task average absolute error scores, we analyzed the onsite direction estimation error score data with a Sex x Exploration Group ANCOVA with number of buildings reported to be found as a covariate. Figure 4 shows the unadjusted means and standard error for the onsite direction estimation task average error scores. Number of buildings reported to be found was significantly associated with onsite direction estimation task scores in the ANCOVA, $F(1, 155) = 25.7$, $p < .001$, $\eta_p^2 = .14$. Controlling for the number of buildings reported, the main effect of sex (males: $M = 29.45$, $SE = 1.35$, females: $M = 34.23$, $SE = 1.24$) was significant, $F(1, 155) = 6.73$, $p = .01$, $\eta_p^2 = .04$. The main effect of group (Sketch Group: $M = 29.87$, $SE = 1.81$, Silcton Task Group: $M = 32.60$, $SE = 1.81$, Non-Silcton Group: $M = 31.924$, $SE = 1.86$, Baseline Group: $M = 32.96$, $SE = 1.85$), was not significant, $F(3, 155) = .58$, $p = .63$, $\eta_p^2 = .01$, nor was the interaction of sex and group, $F(3, 155) = 1.61$, $p = .19$, $\eta_p^2 = .03$. Therefore, there was no effect of group intervention on onsite direction estimation task accuracy but there was an effect of sex on onsite direction estimation task performance with males showing lower, more accurate scores compared with females.

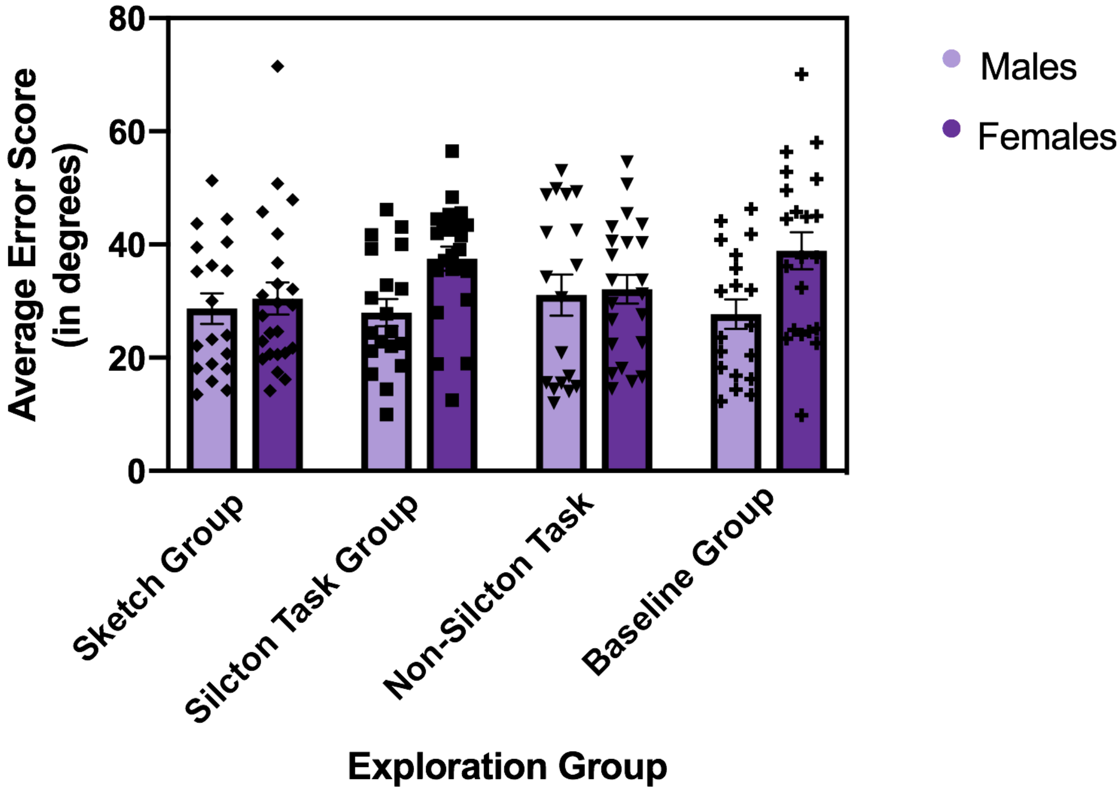

Figure 4: The unadjusted means for onsite direction estimation error across exploration groups. Error bars indicate standard error.

Time of Map Sketch x Sex Mixed ANOVA for the Sketch group. A Time of Map Sketch x Sex mixed ANOVA with a Greenhouse-Geisser correction was performed across all sketches across the exploration period (Figure 5). Individual scores were computed for each participant's four sketch maps using GMDA. Results showed a significant main effect of time of each sketch across the exploration period, $F(2.42, 96.91) = 57.96$, $p < .001$, $\eta_p^2 = .59$. This indicates that there were still significant differences between sketches. The pairwise comparisons for the main effect of time of sketch map using a Bonferroni correction revealed that sketch map accuracy significantly increased between Sketch 1 ($M = .30$, $SE = .04$) and Sketch 2 ($M = .47$, $SE = .03$), between Sketch 1 and Sketch 3 (*M* = .63, *SE* = .03), and between Sketch 1 and Sketch 4 (*M* = .77, *SE* = .02). Post hocs also revealed a significant increase in accuracy between Sketch 2 and Sketch 3, between Sketch 2 and Sketch 4, and between Sketch 3 and Sketch 4. This demonstrated a steady, overall improvement in sketch map accuracy for all participants across the 4 sketch maps. There was no significant main effect of sex (males: *M* = .52, *SE* = .03, females: *M* = .57, *SE* = .03), $F(1,40) = 1.42$, $p = .24$, $\eta_p^2 = .03$. As shown in Figure 5, there was no significant interaction between sex and time of map sketch on sketch map accuracy, Greenhouse-Geisser $F(2.42, 96.91) = 1.86$, $p = .153$, $\eta_p^2 = .04$.

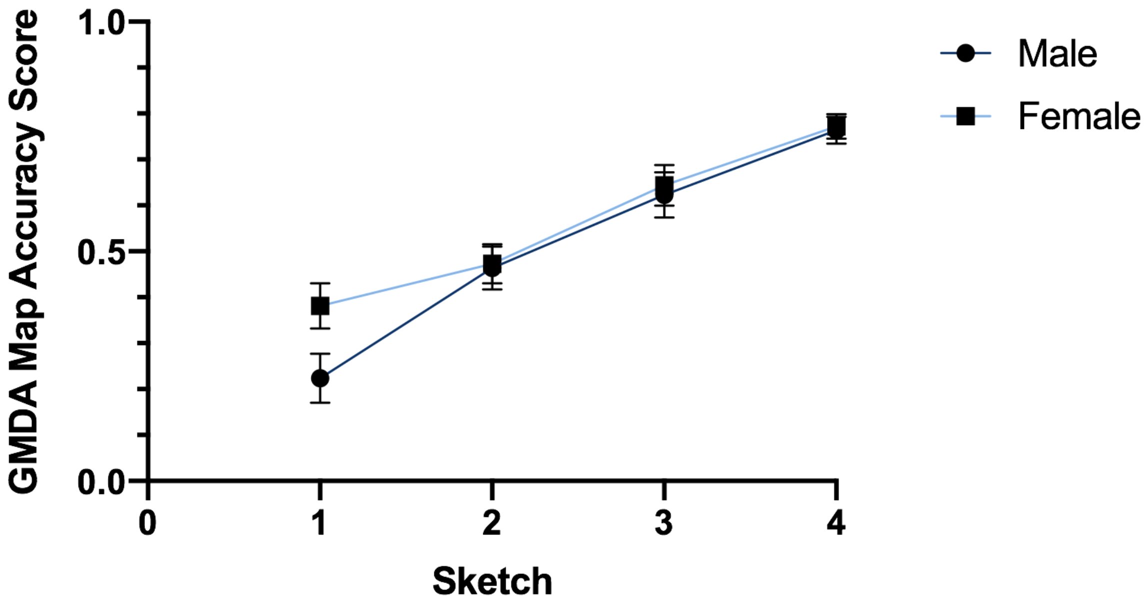

Figure 5: Mixed ANOVA examining sex at each individual sketch within the Sketch Group. Error bars indicate standard error.

Observations Within the Sketch Group Condition. In addition to the Mixed Measures ANOVA, data across time points from individuals in the Sketch Group were plotted on a line graph to examine trends across each participant's sketch maps. Two specific trends appeared within the data and were plotted on two separate graphs seen below. The first group (Figure 6) included any data that showed fluctuation in accuracy and could start with either a higher or lower scoring initial sketch map. These fluctuations could include maps that started off highly accurate, became less accurate in the second or third sketches, and then returned to a more accurate sketch by the final map. Three participants in this category showed extreme fluctuations due to a score of 0 on either Sketch 2 or Sketch 3 (see example in Figure 8). This was the result of participants who completely erased all or part of their previous maps and were left with one or less buildings resulting in a score of zero for that map. As a result of these fluctuations, this group was termed the Seesaw Group. The second trend (Figure 7) consisted of participants who demonstrated mostly continuous improvement in accuracy over the course of all four maps. Some individuals within this group showed a sudden improvement followed by a continuously improving score for the remainder of their maps while others showed steady (sometimes subtle) improvements throughout (see example in Figure 8). This group was termed the Improving Group.

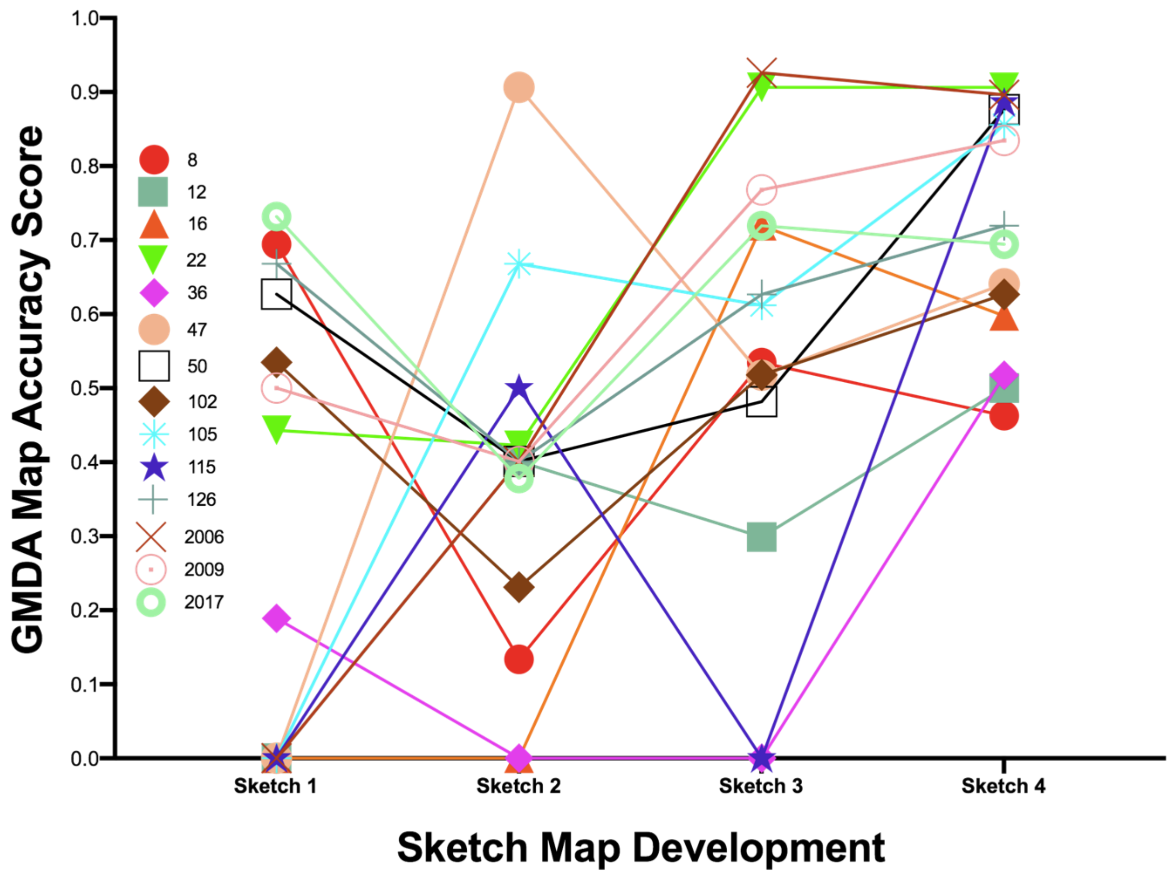

Figure 6: Seesaw Group trend across each individual sketch within the Sketch Group.

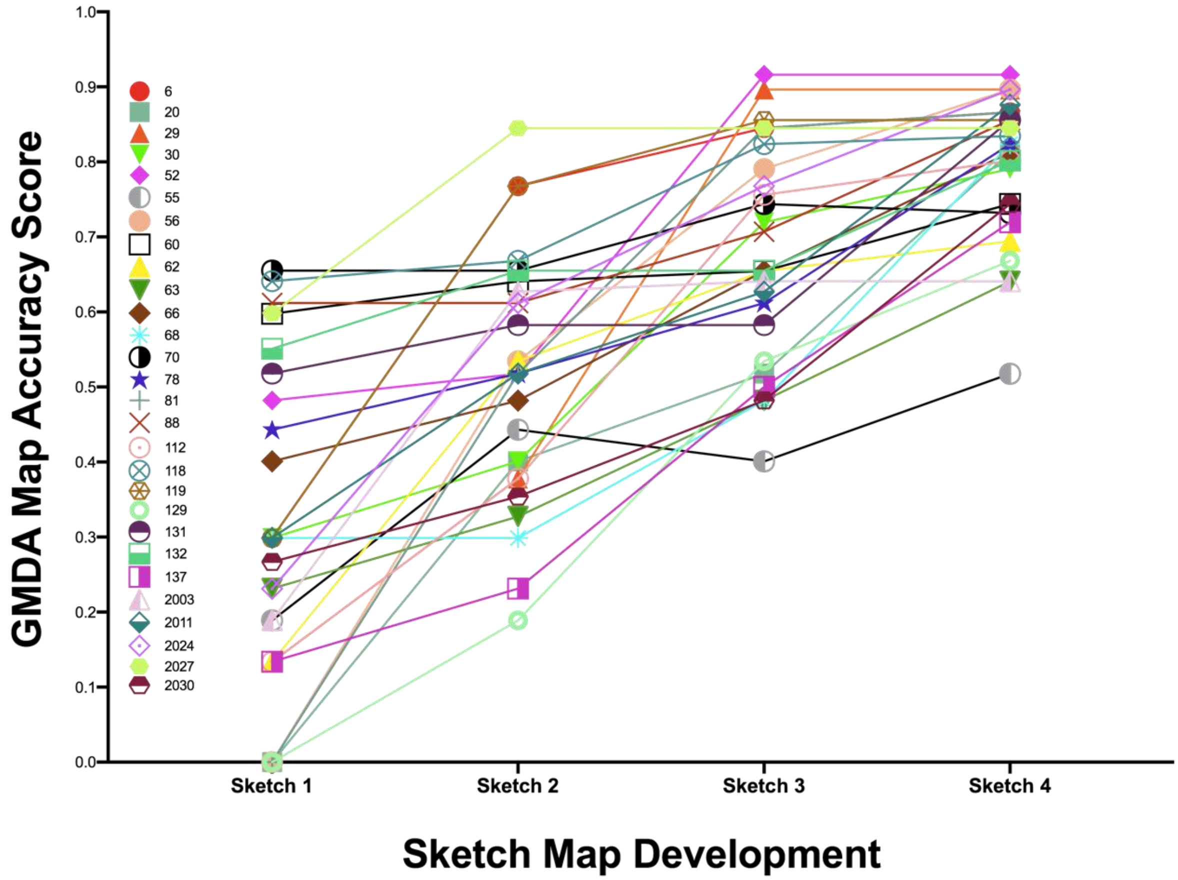

Figure 7: Improving Group trend across each individual sketch within the Sketch Group.

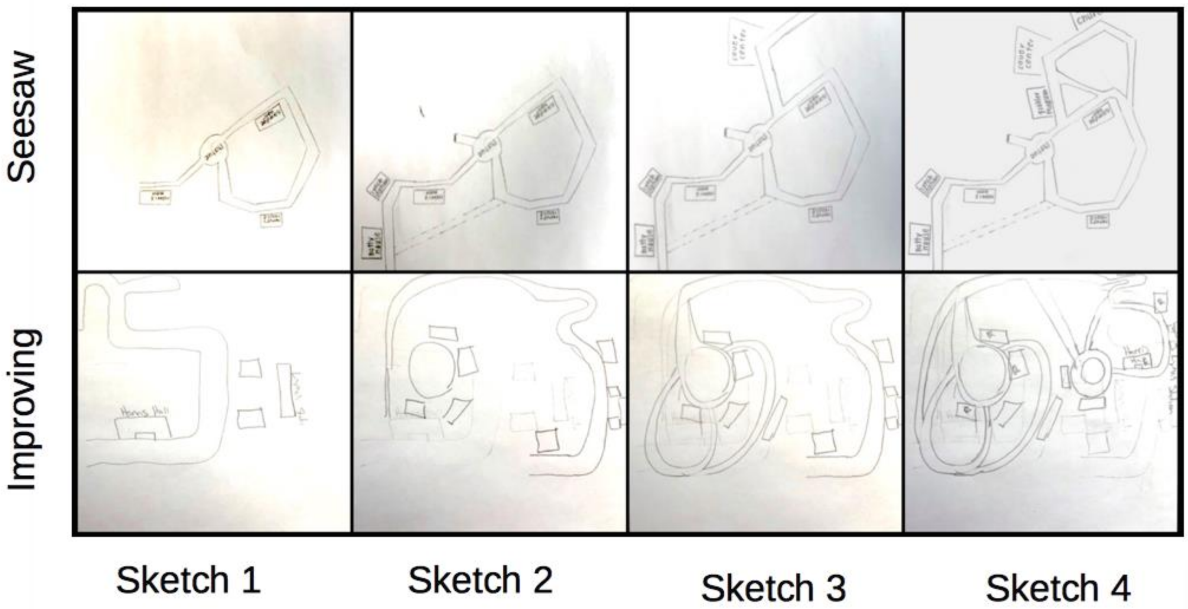

Figure 8: Top row: Example of a participant in the Seesaw group trend within the Sketch group. This participant scored 0 on Sketch 2 and Sketch 3 as a result of erasing and redrawing their map during the exploration process. Bottom row: Example of a participant in the Improving group trend within the Sketch group. This participant showed continuous improvement on their sketches.

Top Tertile and Bottom Tertile within the Sketch Group. Final sketch map scores for participants in the Sketch Group were divided into the strongest third (Figure 9) and weakest third (Figure 10) of mappers. There were 14 participants in each tertile. The highest scoring participant had a score of 0.92 out of a possible 1.0 and the lowest scoring participant had a score of 0.46. Interestingly, the lowest scoring participant across all groups had a score of 0.13, a much lower score than that of the lowest scoring participant in the Sketch group. Based on the trends mentioned above, participants in both groups followed both the seesaw and improving trends. In general, the strongest mappers demonstrated more of the improving trend and the weakest mappers demonstrated more of the seesaw trend. Both the strongest and weakest mappers included participants who showed extreme seesaw trends with a score of 0 on at least one of their middle maps.

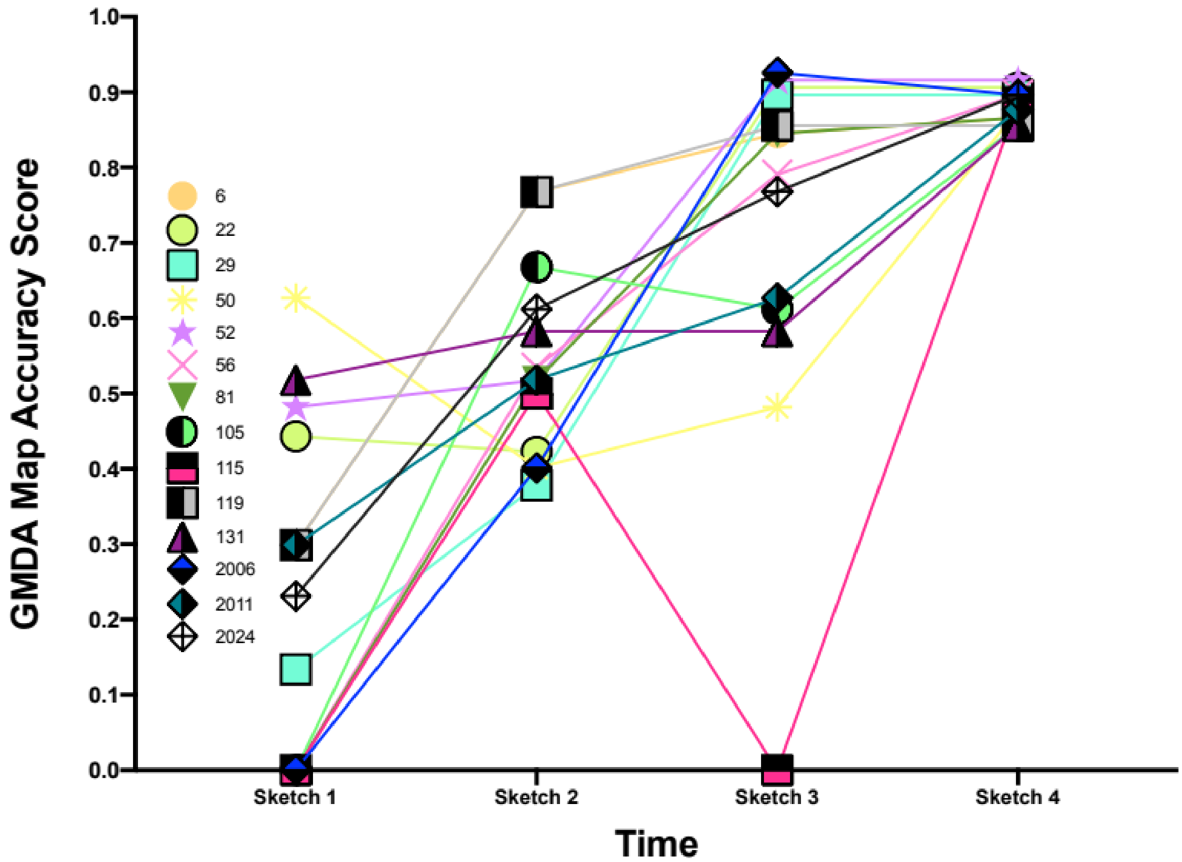

Figure 9: The top tertile of mappers within the Sketch Map group based on final sketch map accuracy. The top tertile of mappers trend more towards the improving group trend, but the seesaw group trend also occurred.

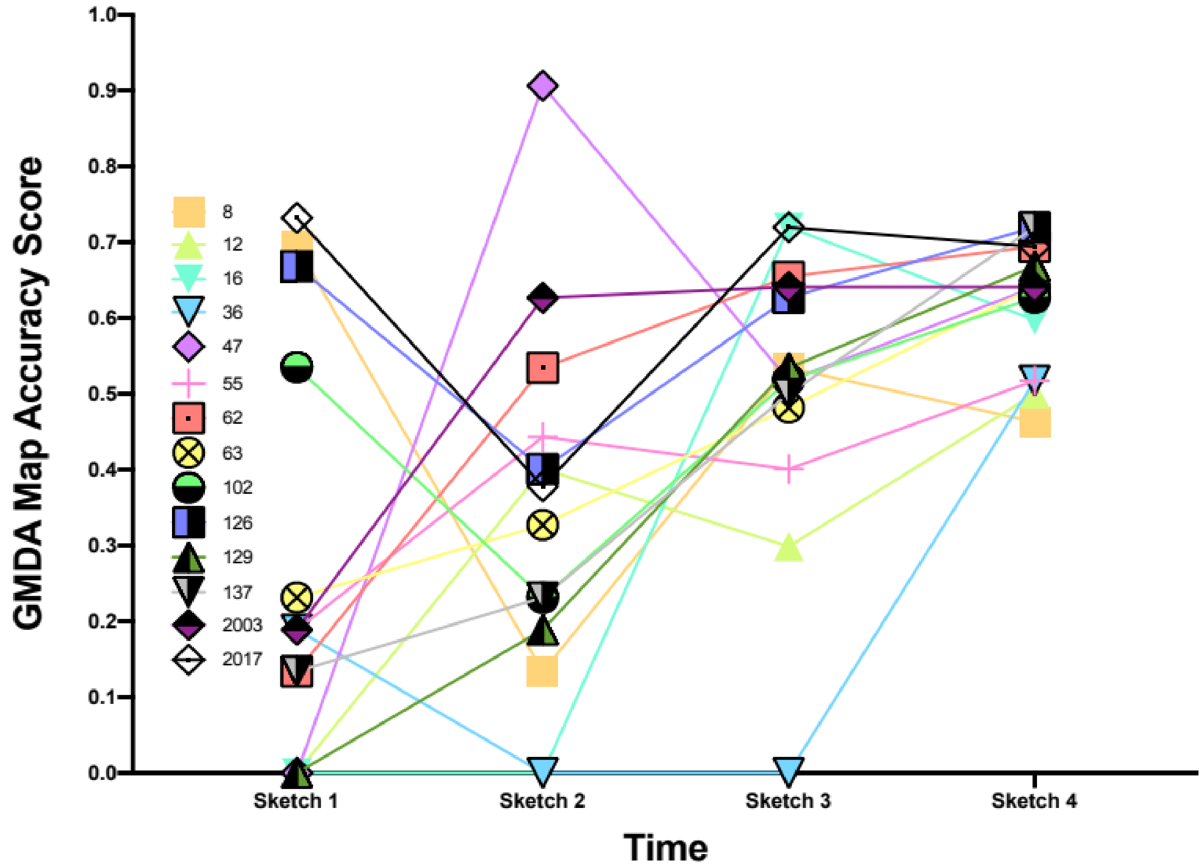

Figure 10: The bottom tertile of mappers within the Sketch Map group based on final sketch map accuracy. The bottom tertile of mappers trend more towards the seesaw group trend, but the improving group trend also occurred.

Discussion

The current study used periodic testing during the exploration period to measure cognitive map development of a novel virtual environment and examine how cognitive map development can improve over time. Analyses revealed that the number of buildings that a participant reported as found during the exploration period was related to both onsite direction estimation task performance and sketch map accuracy. There were sex differences in onsite direction estimation task performance, in which males had lower error scores than females, but this was not related to how participants experienced the exploration period in the different groups. There was no effect of sex on sketch map accuracy across groups. There were group differences in final sketch map accuracy, with those in the Sketch group performing more accurately than those in the Silcton task group. Within the Sketch group, there was no main effect of sex on sketch map accuracy. Participants showed improvement in sketch accuracy across each periodic sketching interval.

In accordance with Parush et al's (2007) findings and the testing effect (Wheeler & Roediger, 1992), participants exhibited better performance due to periodic testing in the current study. Although there were no observed benefits of periodic testing on onsite direction estimation performance, there were benefits of periodic testing on sketch map accuracy. These findings are consistent with research on the *testing effect* which involves using free recall during the encoding process to enhance memory (Karpicke, 2012; McDaniel & Einstein, 2000; Roediger & Karpicke, 2006, Wheeler & Roediger, 1992). More specifically, the results of the current study can be partially made clear by the *transfer-appropriate-processing view*, a possible explanation of the testing effect which suggests that the greater the similarity between the cognitive processes during the intervening test and final memory test, the better the overall performance (Morris, Bransford, & Franks, 1977; McDaniel, Friedman, & Bourne, 1978; Kolers & Roediger, 1984; Roediger, Guynn, 1996; Marsh, Edelman, & Bower, 2001; Roediger & Karpicke, 2006a, 2006b). The sketches drawn during periodic testing were exactly the same as, and were the beginning stages of, the final sketch map. The testing effect and transfer-appropriate-processing view help to explain why participants in the Sketch group showed the more accurate final sketch maps overall.

It is possible that participants in the Silcton Task group may have inadvertently had their attention directed to irrelevant information in the Silcton environment during exploration. In the current study, participants in the Silcton Task group were asked to stop and identify a number of random items on a list that might or might not have been in the Silcton environment at each periodic testing interval. It was emphasized that this list changed at each interval and that they did not need to try and find any items that they missed on previous lists. Wen et al., (2013) used sketch map performance to infer that individuals with a poor sense of direction may attend to information that is not relevant for effective spatial learning and therefore have difficulty acquiring the survey knowledge that is necessary for building an accurate map. If individuals with poor sense of direction already attend to information in the environment that is not relevant for spatial learning, then these individuals in the Silcton Task group may have had their attention diverted even further from relevant spatial information as a result of the irrelevant items that were included on the checklists. Attention is a necessary and crucial part of the encoding process (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Mulligan, 1998). Previous research by Dudukovic, DuBrow, and Wagner (2009) examined the relationship between full and divided attention during the encoding process and its impact on accurate retrieval. They found that the power of retrieval as an encoding mechanism was attention dependent and that divided attention during the encoding process was detrimental to retrieval accuracy. This accidental diversion may have interfered with the Silcton Task group's ability to accurately encode pertinent information about the environment and could have ultimately led to less accurate sketch maps. It is important to note, however, that this division of attention could have affected strong mappers in the Silcton Task group as well. While this does not completely explain the significant difference between the Sketch group and the Silcton Task group, it may explain part of the difference observed in their performances. It could also be inferred that the lack of periodic tests in the Baseline group could mean that this group did not have any testing-induced distractions and therefore may have performed better as compared to participants who were inadvertently distracted by periodic breaks. It does not, however, explain the lack of differences among the rest of the groups. Further research using these groups may help to identify the underlying mechanisms responsible for this outcome.

Periodic breaks used in the current study may have unintentionally introduced preparatory periods (Wammes et al., 2018) during exploration. In the current study, the Sketch group only showed significantly better performance than the Silcton group on final sketch map accuracy. The rest of the groups showed no significant differences in accuracy on final sketch maps. Note that no differences were seen in onsite direction estimation performance across all four groups. Given the known benefits of drawing and memory (Wammes et al., 2016; Wammes et al., 2017; Fernandes et al., 2018; Meade et al., 2018; Wammes et al., 2018; Wammes et al., 2018; Meade et al., 2019; Wammes, Jonker, & Fernandes, 2019), it is surprising to see that the Sketch group did not perform better than all other groups in the current study. One possible explanation may lie in the preparatory period associated with drawing. Wammes et al. (2018) explained the preparatory period as the time after the participants have been exposed to the target item but before they are allowed to draw it. They found that the simple act of preparing to draw was enough to produce a reliable increase in later memory accuracy when compared to writing. All participants in the current study were told that they would be drawing a sketch map at the end of the exploration period and were exposed to the target buildings prior to being allowed to draw them. Although this was a common instruction in previous research using sketch maps, the current study included various types of periodic testing, an area that has not been extensively explored in spatial research. Participants in the Silcton Task and Non-Silcton groups often used part of the 1-minute testing interval as a break after they had completed their task. When paired together, it is possible that the non-sketching periodic test(s) may have acted as a preparatory period during which participants were able to imagine how they might complete their final sketch map. This may partially explain why there were no significant differences observed between the Sketch group and Non-Silcton group. This idea can be further explained by massed versus spaced learning, where testing that uses intervening items (spaced) between trials during the learning phase has been found to improve memory recall when compared to learning that is consecutive or does not include any breaks (massed) (Atkinson & Shiffrin, 1968). While this does not explain the Baseline group's performance, it does help to partially explain the lack of differences displayed across the groups.

The ways in which accurate and inaccurate mappers develop their cognitive maps is an area that researchers are still working to understand. Many accurate mappers have been found to show consistently precise maps when tested throughout 10 weeks of separate exposures to connecting routes (Ishikawa & Montello, 2006). In accordance with

Ishikawa & Montello's (2006) findings, some accurate mappers in the Sketch group (individuals who scored 0.85 or higher on their final map using the Gardony Map Drawing Analyzer measure) showed accurate maps throughout the exploration process. In contrast to Ishikawa and Montello, however, some highly accurate mappers showed exceptionally inaccurate maps in their initial sketches, and then finished with a very precise final sketch map. Inaccurate mappers also showed a range in their development, with some inaccurate mappers showing more accurate maps in the middle stages but ultimately finishing with a less precise final map. Importantly, all mappers (including inaccurate mappers) in the Sketch group showed improvement in accuracy (their final sketch maps were always more accurate than their first map) across the span of the exploration period. There was not a single participant in the Sketch group who showed a strict decline (a less accurate final sketch map as compared to their first sketch with decreasing accuracy across all four sketches) in performance across their sketch maps. These findings suggest that not all accurate mappers start with accurate maps and not all inaccurate mappers begin with inaccurate maps. Map development fluctuates over the course of development and it is not always easy to decipher an individual's mapping ability based on their initial sketches. It is important to note that the current study was the first to use multiple sketch maps that were generated and compared during exploration of a novel environment across one individual session. Considering our understanding of the developmental stages of cognitive maps is limited, future work should focus on further documenting sketch map creation across a single session and specifically focus on the differences in development in accurate and inaccurate mappers.

After classifying participants in the Sketch Map group into different trends, it was observed that, regardless of sex, participants in this group performed in one of two different ways: the Seesaw trend or the Improving trend. All participants in the Sketch group followed one of these two patterns. The Seesaw trend included participants that showed some form of fluctuation in their maps regardless of whether they started with a more accurate or less accurate map. The Improving trend involved participants who continued to improve across all four sketches. No participants showed a steady decline in their accuracy. Though they only provided visuals for three participants, both the Seesaw and Improving trends are observed in Ishikawa and Montello's (2006) study as well. Participants in their study sketched multiple maps across multiple exposures to routes over a 10-week period. It is interesting to note that the same trends can be observed in the current study, which consisted of multiple sketch maps over the course of one session. These consistent observations support the idea that robust individual differences (Ishikawa & Montello, 2006) exist in cognitive map development regardless of the duration of time for which an individual is exposed to an environment.

Sex differences are a common finding in spatial research in both real-world and virtual environments (Coluccia & Louse, 2004). Males are often found to outperform females when survey knowledge (or cognitive map accuracy) is measured (Coluccia & Louse, 2004; Montello, Lovelace, Golledge, & Self, 1999; Ishikawa & Montello, 2006; Sholl, Acacio, Makar, & Leon, 2000; Silverman, Choi, Mackewn, Fisher, Moro, & Olshansky, 2000; Saucier, Green, Leason, MacFadden, Bell & Elias, 2002; Grön, Wunderlich, Spitzer, Tomczak, & Riepe, 2000; Moffat, Hampson, & Hatzipantelis, 1998; Cutmore, Hine, Maberly, Langford, & Hawgood, 2000). Differences in the way that members of each sex develop their sketch maps may explain differences in sketch map accuracy. For example, males have been found to rely on orientation and direction in order to create sketch maps and tend to form a geometric framework before sketching landmarks (McGuinness & Sparks, 1983; Galea & Kimura, 1993). In contrast, females tend to identify more landmarks on their sketches (Appleyard, 1970; Lawton, 1996; Saucier, Green, Leason, MacFadden, Bell, & Elias, 2002; Kim, Lee, & Lee, 2007; Castelli, Corazzini, & Geminiani, 2007) and create their sketch maps starting from individual parts to an eventual whole by organizing landmarks based on proximity (McGuinness & Sparks, 1983). In the current study, there were no sex differences found in relation to sketch map accuracy. This might suggest that the Sketch group intervention somehow eliminated the sex differences that are often seen in sketching research. Within the Sketch group, the periodic testing using sketching required individuals to build their sketch map in sections across four different testing points from individual parts to a whole. It could be that female participants in this group somehow benefited from the fact that the periodic tests operated in a similar manner to how they would usually create a sketch map. This could have potentially led to a more accurate performance on their final sketch map and may have attributed to the lack of sex differences seen in their map accuracy. It is not clear why sex differences were not observed in final sketch map accuracy across the other groups. While these previous finding help to partially explain these sex difference inconsistencies, it is clear that more research utilizing these groups would be required to determine which elements of periodic testing may aid in eliminating sex differences.

The male navigation advantage predominantly occurs when participants are actively involved in the exploration process, meaning they control their movements and route decisions in the environment (also known as free exploration) (Malinowski & Gillespie, 2001; Waller, Knapp, & Hunt, 2001; Montello et al.,1999; Rossano & Moak, 1998; Silverman & Eals, 1992; Sadalla & Montello, 1989). Previous research has also found that males outperform females on pointing tasks (Gagnon et al., 2018) and specifically on pointing tasks in combination with free exploration (Gagnon et al., 2018). In accordance with these findings, the current study found sex differences in onsite direction estimation error (which requires a sound understanding of orientation and direction as opposed to strictly landmark identification), with males showing lower error scores than females overall. Interestingly, this was the only measure in which a sex difference occurred. It is plausible that the typical sex differences seen in onsite pointing performance were impermeable to the manipulations used in the four groups. The pointing task also occurred further away temporally from the exploration period than the final sketch maps which may have been a contributing factor to these findings. Additional research investigating the relationship between periodic testing and tasks that measure direction estimation will help to better understand how differences are influenced by periodic testing.

In conclusion, cognitive map accuracy appears to be associated with periodic testing using sketching when measured using sketch map accuracy. Periodic testing does not appear to be associated with the ability to estimate the distances between landmark objects outside of the exploration period, as measured by the onsite direction estimation task. Inconsistent with previous findings, accurate mappers were found to not always create accurate maps at all stages of map development and inaccurate mappers showed a fluctuation in accuracy across development as well. Within the Sketch group, periodic testing was associated with overall improvement in sketch map accuracy across the exploration period, which alludes to the development of more accurate cognitive maps. The commonly reported sex differences were found in onsite direction estimation task but were not found in sketch map accuracy. The current study advances the field by providing evidence that supports the hypothesis that periodic testing is effective in improving some measures of cognitive map accuracy but not others and provides novel insight into the developmental stages of cognitive maps in a single testing session. More research is required to tease apart exactly which elements of sketching are beneficial to cognitive map development, to understand more about how these interventions interact with sex differences, and why those individual differences in accuracy occur in the development stages for both accurate and inaccurate mappers. This will further enhance our understanding of how we encode survey knowledge during the exploration process, and where those differences in encoding occur for all types of mappers. Perhaps expanding these findings could contributing to techniques that would help us to improve, and develop, and teach navigation abilities. This information could also aid in the development of navigation tools and devices that are catered to specific types of mappers.

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Appendix A: Ethics Approval

Western Research

Date: 25 January 2019

To: Dr. Jennifer Sutton

Project ID: 112401

Study Title: Exploring Cognitive Maps Through Sketching

Application Type: NMREB Initial Application

Review Type: Delegated

Full Board Reporting Date: 01/Feb/2019

Date Approval Issued: 25/Jan/2019 09:39

REB Approval Expiry Date: 25/Jan/2020

Dear Dr. Jennifer Sutton

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
COGMAPSKETCH - Letter of Information and Consent	Written Consent/Assent	24/Jan/2019	3
COGSKETCHMAP - Debriefing Form	Debriefing document	23/Jan/2019	2
COGSKETCHMAP - SONA Recruitment	Recruitment Materials	23/Jan/2019	2
Demographic Questionnaire - COGSKETCHMAP	Paper Survey	02/Nov/2018	1
Onsite Pointing Task Screenshot (Online Task) - COGSKETCHMAP	Online Survey	25/Nov/2018	1

No deviations from, or changes to the protocol should be initiated without prior written approval from the NMREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Katelyn Harris, Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B: Ethics Amendment

Western Research

Date: 13 May 2019

To: Dr. Jennifer Sutton

Project ID: 112401

Study Title: Exploring Cognitive Maps Through Sketching

Application Type: NMREB Amendment Form

Review Type: Delegated

Full Board Reporting Date: 07/Jun/2019

Date Approval Issued: 13/May/2019 12:09

REB Approval Expiry Date: 25/Jan/2020

Dear Dr. Jennifer Sutton,

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the amendment, as of the date noted above.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
COGMAPSKETCH - Letter of Information and Consent (Amendment)	Written Consent/Assent	06/May/2019	1
COGSKETCHMAP - Recruitment Email	Recruitment Materials	07/May/2019	1
COGSKETCHMAP - RECRUITMENT POSTER	Recruiting Advertisements	06/May/2019	1

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Katelyn Harris, Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Page 1 of 1

Curriculum Vitae

Name:	Melissa Nantais
Post-secondary Education and Degrees:	Brescia University College London, Ontario, Canada 2009 – 2014 B.A (Honours Specialization, Psychology)
	The University of Western Ontario London, Ontario, Canada 2017 – Present M.Sc. (Cognitive, Developmental, and Brain Sciences, Psychology)
Honours and Awards:	Thomas Underwood Award 2013
	Valedictorian 2014
	Brescia Honour Society 2014
Related Work Experience	Teaching Assistant The University of Western Ontario 2017 – 2019

Publications:

Sutton, J. E., Vollebregt, M., Grogan, B., Nantais, M. (*submitted*). Building a cognitive map of a virtual environment is easier if you can go your own way.

Presentations:

Nantais, M., Sutton, J., (2019, June). *Exploring Cognitive Maps Through Sketching*. Canadian Society for Brain, Behaviour and Cognitive Science National Conference, Waterloo, Ontario.

Nantais, M., Gibson M., (2014, February). *Does Participation in Creative Activity Help Support Cognitive Vitality?* Aging, Rehabilitation & Geriatric Care/Faculty of Health Sciences Symposium "Partnerships & Possibilities in Health Research," London, Ontario.