NAVIGATIONAL DECISION MAKING AND SPATIAL ABILITIES

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By

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ABSTRACT

Understanding human spatial cognition and behaviour is not something easily studied. Many factors are involved that contribute in different ways for different individuals. Navigation and wayfinding have been used as an approach, or starting point, for such studies. Spatial abilities tests have long been used as reference points to generalize to overt navigational behaviour. Care needs to be taken in generalizing from paper to behaviour to make certain that it is a valid relationship exists.

The purpose of this study was to examine the extent to which certain psychometric spatial abilities tests are indicators of actual navigational decision making. The study was conducted in two phases. The navigational decision tasks were made up of four paths with two variables: length and number of turns. The participants were required to make a decision on which direction to go after being lead part of the way around a hallway. The choices were to either go back the way they were led or take a novel route along a previously un-travelled path (shortcut). Spatial abilities tests (MRT, PFT, and OLMT), a self-rating of SOD, and learning preference for novel environments were administered in phase two.

While efficient navigation was not explicitly required in the navigation tasks those participants making the most efficient decisions shared similar characteristics. Efficient navigators have a higher aptitude for mental manipulation (as measured by the MRT), express a preference for a more ‘exploratory’ environmental learning style, are disproportionately male, and have a slightly higher self-rating of SOD. In addition to the collective set of four navigation decisions (one for each experimental path), path 2 demonstrated the ‘efficient vs. non-efficient’ distinction quite well: in order to make the

most efficient decision the individual must maintain the correct metric distance from the origin point and not be deterred by the passage of only half of the turns in the rectangular experimental environment.

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LIST OF ACRONYMS

ANOVA: Analysis of Variance

MANOVA: Multivariate Analysis of Variance

MRT: Mental Rotations Test

OLMT: Object Location Memory Test

PFT: Paper Folding Test

SOD: Sense of Direction

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Not all individuals look at the environment and notice the same world. This is most apparent when examining individual differences in navigation and wayfinding. Some tend to notice the sun's position and maintain its relationship to the path they are following and the cardinal direction they are going, others focus on specific landmarks and the sequences in the path they are taking. Examining these differences and understanding how people utilize their environment is the focus of much inquiry.

Spatial awareness, knowledge, and skill are necessary to negotiate through the environment. Many studies have tried to narrow down precisely how humans navigate and the relationship to other cognitive processes (e.g., Vandenberg & Kuse, 1978; Silverman & Eals, 1992; O'Laughlin & Brubaker, 1998; Gugerty & Brooks, 2004; Ishikawa & Montello, 2006). Spatial abilities tasks, such as the mental rotations test (MRT) (Cooper & Shepard, 1973; Vandenberg & Kuse, 1978), the paper folding task (PFT) (Ekstrom, French, Harman, & Dermen, 1976) and the object location memory task (OLMT) (Silverman & Eals, 1992), are useful tools for examining spatial behaviour but should not be taken as a reliable predictor of spatial behaviour (Dabbs, Chang, Strong, & Milun, 1997; Montello, Lovelace, Golledge, & Self, 1999; Malinowski, 2001). Other, more informal mechanisms, such as sense of direction (SOD) (Kozlowski & Bryant, 1977; Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002) and personal preference for learning a novel environment might also be useful for better understanding how people navigate. These individual reference scores/values may not be directly correlated with general spatial behaviour but they might indicate an indirect or mediated relationship exists and as such should be interpreted with caution (Bryant, 1982, 1991). While there have been some studies conducted to evaluate the relationship between spatial abilities tasks and navigation (Allen, Kirasic, Dobson, Long, & Beck, 1996; Montello, Lovelace et al., 1999), more research needs to be done in order to establish more precise parameters for predicting behaviour and the extent to which performance on these tests may be generalized to navigational behaviour.

As individuals move through the environment they consult and contribute to an 'internal representation of spatial information' referred to as our cognitive map (Golledge, 1999, p.15). Cognitive maps are an important part of navigation, as they contain information about the entire route to be traveled as well as information in the surrounding environment (Lloyd, 2000). Wayfinding is a specific kind of navigation and can be defined as 'purposeful movement to a specific destination that is distal and, thus, cannot be perceived directly by the traveler' (Allen, 1999b, p. 47). Several studies have demonstrated varying methods of studying wayfinding and the integration of cognitive maps (Allen, 1999b; Golledge, 1999).

There are certain psychometric tests that are used to measure spatial adeptness, for example spatial abilities tests such as the MRT, PFT and the OLMT. These tests claim to measure certain mental functions of spatial behaviour that can be used to help solve wayfinding tasks (Allen et al., 1996; Dabbs et al., 1997; Montello, Lovelace et al., 1999). Opposition has been voiced with regards to the validity of using pencil and paper tests to generalize behaviour outside of the laboratory setting (Dabbs et al., 1997) and the relevance of scale (between the paper test and actual behaviour) in any generalizations (Malinowski, 2001; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). Specifically, what precisely are these pencil and paper tasks measuring and are those components relevant to the study of environmental navigation (Dabbs et al., 1997; Montello, Lovelace et al., 1999; Malinowski, 2001).

This study intends to examine the relevance of the MRT, PFT, and OLMT as well as self-reported SOD score and learning preference for novel environments compared to navigational shortcutting behaviour in order to help elucidate the relationship(s) among these variables. Shortcutting, for the purpose of this study, is defined as choosing a novel path to a specific origin point instead of retracing the path just taken from that point. This critical comparison will help to narrow the focus from general spatial cognition (or even environmental navigation) to a specific type of navigation decision: it is hoped this will provide a more effective approach to integrating psychometric tests into the study of human spatial behaviour.

1.2 Spatial Knowledge Acquisition

There are several different levels of information that an individual can know about a specific environment. There are differences in experience and knowledge that manifest themselves in many ways. Learning can be goal directed, needing to find a particular place, or casual, learning an area for exploration or familiarization each of which might result in different knowledge (Garling, Book, & Lindberg, 1984; Garling, 1989). There is evidence that sex differences exist in the application and use of specific strategies used in learning new environments. Research suggests that females tend to focus on number of turns and useful local landmarks in order to find their way: where males appear to prefer to monitor their position in reference to distant waypoints and metric information (Lawton, 1994). These individual and sex variations involve many factors and have lead to quite a large body of research in environmental knowledge acquisition and navigation areas.

Learning an environment can take place in two general ways: 1) direct experience of the area through travel; and 2) learning from a vantage point or indirectly through some sort of symbol or iconic means (e.g. maps or photographs), and result in different aspects of the environment being learned (Golledge, 1999). Environmental learning is hierarchical (Stevens & Coupe, 1978; Tversky, 1981) and categorical in nature and is therefore subject to systematic degradation or distortions from mental organization processes (Tversky, 1992). Essentially, this means that in learning an environment, the individual stores relevant information in relation to previously learned information which may not be completely correct but maintains its usefulness (Allen & Willenborg, 1998). Of these representations, two broad categories of knowledge exist: 1) non-metric hierarchical associations that consist of relational/topological information and 2) knowledge associated with metric information (McNamara, 1992)

Siegel and White (1975) distinguished three types of environmental knowledge that are developed: landmark, route, and configurational. Landmark knowledge is characterized by the identification of specific geographical location of strategic items (i.e. school, office, home or any other place that has meaning to the individual). Landmark is the most basic environmental knowledge consisting of mostly visual information and is the first type learned. Route knowledge is built on landmark knowledge integrating a sequence of landmarks into a path that can be repeated or reversed. If a person was suddenly not on that particular path or was given information out of sequence they would have difficulty reorienting themselves. Configurational knowledge (also known as survey) is a holistic or gestalt picture of the environment with the landmarks and paths all interconnected into one large mental image. Survey knowledge is the last type learned. This type of knowledge is necessary in order to alter a route if there were any reason that the original one was not available, or for the purpose of this study to shortcut (Siegel & White, 1975).

1.3 Navigation and Wayfinding

Information that has been learned needs to be accessed in order to be useful in solving navigation and wayfinding problems. The internal representation of spatial information is the 'cognitive map' and has been accepted as consisting of points, lines, areas, and surfaces that are learned over repeated exposure to the environment and that continues to change as we gain more experience (Golledge, 1999). The point of a cognitive map is to have a flexible representation of a large amount of spatial and related categorical information that is in an economical form (Allen, 1999b). As well, individuals vary in personal style that results in differences in engaging the spatial environment, revealing accuracy discrepancies in mental representations (Bryant, 1982; Tversky, 1992). With repeated exposure to an environment the cognitive map is updated with new information (Lloyd, 2000) that leads to a 'steady state' that is useful to the individual but not necessarily accurate (Stern & Portugali, 1999). Mature cognitive maps have been shown to be the same as configurational or survey knowledge of an environment (Siegel & White, 1975).

Navigation was traditionally defined as a science of locating position and course plotting for planes and ships but has been applied to research on human spatial behaviour, particularly that behaviour related to deliberately making one's way through space

(Golledge, 1999). Wayfinding has been defined as ‘purposeful movement to a specific destination that is distal and, thus, cannot be perceived by the traveller’ (Allen, 1999, pg 47). Wayfinding is navigation that occurs on or off a known route; basically if a new route is attempted or a known route is forgotten then we can consider the behaviour wayfinding (Cornell & Heth, 2000).

Allen (1999a) identified three types of wayfinding tasks: commute, explore, and quest. In order to accomplish any of these tasks one or more mental means of completion may be employed. *Piloting* is the simplest mental means that a traveller may employ. It involves using landmarks and the connections between landmarks to navigate. *Locomotion pattern repetition* is a repeated version of piloting that evolves into habitual movement which becomes automatic over time. *Path integration* requires the traveller to maintain orientation to an origin and allows them to calculate and execute a fairly direct route back to the origin. *Cognitive map navigation*, as stated earlier, is where individuals refer to their internal representation for appropriate wayfinding information (Allen, 1999a) and is applicable to all types of wayfinding.

Men have outperformed women in several navigation tasks but this difference may be due to a difference in preference or focus on different spatial knowledge than men (Lawton, 1994; Montello, Lovelace et al., 1999). This difference may be that males and females tend to pay attention to and describe different types of spatial information in all types of environments (Holding & Holding, 1989; Galea & Kimura, 1993). When navigating, females tend to refer to sequences of turns and relevant landmarks, where men use an orientation strategy involving self monitoring with respect to distant waypoints by metric information (Lawton, 1994). It has been suggested that the ability to manipulate spatial sets as a whole may be the reason for the male preference to use a survey strategy in navigation (Iachini, Sergi, Ruggiero, & Gnisci, 2005).

1.4 Spatial Abilities

Spatial abilities tests have been used by psychologists and geographers for many years (Vandenberg & Kuse, 1978; Masters & Sanders, 1993; Hegarty et al., 2002; Iachini et al., 2005; Hegarty et al., 2006). They are useful for isolating specific mental processes that individuals use in everyday situations. Overt human behaviour has been generalized from many of these tests (Maccoby & Jacklin, 1974; McGee, 1979; Masters & Sanders, 1993; Malinowski, 2001; Fields & Shelton, 2006; Hegarty et al., 2006). There are generally considered to be two components to spatial ability: visualization and orientation (McGee, 1979). Spatial visualization is the ability to mentally manipulate two- and three-dimensional objects by rotation or twisting, while orientation is the ability to maintain appropriate directions with regards to one's body and remain unconfused during reorganization of spatial configuration (McGee, 1979). The usefulness of these generalizations may be called into question if the mental processes tested in the spatial abilities tests do not exactly match those used by individuals in overt behaviour (McGee, 1979; Hegarty et al., 2006).

Sex differences are frequently found within these spatial tests and encompass the majority of analyses within the literature (Linn & Peterson, 1985; Voyer, Voyer, & Bryden, 1995; Heth, Cornell, & Flood, 2002; Bell & Saucier, 2004). There are a few tests that have been utilized more often than others and that have proven to be useful in assessment of overt behaviour. Extensive use has been made of the MRT (Vandenberg & Kuse, 1978), PFT (Ekstrom et al., 1976), OLMT (Silverman & Eals, 1992), and as well as several forms of SOD analysis (Kozlowski & Bryant, 1977; Hegarty et al., 2002).

Very few studies have looked specifically at learning preferences in novel environments (Devlin & Bernstein, 1995), most indicate vague references to a single preference (Bryant, 1982; Linn & Peterson, 1985; Kato & Takeuchi, 2003; Nori & Giusberti, 2006).

1.4.1 Sense of Direction

Most people have heard the term 'Sense of Direction' in some form. It seems logical that, with the extent of personal navigation that occurs daily in people's lives, that they would have some personal gauge or reference regarding their own capabilities. A single item question that asks for their own opinion of their SOD may be useful if given enough sensitivity to indicate individual differences. The evaluation of SOD has been fairly erratic over the years with different approaches and methodologies used making comparison between studies very difficult.

There are many studies that have used different approaches in measuring and defining what constitutes SOD. There are basically two schools of evaluation. One involves a single question using 1 to 7 or 1 to 9 likert scale (Kozlowski & Bryant, 1977; Sholl, 1988; Montello & Pick., 1993; Prestopnik & Roskos-Ewoldsen, 2000; Sholl, Acacio, Makar, & Leon, 2000; Muehl & Sholl, 2004) and the other uses a multi-item scale of questions (Bryant, 1982; Vandenberg, Kuse, & Vogler, 1985; Lorenz & Neisser, 1986; Bryant, 1991; Hegarty et al., 2002; Hegarty et al., 2006; Ishikawa & Montello, 2006). This variety in questioning has led to quite an array of findings and conflicting results within the literature. For example, SOD was found to be not related to MRT and psychometric spatial ability (Bryant, 1982; Sholl, 1988; Hegarty et al., 2002). Other studies have found a positively correlation between navigational behaviour (i.e. spatial updating) and the same spatial abilities (Montello, Lovelace et al., 1999; Fields & Shelton, 2006; Hegarty et al., 2006). Also, women are generally less confident in their orientation skills than men (Kozlowski & Bryant, 1977; Lawton, 1994) which may explain the sex difference in self-rated SOD. The validity of using SOD has been confirmed in these studies in that both methods were found to be significantly related to spatial updating (Kozlowski & Bryant, 1977; Hegarty et al., 2002).

One of the difficulties with using a self-report measure is that there is no way to validate whether the participant is accurate in their reporting. Bryant (1982) indicated that there was little evidence for participants to self-deceive or to deceive others regarding their reports. Hegarty et al. (2002) developed a multi-item scale measure of SOD that they felt would be a useful tool to compare between studies. One difficulty with a scale method was that there was no correlation found with the MRT or other psychometric spatial abilities (Bryant, 1982; Sholl, 1988; Hegarty et al., 2006) with some scales although others did find a positive significant correlation (Vandenberg et al., 1985). The usefulness of a multi-item scale is obviously still unsettled.

Some of the studies utilizing SOD have split or purposely selected participants into two categories: good SOD or poor SOD (Kozlowski & Bryant, 1977; Kato & Takeuchi, 2003). This distinction has been used by researchers but may dilute the variation of possible scores in the population and behavioural relationships between behaviour and SOD. By using scores from the entire scale it may be possible to get a clearer picture of individual differences in comparison to other spatial abilities tests and navigation tasks.

Hegarty et al. (2006) reported the highest test-retest correlation for one item in their scale that asked solely about a sense of direction. Most studies that use single question SOD are rated on a 7 or 9 point scale (Kozlowski & Bryant, 1977; Sholl, 1988;

Montello & Pick., 1993; Saccuzzo, Craig, Johnson, & Larson, 1996; Sholl et al., 2000) and yielded very small differences between groups. Rating the scores on a scale of 0 – 100 may lead to a more sensitive measure of SOD and provide data that are more consistent with the ratio data of other measures generally used in navigation studies (such as pointing accuracy and distance estimation).

1.4.2 Mental Rotations Test

Shepard and Metzler first introduced the stimuli used in the MRT in 1971. The task involved looking at two objects and responding that they were either the same object or different objects. One object was rotated on a predetermined axis from the first object for the 'same' rating, and mirrored images of the rotated objects were used for the 'different' ratings. The original application of this task was to examine the relationship between degrees of rotation (of the original object) with reaction time; sex differences were not examined. Shepard and Metzler stated the method used to determine if the objects are the same or different was a result of a 'mental rotation.' In other words, the participants were mentally rotating the objects in order to determine similarity or difference.

In further examination of MRT, Shepard and Judd (1976) designed a slightly different approach. Objects (from Shepard & Metzler, 1971) were flashed one after another in pairs on a computer screen to facilitate the illusion of the objects being rotated. Human perception would see these objects as being rotated (similar to how a movie works from still pictures), and would increase the reaction time accordingly (Shepard & Judd, 1976). Participants found the pairs judged to be the same as easier to see, with resulting shorter response times; yet a similar linear relationship was found between amount of rotation and reaction time as the original Shepard and Metzler (1971) study.

Vandenberg and Kuse (1978) developed a version of the MRT using the same stimuli as Shepard and Metzler (1971). The test consisted of twenty items, of which, each item contained a target figure with two each correct and incorrect figures. The correct figures were rotated versions of the target and the incorrect figures were either rotated mirror images of the target or rotated mirror of a different item. This test was correlated with other tests of spatial and verbal ability. There was a high correlation between the MRT and spatial visualization tasks, whereas, there was no correlation found with the verbal tasks. A reliable sex difference was also found with this new task. The MRT has been used for many years as a reliable predictor of spatial ability by many groups of researchers (Galea & Kimura, 1993; Masters & Sanders, 1993; Bell & Saucier, 2004; Fields & Shelton, 2006; Hegarty et al., 2006).

The mental processes involved in completing the MRT have been related to many components of navigation and environmental learning (Dabbs, Chang, Strong, & Milun, 1998; O'Laughlin & Brubaker, 1998; Allen, 1999a; Montello, Richardson, Hegarty, & Provenza, 1999; Silverman et al., 2000; Malinowski, 2001; Hegarty et al., 2006). It has also been suggested that the MRT may relate to pointing accuracy or ability to visualize oneself standing in a particular orientation position (Bryant, 1982). The comparison between the MRT and navigation tasks may be useful because of the nature of the mental processes involved in solving both types of tasks.

1.4.3 Paper Folding Test

The PFT was initially presented as a spatial visualization test in the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963) and was republished in the Kit of Factor Referenced Cognitive Tests (Ekstrom et al., 1976). The kits were developed in order to give researchers tests that focus on a specific cognitive aptitude factors ranging from memory to reasoning and verbal skills as well as to have a collection of tests that can be used to compare more easily between different studies by using the same test and procedure (Ekstrom et al., 1976). The premise of this particular test is to measure the ability of persons to visualize, transform and manipulate spatial patterns in their head (McGee, 1979).

This test has been found to show a significant male advantage (French et al., 1963; McGee, 1979). There have also been other studies that have found similar male trends but have failed to reach significance using both parts of the test (Watson & Kimura, 1991) as well as using only half of the test (Gouchie & Kimura, 1991). Even with these failures in finding significance, the studies all state that males score higher.

The purpose of utilizing this test is to measure spatial visualization abilities that might be useful in real-world navigation problem solving. General spatial ability has been associated with the cognitive processes that relate to successful environmental learning (Allen, 1999a). Given that the PFT has been found to be highly correlated to the MRT (Blajenkova, Kozhevnikov, & Motes, 2006), including this test may provide useful comparisons.

1.4.4 Object Location Memory Test

Spatial abilities tasks, until recently, have focused mostly on mental manipulation of objects (Maccoby & Jacklin, 1974; McGee, 1979; Linn & Peterson, 1985; Voyer et al., 1995; Bell & Saucier, 2004; Fields & Shelton, 2006; Hegarty et al., 2006). One set of tasks looks at the possibility of a female advantage in object memory for items presented within a complex array (Silverman & Eals, 1992). Silverman and Eals developed their task from evolutionary theory based on archaeological evidence of sexual division of labour in hunter-gatherer societies. They proposed that because of this dimorphism in daily activities, there would be evolutionary selection for different spatial aptitudes for males than for females. Men went away from the home base and hunted in novel territories and would have had to be able to find the easiest and most direct route home. Women stayed closer to home and gathered edible plants and would therefore need to remember where certain plants are located within a complex array of vegetation. This difference in spatial tasks provides the basis of Silverman and Eals' (1992) evolutionary theory. Women with a good memory for items within the complex array would have obtained more food and subsequently been more likely to survive as well as their children, passing on their genes.

The OLMT was presented in two forms: pencil/paper and natural environment (Silverman & Eals, 1992). The pencil and paper task consisted of an array of common objects. The response array consisted of the same array of objects, but where some random pairs of objects had switched places. Participants were to decide whether each object had moved or not in the response array. The natural environment task required participants to wait in a small desk area. After two minutes they were lead into a different room and were asked to recall the items, both name and location, from the room where they had been asked to wait. Women were found to be better at remembering the location of objects in both conditions, paper and environmental, as well as for both directed and incidental memory. These tasks were innovative in spatial abilities research because they were the first to specify a spatial advantage for females (Silverman & Eals, 1992; Eals & Silverman, 1994; James & Kimura, 1997).

The honeymoon phase of this test did not last long as questions surfaced with regards to the test's validity. Specifically, it was suggested that females may be using a verbal strategy to solve the task (Eals & Silverman, 1994) and that the objects were only switched places and did not occupy previously unoccupied space on the page (James & Kimura, 1997). These qualifications made an interesting case for using the OLMT as presented in paper form. A more recent study has found that women perform better on tasks of exchange, object shift and novel objects in a similar array to the OLMT (Levy, Astur, & Frick, 2005) disputing the previous research arguments.

Even with these clarifications, there still remains a valid premise of having a female advantage spatial task like the OLMT. Women have been found to use features rather than location in memory if there was a choice and have a poor memory for spatial information (Jones & Healy, 2006). Women also remember the locations of common objects in a room (Montello, Lovelace et al., 1999) and are better at the game Memory (McBurney, Gaulin, Devineni, & Adams, 1997). These all involve similar mental qualifications as the OLMT in that they all have a focus on features or visual landmarks as compared to specific metric or location information. The use of the OLMT is a simple way of examining the possible verbal/feature focus of individuals and their use in navigation problem solving.

1.4.5 Learning Preference

For the purposes of this research, I wanted to evaluate participants' preferences for learning novel environments. Because this was not explicitly asked in any other research, a question needed to be developed that would encompass a variety of possible strategies. There are several ways that a person may attempt to learn an environment, depending on what resources are available at the time.

Most individuals have used a map at some point in their lives. The usefulness of a map to navigate depends on the particular individual's skill set in order to make sense of the symbology and relatively abstract illustrated environment in comparison to the actual environment. Map learning involves some type of manipulation of the information given in the map into useful information relating directly to the environment (Levine, 1982; Levine, Marchon, & Hanley, 1984). Map learning also requires maintenance and updating their current position and heading with the orientation of the map (Levine, 1982). Individuals who find such mental manipulations and translations easy may find a map to be their preferable learning strategy. Previous studies have included a map learning preference component and found a male preference for map learning (Devlin & Bernstein, 1995, 1997).

Another possible preferred learning strategy involves having an individual familiar with the environment show the person new to the area around. One aspect of this preference may indicate an individual's reluctance to rely on their own capacities or skills to move successfully around in a novel environment. A timid attitude and dependence on others (Kato & Takeuchi, 2003) as well as cautiousness (Linn & Peterson, 1985) may be factors in a person's preference for being shown around a new environment. This preference could be as simple as basic lack of experience, a non-adventurous nature, a fear of getting lost, or even a more sociable personality.

Exploring alone may be a very popular learning strategy. Conceptually this is the opposite of being shown around: exploring on their own would indicate confidence in their abilities and possibly less of a concern regarding becoming lost. A previous study has looked at a 'like to explore' component with regard to navigation in novel environments and pointing accuracy and proposed a mediating relationship of 'explore' and fear of becoming lost between certain personality measures and pointing task performance (Bryant, 1982). Experience in exploration and self-reliance would be useful in this learning strategy.

Some individuals may prefer to get a verbal description of a novel environment. Females have been shown to be better at verbal memory and also tend to score lower on some spatial abilities tests (Vandenberg & Kuse, 1978; Eals & Silverman, 1994). This again may indicate less confidence in their navigational skill set and yet have somewhat more confidence than individuals who prefer to have another person show them around. A female learning preference has been found for information given verbally (Devlin & Bernstein, 1995, 1997). With this in mind it may be that some individuals may prefer verbal descriptions of a novel environment to learn.

1.5 Spatial Abilities and Navigation

Recent studies have examined the relationship between spatial abilities tasks and real-world navigation (Malinowski, 2001), geographic and environmental abilities (Montello, Lovelace et al., 1999), navigational strategy and geographic knowledge (Dabbs et al., 1998), and even testosterone levels (Gouchie & Kimura, 1991). A few studies have attempted to model the relationship between spatial abilities as tested by psychometric tests and actual behaviour but have reported conflicting associations (Allen et al., 1996; Hegarty et al., 2006).

It has been suggested that it is difficult to predict skill regarding wayfinding ability because the mental processes are multi-factored and complex (Prestopnik & Roskos-Ewoldsen, 2000). Researchers have taken on this challenge and have set out to define the relationships. This complexity was demonstrated by the revealed interactions between both internal (i.e. personal attributes) and external (i.e. environmental situations) factors that combine to complicate the prediction process (Kitchin, 1994). In addition, the physical features of the designed environment can affect human knowledge and navigation behaviour in buildings (Evans, Fellows, Zorn, & Doty, 1980). For example, SOD was found to independently predict learning in real environments (Hegarty et al., 2006), SOD was also found to predict distance estimation ability (Kozlowski & Bryant, 1977), and high MRT scores were necessary for individuals to complete an orienteering task (Malinowski, 2001).

The MRT has been used extensively and was found to be significantly correlated to SOD (Vandenberg et al., 1985), the PFT (Blajenkova et al., 2006), general geographic knowledge (Montello, Lovelace et al., 1999), pointing task completion (Bryant, 1982), abstract and Euclidean references in directions (Dabbs et al., 1998), low navigational errors when following Euclidean directions (Saucier, Green et al., 2002), orienteering tasks (Malinowski, 2001), and maze completion times and errors (Moffat, Hampson, & Hatzipantelis, 1998). These correlations demonstrate the pervasiveness of the MRT and its relation to different types of spatial abilities and navigation tasks. There have also been studies that have found no correlation between multi-item SOD, MRT, and psychometric ability (Bryant, 1982; Sholl, 1988; Hegarty et al., 2002), contradicting some of the previous studies.

Decision making based wayfinding tasks focus on what strategy participants are using (Lawton, 1994, 1996). One study found no sex difference in response times between males and females (Lawton, 1996) suggesting that the sex differences found were found in strategy and processing operations. Men utilize survey (using holistic information that is interconnected) strategy to solve wayfinding tasks where females tend to use the route (maintaining an ordered path that can be retraced easily) strategy

(Lawton, 1994, 1996, 2001; Nori & Giusberti, 2006) confirming the notion that males are better at some applications (i.e. holistic manipulations) and women in others (i.e. patterned repletion of routes) (Montello, Lovelace et al., 1999). In another application, landmark strategy users tend to use active navigation modes (i.e. driving or biking) less often and prefer to be lead along passively (i.e. bus or cab) in everyday navigation regardless of sex (Nori & Giusberti, 2006).

A person may take a novel route for no other reason than that they know it will lead them in the correct relative direction of their goal (Cornell & Heth, 2000). Visual landmarks are important to shortcutting and greatly increase accuracy and success (Allen, 1999a). Jansen-Osmann and Wiedenbauer (2004) showed that routes with more turns were found to be estimated as longer than ones with fewer turns. As well, females tended to focus on the number of turns and landmark sequences where males relied on metric information and survey knowledge references (Lawton, 1994). In one other study, subjects retained a memory of the entire route that they were shown, even when they knew it may be required to shortcut back to an origin (Loomis et al., 1993). From these studies, solving strategy (including the use of landmarks, metric distance, environmental knowledge and memory) presents itself to be a critical factor in the differences between the sexes in navigation use and efficiency.

Nevertheless, SOD, MRT, and OLMT are also important factors that distinguish an individual's wayfinding efficiency. Good SOD participants were found to use absolute referencing system along with memorizing landmarks and were able to change strategies to suit different situations, whereas poor SOD participants showed a timid or dependent attitude on others and had difficulty in choice and use of suitable wayfinding strategies (Kato & Takeuchi, 2003). Individuals with higher scores in MRT, regardless of sex, were better able to compensate for the lack of significant landmarks in a video tour (O'Laughlin & Brubaker, 1998). The OLMT has been shown to be significantly correlated to landmark use and using left-right terms in giving directions (Dabbs et al., 1998). These spatial ability tests show the importance of comparing these to actual navigational behaviour.

1.6 Summary

Many of the processes involved in spatial abilities tests are similar to those used in navigation or wayfinding. In order to be able to go to the origin in a wayfinding task, the individual has to maintain the information about the path that they have taken and manipulate that information to make a decision on how to get back. Some people will pay more attention to the number of turns that they have encountered; others will maintain information about their location with regards to the origin and will be able to try a different path if they think that it will be more efficient. The current study attempted to expand on the similar solving strategy components between spatial abilities tests and wayfinding decision making as well as identify factors involved in making efficient (shortest path) navigation choices.

1.7 Research Question

The purpose of this research is to examine the extent to which spatial abilities tasks are correlated to actual navigational shortcutting behaviour. There are several hypotheses that follow from this inquiry and will be examined in this study. First, those individuals who score higher on the MRT, PFT, self rating of SOD, and/or choose the 'explore' learning preference (regardless of sex) will be more likely to shortcut. There is a reliable significant difference between the scores of males and females in the MRT

(Vandenberg & Kuse, 1978) and the PFT (Ekstrom et al., 1976), but there is some overlap between the scores that needs to be addressed as well as the similarity in solving strategy of the tasks. Second, following from the similarity in solving strategies of the MRT, the PFT, and the shortcutting task, males will be more likely to shortcut than females. These tasks require mental manipulation of either the stimuli or environment and to maintain these manipulations in the mind to solve the problem. Third, individuals who score higher on the OLMT will be more likely to choose not to shortcut. Specifically, there is an increased tendency to rely on relevant experienced landmarks. Fourth, this study will attempt to replicate the sex differences found with the MRT (Vandenberg & Kuse, 1978), the PFT (Ekstrom et al., 1976), the OLMT (Silverman & Eals, 1992) and a self-rating of SOD (Hegarty et al., 2006).

CHAPTER 2
METHODS

2.1 Participant Characteristics

Participants were recruited through the first year Psychology participant pool and undergraduate and graduate classes in Geography. The students in both Psychology and undergraduate Geography were volunteers and received class credit for their participation. The graduate participants were volunteers and were not compensated for their participation. A total of 67 participants were tested. The age of the male participants range from 16-26 with an average of 20.19 ± 2.856 (Mean ± Standard Deviation) and the female participants range from 17-40 with an average of 20.12 ± 4.898 (non-significant difference). Ethics guidelines of the University of Saskatchewan and the Tri-council were followed regarding testing with human subjects.

2.2 Materials

Three spatial abilities tasks were used in this study. The first test is the MRT, as modified by Vandenberg and Kuse (1978). The test consists of twenty (20) item sets. Each item set consists of five (5) figures: one target object, two correct items, and two incorrect distracters (see Figure 2.1 for example). Each figure is a two-dimensional depiction of three-dimensional cubed object (for a full description of figure construction see Shepard and Metzler (1971). The task is administered in two parts with a time limit of 4 minutes for each section. Respondents are asked to mark the two correct items, leaving the incorrect ones unmarked. Because of the time restraints for this study, only the first part of this test was given. A reliable sex difference has been found by previous researchers using half of the full test (Gouchie & Kimura, 1991; Saucier, Green et al., 2002; Saucier, McCreary, & Saxberg, 2002; Bell & Saucier, 2004). A total score for this test was calculated by giving one point for each correct response and subtracting one quarter of the incorrect responses for a total out of a maximum of 20.

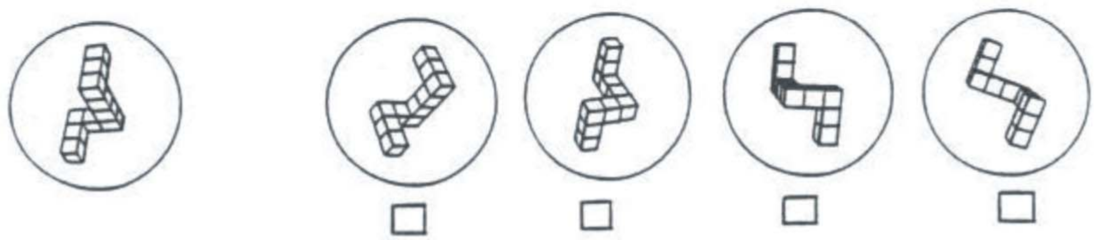

Figure 2.1 Example of Mental Rotations Test item set (Vandenberg & Kuse, 1978).

The PFT used in this study is taken from the Kit of Factor-Referenced Cognitive tests (Ekstrom et al., 1976). This test consists of 20 questions separated into two parts of 10 questions. Each part is given separately with a time limit of 3 minutes each. Each question (see Figure 2.2 for example) has figures to the left of a vertical line that show how a piece of paper is being folded and a circle where a hole has been punched through the paper. The figures to the left of the vertical line are possible arrangements of the holes after the paper has been unfolded. Participants are asked to indicate with an X which figure correctly displays the holes. Due to time constraints only half of this test was given. This test has been previously administered using only half of the test that was significant for a one-tailed test (Gouchie & Kimura, 1991). Scores for this test are calculated by adding the number of correct responses and subtracting one quarter of the incorrect responses for a maximum of 10.

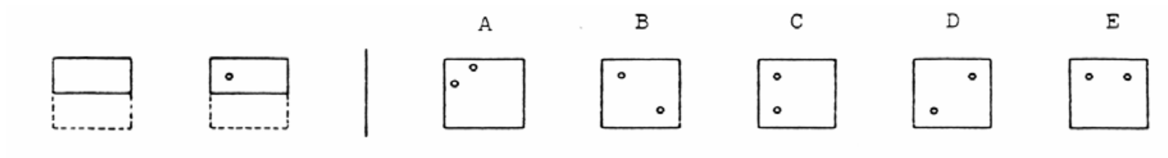

Figure 2.2 Example of Paper Folding Task item set (Ekstrom et al., 1976).

The third spatial abilities task is the OLMT. This task was developed by Silverman and Eals in 1992. The OLMT consists of a stimulus array of 27 common objects on a piece of paper (Figure 2.3) and a response array where seven pairs of objects (14 objects) have switched place. The participants are given the stimulus array and are asked to 'examine the array' for 1 minute, after which, the paper is returned to the researcher upside down. They are then given the response array where they are asked to indicate for each object whether it is in the same place or has moved. The score for this test is the total number of objects correctly identified as either moved or in the same place for a maximum of 27. No penalty is given for incorrect responses.


Figure 2.3 Object Location Memory Task Stimulus Array (Silverman & Eals, 1992).

Participants completed four navigational shortcutting tasks. All tasks involved the use of an indoor rectangular hallway (Figure 2.4). The paths began at a specific point in the hallway (indicated by an X or O) and follow around to the decision point, as indicated by the numbers 1 through 4. The participants are required to make a decision on the path taken to go to the starting point. Each path differs on one of two variables: length and number of corners. **Path 1** is roughly half the total distance around the hallway with two corners to navigate (starts at X). **Path 2** is longer than path 1 and has two corners (starts at X). **Path 3** is the same length as path 1, but has three corners (starts at 0). **Path 4** is the same length as path 2, but has three corners to negotiate (starts at X).

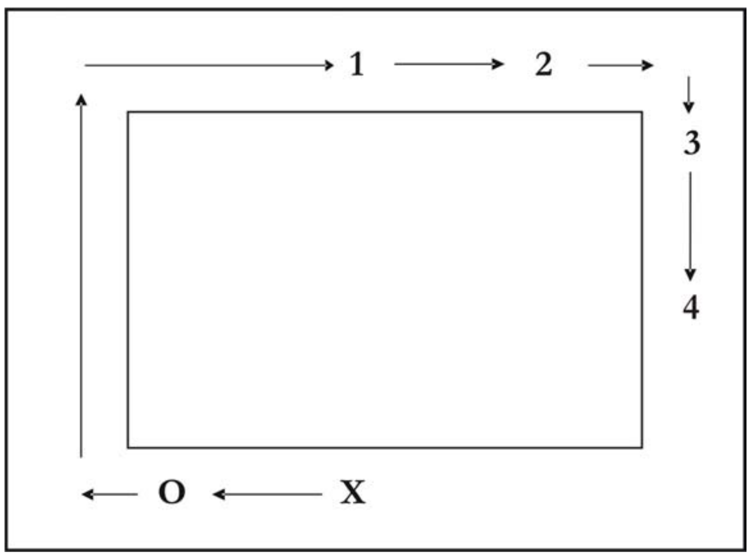

Figure 2.4 Schematic of the hallway used in the Navigation Task.

Two demographic questionnaires were administered at the end of each phase. The Phase 1 questionnaire consisted of questions to determine the participant's experience with the test building and strategies used to complete the navigation task. Phase 2 questionnaire consisted of basic demographic information (age, sex, dominant hand, year of university, and major), previous experience with any of the spatial abilities tests, perceived difficulty of the MRT test, completion strategies for each spatial ability test, self-rating of sense of direction (scale 0-100), and preference strategy for learning a new environment (as outlined in Section 1.4.5).

Because of the implicit nature of the tasks and the possibility of practice effects, if it is found that a participant has previous knowledge of the spatial abilities tasks, they will be removed from the statistical analysis. Completion strategies are valuable in completing the analysis of these data in order to get a general sense of the mental processes participants used when solving each of the tasks.

2.3 Procedure

Testing was completed in two phases. Phase 1 consisted of the navigation task and a short questionnaire and phase 2 consisted of the MRT, PFT, OLMT, SOD, learning preference and questionnaire. Testing was separated to allow for ease of testing and sufficient separation of the navigation task from specific questions in the second questionnaire. Each participant completed phase 2 within two weeks of completing phase 1.

2.3.1 Phase 1

Participants were met on the ground floor of the Health Science building on the University of Saskatchewan campus. They were given a verbal overview of the procedure while being taken to the 3rd floor in the elevator. Participants gave their written informed consent (Appendix A) in a lounge area to the side of the elevator out of view of the path used for the navigation task. Participants were randomly placed in one of the four orders for path presentation based on their sex and the order that they signed up to be tested. The presentation orders are 1234, 1324, 4321, and 4231 (where each number indicates the respective path number).

Each participant was lead to the starting point by the researcher, indicated by a large X (or O for path 3) on the floor (see Figure 2.4 for path schematic). They were told to remember where the 'X' (or O) is located. Upon confirmation that they understood, they were lead to the predetermined decision point for the path. The participants were then told to ‘go to the X (or O).’ The decision the participant made either choosing to shortcut (follow a novel path) or to retrace the path back to the origin, was documented. Upon successfully returning to the X (or O) the next path was administered according to the presentation order assigned to that participant. The same procedure was followed for each path.

After completing the navigation tasks, the participant was returned to the lounge area to complete a questionnaire (see Appendix B). The questionnaire asked for the participant’s experience with the building and completion strategy information for the navigation tasks. The participant was then asked for confirmation of a time for completing phase 2 and was escorted back to the ground floor. Any participant who had questions was asked to remember their question until the end of phase 2, as to not bias the results.

2.3.2 Phase 2

Participants were tested in groups of 1-5 in a quiet room. Informed consent was given again via a written form (Appendix C) while a verbal description of the procedure was provided. The three spatial abilities tests were presented in different orders throughout testing sessions in order to be able to establish any order effects. Because this phase was completed in groups and all of the tasks were timed, participants were urged to follow at the pace of the group and not to go ahead with the next task until told to do so by the researcher.

The MRT was administered as per the instructions outlined by Vandenberg and Kuse (1978). The instruction pages were read aloud while the participant followed along. The instructions allow the participant to familiarize themselves with the item sets and how they should respond. They were encouraged to ask any questions before the timing started. After the researcher finished the instructions, the participants were asked if they had any final questions. A time limit of four (4) minutes was given for them to complete the two pages of the test.

The PFT was given following the instructions laid out by Ekstrom et al. (1976). The instructions were read aloud as the participant read along. In the instructions involved a detailed explanation of the processes involved in solving the task. Questions were encouraged to be voiced before the time started for the test. A time limit of three (3) minutes was given to complete one page of the test.

The OLMT followed the procedure described in Silverman and Eals (1992). The participants were shown the stimulus array for 1 minute. They then returned the array upside down to the researcher. They were then given the response array where they indicated for each object if it had moved or remained in the same place. No time limit was given for responding and the participants were encouraged to guess if they could not remember.

The final part of phase 2 consisted of the demographic and completion strategy questionnaire (Appendix D). In filling out this questionnaire, participants were encouraged to be as explicit and descriptive as possible in their responses. Participants were debriefed with a verbal explanation and any questions the participant had was answered as well as received a debriefing form (Appendix E) for he/she to keep containing contact information for any questions and/or concerns they may have after they left.

CHAPTER 3
RESULTS

One male participant was excluded from all analyses because his SOD self rating score was more than 3 standard deviations from the mean. As well, one female did not complete the question regarding SOD or learning preference and was subsequently removed from analyses involving both of these specific questions. As well, the term 'efficient' refers to the shortest metric distance decision for the navigation tasks for this study.

3.1 Main Effects

3.1.1 Navigation Task

The navigation task consisted of four discrete path decisions (one for each path). Participants either returned along the path they were lead or chose a novel path (shortcutted) in order to return to the origin. Of the 66 participants included in the analysis, thirteen (13) shortcutted on all 4 paths and eight (8) returned on all 4 paths. This may indicate a tendency for repetition of a decision, since by the time the participants reached the last decision they had already experienced the same environment three times and possibly just continued the pattern to complete the last decision.

The combination of four decisions that would be the most efficient (shortest actual distance) would be to return on path 1 and shortcut on 2, 3, and 4. This single combination of decisions was exhibited by the largest number of participants (n = 25) and in this analysis is the 'efficient' group of participants. Another popular combination was to return on paths 1 and 2 and shortcut on paths 3 and 4, where eight (8) participants followed this pattern. This combination may be due to participants relying on the number of corners they have traversed rather than relying on metric distance judgments in order to determine how to get to the origin most efficiently. Perhaps these participants were using the number of turns to evaluate distance or efficiency of their decision by returning after having experienced two or less turns and shortcutting after 3 or more turns. (This would rely on them knowing that the experimental environment was a rectangular shape, a fact that could be evident following the first trial or from pre-trial observation.)

Several other combinations of responses occurred. Five participants chose to return on paths 1 and 3, and shortcut on paths 2 and 4. This combination was somewhat surprising but is unlikely to be attributed to path presentation effects, as there are three different path orders represented in this group. The rest of the participants chose different patterns (two returned on path 3 and shortcutted on 1, 2, and 4; one returned on path 4 and shortcutted on 1, 2, and 3; one returned on paths 2 and 4 but shortcutted on 1 and 3; one returned on 1 and 4 while shortcutting on paths 2 and 3; one returned on paths 1, 2, and 3 and shortcutted on path 4; and one returned on path 2 and shortcutted on 1, 3, and 4).

Participants were separated into two categories (efficient vs. non-efficient) in order to examine whether there was a main effect of sex for correct decision making. Participants who made the most efficient decision for all 4 paths were placed in the 'efficient' group, with all other participants in the non-efficient group. A Chi Square test was performed in order to evaluate if a main effect of sex was present for the efficient vs. non-efficient participants as well as shortcutters or returnees for each path. Overall, there were a significantly higher percent of males in the study who chose all efficient decisions (53.1%) as compared to the females making the same efficient decisions (23.5%). The values show that significantly more males (87.5%) shortcutted than females (58.8%) on path 2. This may be an indication of males being more adept at gauging actual metric distance than women. Paths 1, 3, and 4 all demonstrated non-significant values (see Table 3.1).

Table 3.1 Pearson chi-squared calculations for percentage of participant's decisions for each path by sex.

		Sex (%)		Pearson Chi-Sq (χ^2)	Significance (*p*)
		Male	Female		
Overall	Efficient	53.12	23.53	6.136	0.013
	Non-Efficient	46.88	76.47		
Path 1	Shortcut	75.00	70.59	0.162	0.688
	Return	25.00	29.41		
Path 2	Shortcut	12.50	41.18	5.250	0.022
	Return	87.50	58.82		
Path 3	Shortcut	18.75	29.41	1.020	0.312
	Return	81.25	70.59		
Path 4	Shortcut	9.38	23.53	2.378	0.123
	Return	90.62	76.47		

3.1.2 Spatial Abilities Tests and Sense of Direction

For the purpose of this analysis, SOD is included as a spatial abilities test for the remainder of the results and discussion. There were no order effects found among the spatial abilities tests.

3.1.2.1 Sex Differences

All spatial abilities tests were analyzed for main effect of sex. Figure 3.2 provides means and standard deviations for all tests. Males self-rated their sense of direction higher than females (F (1, 63) = 8.957, p = .004) which replicates previous findings (Hegarty et al., 2006). Males scored higher on MRT than females (F (1, 64) = 10.765, p

= .002). This finding supports previous research involving the MRT (Resnick, 1993; O'Laughlin & Brubaker, 1998; Malinowski, 2001; Bell & Saucier, 2004). Males did not prove to be significantly different than females on the PFT (*F* (1, 64) = 2.659, *p* = .108). Some previous research has shown to have males scoring higher than females on this test (Gouchie & Kimura, 1991; Peters et al., 1995) but some others have shown no difference (Watson & Kimura, 1991). This non-significant finding may be attributed to only half of the test being administered and/or the relatively low number of participants which would result in a reduction in statistical power. Further testing of this procedure needs to be done to evaluate the validity of using only 10 questions of this test.

Males and females scored almost exactly the same on the OLMT (*F* (1, 64) = .320, *p* = .573). This finding does not support the original findings of Silverman and Eals (1992, 1994) on this test. Some researchers have demonstrated support for this test, reporting a significant sex difference (James & Kimura, 1997), where others have reported no sex difference in OLMT scores (Dabbs et al., 1997).

Table 3.2 Mean Scores and main effect analysis for all tested spatial abilities tests.

		N	Mean	Standard Deviation	F	Significance (*p*)
SOD	Male	32	79.81	15.385	8.957	0.004
	Female	33*	67.18	18.450		
MRT	Male	32	15.14	4.020	10.765	0.002
	Female	34	11.86	4.096		
OLMT	Male	32	21.47	2.747	0.320	0.573
	Female	34	21.88	3.160		
PFT	Male	32	6.78	2.305	2.659	0.108
	Female	34	5.79	2.626		

* One female did not answer the question regarding SOD.

3.1.2.2 Correlations among Spatial Ability Tests

All of the spatial abilities tests were analyzed using Pearson correlations (see Table 3.3). SOD was found to be positively correlated with the MRT (r (65) = .361, p = .003) and the PFT (r (65) = .373, p = .002). MRT was also found to be positively correlated with the PFT (r (66) = .425, p < .001). These variables may all be correlated because of the similar completion strategies of the tests and are connected to the confidence of individuals to find their way in the world. Within this framework, the OLMT would logically be thought to be negatively correlated to the others in that high scores on any of the others should mean a low score in the OLMT. This was not the case in this sample, as the OLMT was found to be not correlated with any of the other tests. The finding of non-significance is most likely related directly to the lack of a sex difference in this study for the OLMT.

Table 3.3 Correlations between tested spatial ability tests.

		MRT	OLMT	PFT
SOD	Pearson Correlation	.361**	0.177	.373**
	Significance (*p*)	0.003	0.158	0.002
	N	65	65	65
MRT	Pearson Correlation		0.145	.425**
	Significance (*p*)		0.244	0.000
	N	-	66	66
OLMT	Pearson Correlation			0.212
	Significance (*p*)			0.088
	N	-	-	66

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

3.1.3 Preferred Learning Strategies

One question on the phase 2 questionnaire is a question concerned with self-expressed learning preference when experiencing a new environment (see Appendix D, Question 10). There were a few participants who did not answer the question or answered with more than one choice and were subsequently removed from the analysis (n = 4). One note on this analysis is that there was only one participant that answered ‘Use a Description’ as their preferred learning strategy. Because of this, the answer choice was omitted from the analysis. The inclusion of this question in the survey was to evaluate the relationship (if any) among a preference for a specific learning strategy, spatial abilities, and overt navigation behaviour.

In general, 61 participants chose one of the three learning preferences. Over half (n = 34) of the participants indicated that they preferred to ‘explore’ a new environment on their own. The remaining participants were split between a preference for being ‘shown around’ by another person (n = 12) and relying on a ‘map’ to find their way around (n = 15). These numbers will drive the following analysis of spatial ability and the later analysis of shortcutting (path choice) behaviour for all analyses regarding learning preference.

In order to evaluate the actual efficiency behaviour in each of the preferred learning strategies, a chi square analysis was conducted between the efficient vs. non-efficient groups and the three preferred learning strategies. Significantly more efficient individuals chose the ‘explore’ learning preference (75%) over the other two (12.5% each) and there was a statistically even distribution between all of the learning preferences for the non-efficient group (see Table 3.4).

Table 3.4 Pearson chi-squared calculation for percentage of participant's preferred learning strategy for by efficiency.

Learning Preference	Efficiency (%)		Pearson Chi-Sq (χ^2)	Significance (p)
	Efficient	Non-Efficient		
Map	12.50	32.43	6.021	0.049
Shown Around	12.50	24.32		
Explore	75.00	43.24		

A one way analysis of variance (ANOVA) was conducted on each spatial ability test comparing the means between each group of preferred learning strategy. A main effect was found for SOD (F (2, 58) = 5.740, p = .005; see Figure 3.1) indicating that participants who expressed the preference for being 'shown around' also reported significantly lower SOD than participants who prefer either 'map' or 'exploratory' environmental learning. The participants did not show a difference in the scores for the MRT between the categories (F (2, 58) = 2.463, p = .094; see Figure 3.2). With the relatively low numbers in each category, this non-significant result may be attributed to low power in the test. Both OLMT and PFT returned non-significant F values as well. These results are consistent with the suggestion that the SOD self rating is more closely related to environmental scale spatial abilities like navigation than to smaller scale spatial abilities such as MRT, OLMT, or PFT (Bryant, 1982; Sholl, 1988; Hegarty et al., 2002).

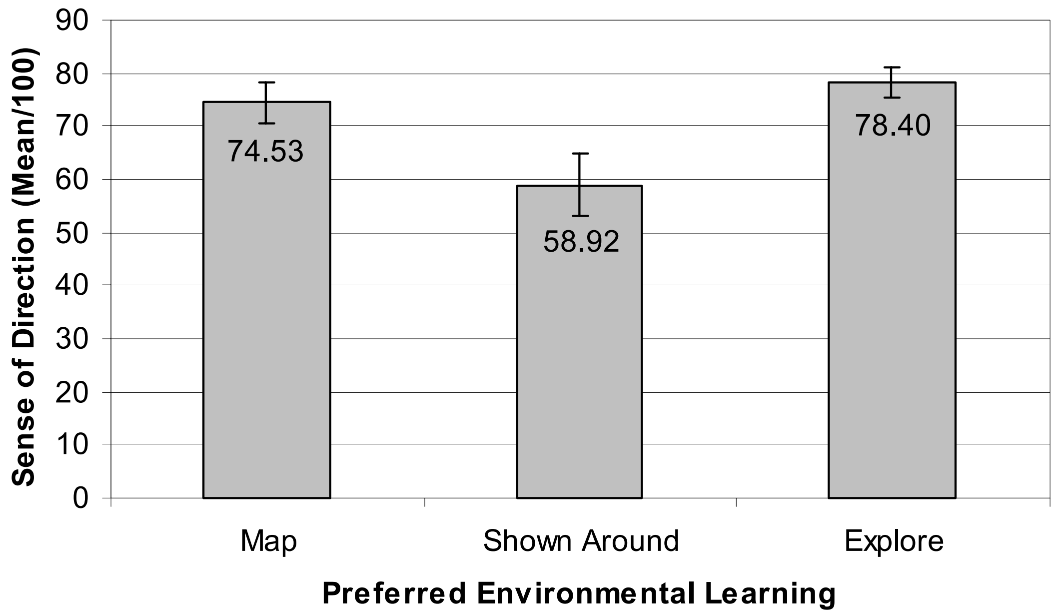

Figure 3.1 SOD scores for preferred environmental learning strategies. (Map: n = 15; Shown Around: n = 12; Explore: n = 34)

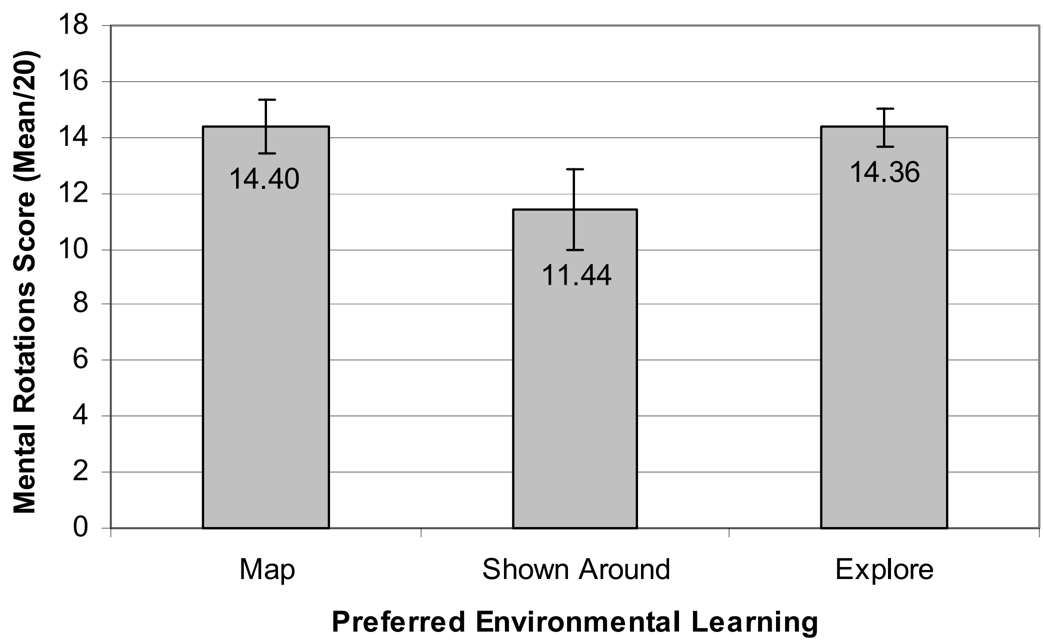

Figure 3.2 MRT scores for preferred environmental learning strategies. (Map: n = 15; Shown Around: n = 12; Explore: n = 34)

3.2 Path Choice and Spatial Abilities

In order to compare the spatial abilities tests to path decisions each path (or overall efficiency) was analyzed separately using one-way ANOVA where the between subject variable was the decision participants made to either shortcut or return.

3.2.1 Overall Choice Pattern

In order to get a clear picture of the general interactions, participants were grouped by their overall performance. Group one consists of all individuals that chose the most efficient way for all 4 paths (i.e. return on path 1, and shortcut on 2, 3, and 4). There were 25 people in this 'Efficient' group (male = 17; female = 8). The other group encompassed all other path decision patterns. This 'Non-Efficient' group consisted of 41 participants (male = 15; female = 26).

There was a main effect found for MRT between the efficient group and the non-efficient group (see Figure 3.3). Efficient participants (n = 24; 15.01 ± 4.378) scored higher than non-efficient participants (n = 41; 12.50 ± 4.105) for MRT scores (F (1, 64) = 5.521, p = .022). This may demonstrate that a higher aptitude with mental transformations aids in correctly maintaining an origin point when in novel environments. All other spatial abilities tests showed non-significant results.

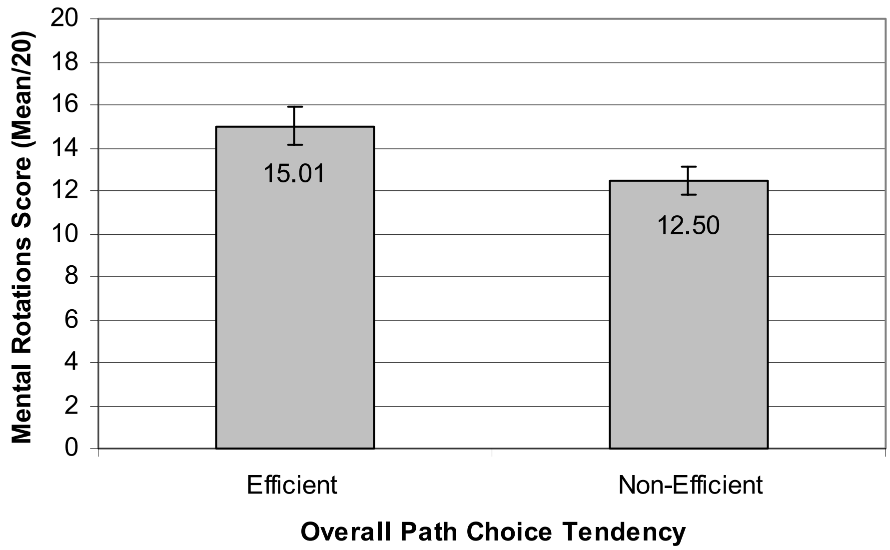

Figure 3.3 MRT scores for efficient vs. non-efficient overall path choice tendency.

3.2.2 Path 1

All spatial abilities tests showed non-significant differences in mean scores between the shortcutters and returnees on path 1.

3.2.3 Path 2

There was a main effect for MRT and PFT between shortcutters and returnees for path 2. Shortcutters (14.3032 ± 4.03885) scored higher than returnees (11.3421 ± 4.49089) on the MRT (F (1, 64) = 6.819, p = .011). Shortcutters (n = 46; 6.766 ± 2.32625) scored higher than returnees (n = 19; 5.0395 ± 2.57561) on PFT (F (1, 64) = 7.008, p = .010). These results may indicate that when an individual is better able to mentally manipulate the environment and maintain the series of steps in their head, they are more likely to choose a novel path (if they think it will be useful). SOD rating and the OLMT indicate no significant results, although the mean difference for SOD approaches significance (F (1, 63) = 3.89, p = .053). Considering the relatively low number of participants in this study, a significant result may be possible with a higher number of individuals tested to increase the power for this test.

3.2.4 Path 3

All spatial abilities tests show non-significant results regarding the means between shortcutters and returnees on path 3.

3.2.5 Path 4

All spatial abilities tests show non-significant differences between means of shortcutters and returnees on path 4. A comparison of the SOD means for shortcutters and returnees for all 4 paths is shown in Figure 3.4.

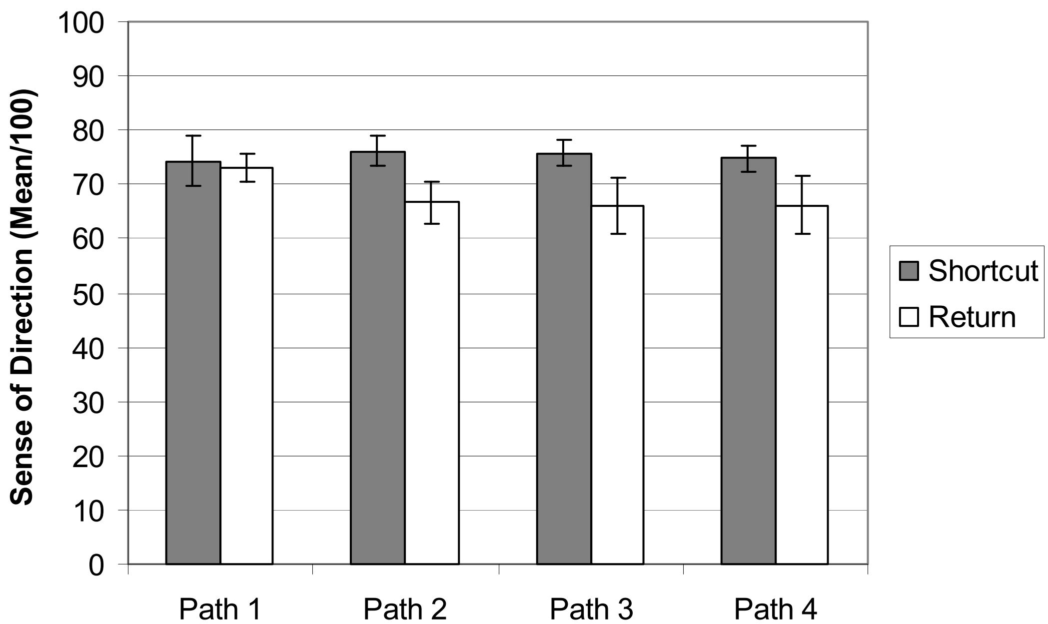

Figure 3.4 Sense of Direction means by Shortcutters and Returnees on each path.

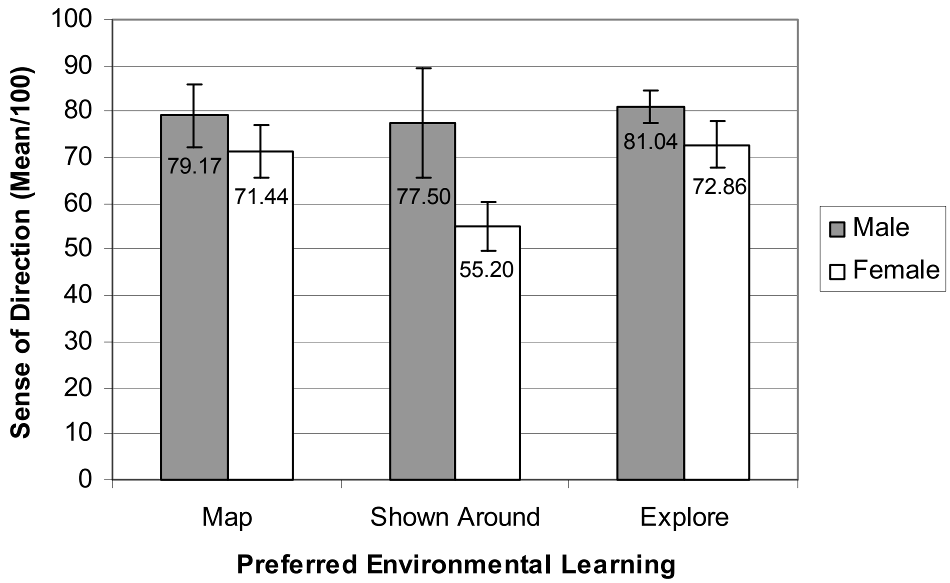

Figure 3.5 SOD scores for males and females for preferred environmental learning strategies. (Map: Males = 6, Females = 9; Shown Around: Males = 2, Females = 10; Explore: Males = 23, Females = 11)

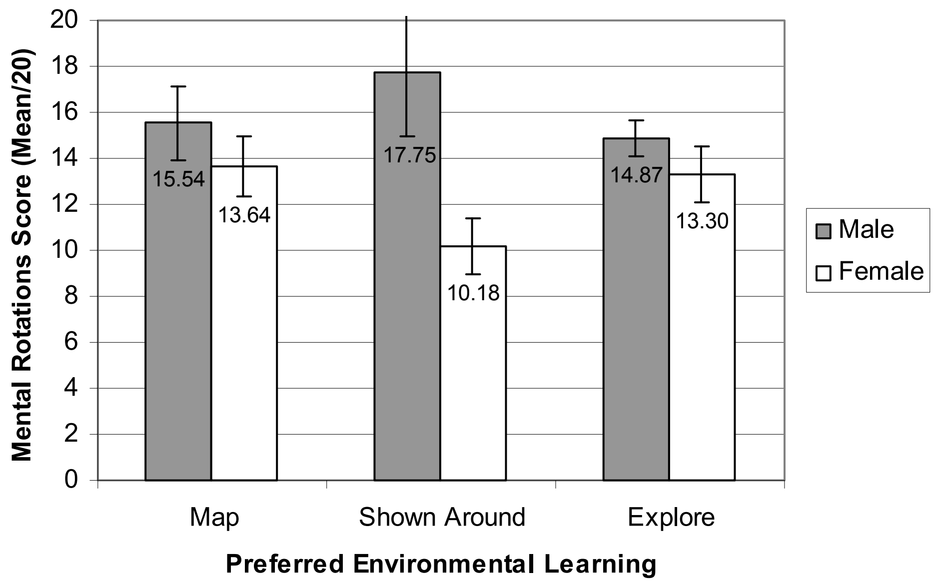

Figure 3.6 MRT scores for males and females for preferred environmental learning strategies. (Map: Males = 6, Females = 9; Shown Around: Males = 2, Females = 10; Explore: Males = 23, Females = 11)

3.3 Path Choice and Learning Preference

Given that there is a main effect of sex for some of the spatial abilities tests; it was proposed that there may be a sex difference in preference of learning strategy. A separate multivariate analysis of variance (MANOVA) was run with the spatial abilities as within-subject variables and *Sex* and *Learning Preference* as between subject variables. Between subject effects of *Sex* x *Learning Preference* were significant for both SOD (F (5, 55) = 3.484, p = .008; See Figure 3.5) and MRT (F (5, 55) = 2.717, p = .029; See Figure 3.6). Considering the number of males (n = 2) that indicated they preferred to be 'shown around,' the females (n = 10) that chose this preference may be driving the main differences found in this data as the males in the 'shown around' group are scoring fairly close to the male averages in both the 'map' and 'explore' preferences for the SOD ratings. Similarly the males scored well above the other groups for the MRT scores, where the females scored significantly lower than the females in the other two groups.

Learning preferences were compared to path choice across all four paths (see Table 3.5 and Figure 3.7). The nature of the paths leave the participant with a most efficient decision choice for all four paths and one would expect a proportion of participants to make that most efficient decision. Of the preferred learning strategies, a greater percentage of participants did in fact chose the more efficient return for path 1 and shortcut on paths 2, 3, and 4. This matches the general tendencies expected for each path. One interesting note is the participants who indicated a preference to 'explore' new environments had higher percentages of participants choosing the most efficient decisions. This may be an indication that these participants are more experienced in novel environment decision making and could possibly be more adept at making appropriate distance and turn judgments. This may also indicate being less afraid of making a mistake as they would have been more likely to have made similar decisions in previous experiences.

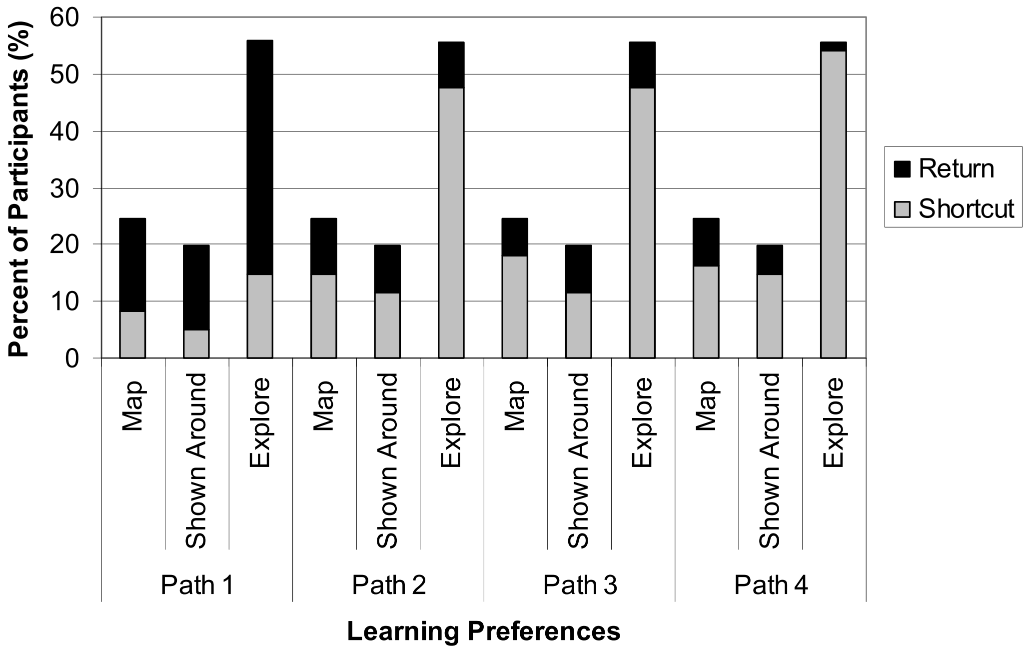

Figure 3.7 Percentage of Participants for each Learning Preference and Path Choice for each Path.

Table 3.5 Learning Preferences by Path Decision for each Navigation Path.

		Percent of Participants (%)	
		Shortcut	Return
Path 1	Map	8.2	16.4
	Shown Around	4.9	14.8
	Explore	14.8	41.0
Path 2	Map	14.8	9.8
	Shown Around	11.5	8.2
	Explore	47.5	8.2
Path 3	Map	18.0	6.6
	Shown Around	11.5	8.2
	Explore	47.5	8.2
Path 4	Map	16.4	8.2
	Shown Around	14.8	4.9
	Explore	54.1	1.6

3.4 Path Choice by Sex Interactions

In order to get a general picture, the efficient vs. non-efficient groups were examined in a MANOVA using each spatial ability test as within subject variables and between subject variables of *Sex* and *Efficiency*. The *Sex* x *Efficiency* interaction was significant for both the SOD and MRT scores. Efficient male participants' SOD scores (80.24 ± 4.2) were close to their non-efficient counterparts (79.33 ± 4.5) whereas the efficient female group (69.29 ± 6.5) is lower and drops in the non-efficient female group (66.61 ± 3.4; F (3, 61) = 2.949, p = .040; see Figure 3.8). A similar pattern emerges for the MRT scores (see Figure 3.9). Efficient male participants (15.81 ± .99) scored higher on the MRT than the non-efficient males (14.38 ± 1.05) and the efficient females (13.43 ± 1.54) scored higher than the non-efficient females (11.41 ± .80) where the non-efficient males and females are significantly different (F (3, 61) = 4.314, p = .008).

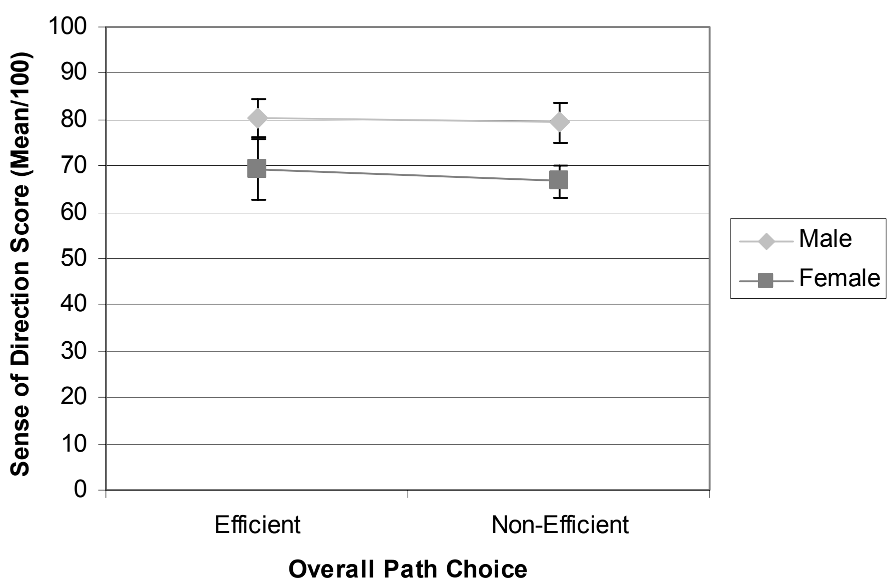

Figure 3.8 SOD scores by sex and overall path choice efficiency.

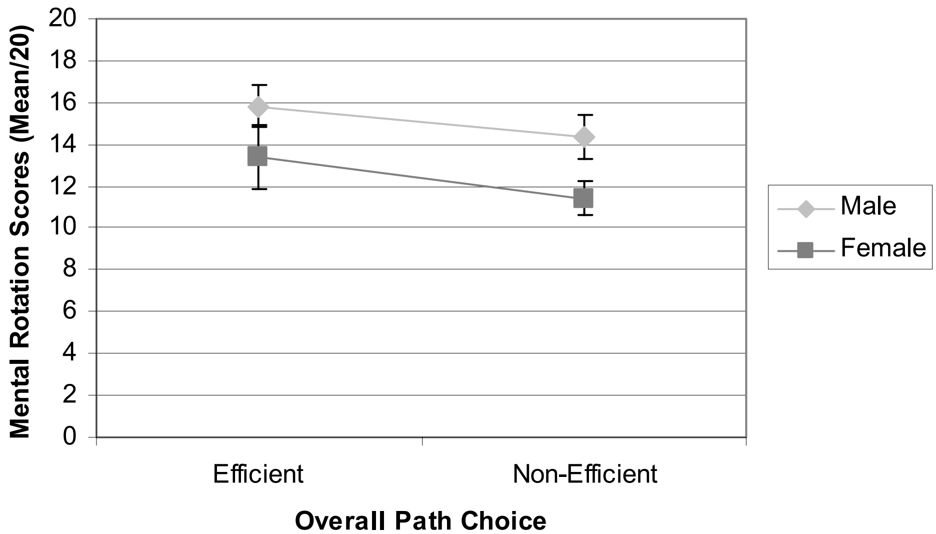

Figure 3.9 MRT scores by sex and overall path choice efficiency.

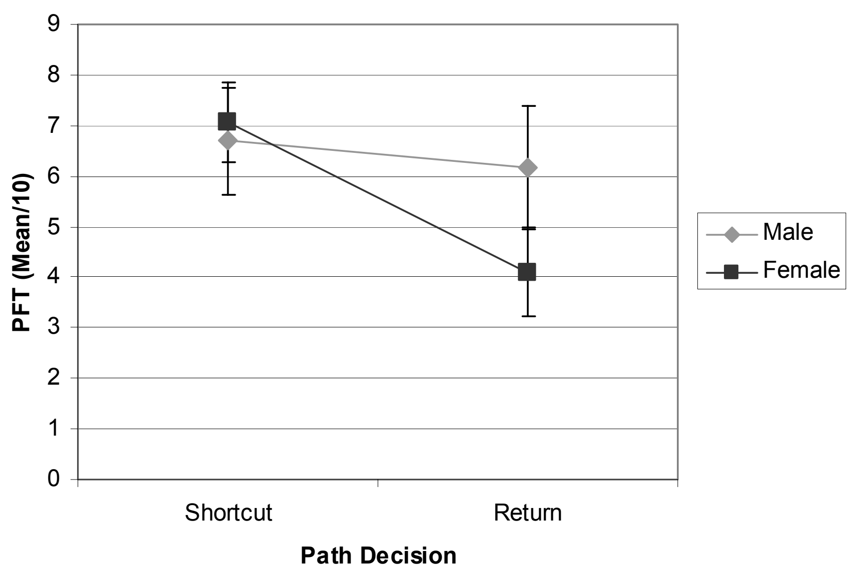

Figure 3.10 Paper Folding Scores by Sex for Shortcutters and Returnees for Path 2.

A separate MANOVA was completed for each path using each spatial ability test as within subject variables and between subject variables of *Sex* and *Path Choice*. All comparisons returned non-significant results, although there is one interaction that bears noting. The *Sex x Path Choice* interaction approaches significance on path 2 (F (2, 55) = 3.125, p = .052) for the PFT and is shown in Figure 3.8.

3.5 Path Presentation Order Effects

The navigation task was administered in four orders. The possibility of order effects required analysis of path decisions to see if they were influenced by the order of presentation. With the four path presentation orders, two orders were realized as possible contributing factors: path 1 versus path 4 presented first, and path 2 versus path 3 presented first.

3.5.1 Path 1 vs. 4

A separate MANOVA was conducted for each of the spatial ability tests as within subject variables and *Decision* and *Path* as between subject variables. All interactions were non-significant (see Table 3.6).

3.5.2 Path 2 vs. 3

As for the opposite Path orders, a separate MANOVA was run with the spatial abilities tests as within subject variables and *Decision* and *Path* as between subject variables. All interactions were non-significant (see Table 3.7).

Table 3.6 Significance and F values for Path 1 vs. 4 interactions.

Path	Test	F	Significance (*p*)
Path 1	SOD	2.307	0.109
	MRT	0.746	0.479
	OLMT	1.572	0.217
	PFT	0.100	0.905
Path 2	SOD	0.379	0.686
	MRT	1.957	0.151
	OLMT	0.471	0.627
	PFT	2.507	0.091
Path 3	SOD	0.319	0.728
	MRT	0.418	0.661
	OLMT	0.583	0.562
	PFT	0.195	0.823
Path 4	SOD	1.007	0.372
	MRT	1.225	0.302
	OLMT	1.969	0.149
	PFT	0.457	0.635

Table 3.7 Significance and F values for Path 2 vs. 3 interactions.

Path	Test	F	Significance (*p*)
Path 1	SOD	2.759	0.072
	MRT	0.223	0.801
	OLMT	2.304	0.109
	PFT	1.505	0.231
Path 2	SOD	0.404	0.670
	MRT	2.422	0.098
	OLMT	0.550	0.580
	PFT	2.295	0.110
Path 3	SOD	0.320	0.728
	MRT	0.280	0.757
	OLMT	0.565	0.572
	PFT	1.667	0.198
Path 4	SOD	1.280	0.286
	MRT	0.273	0.762
	OLMT	0.996	0.376
	PFT	2.137	0.128

3.6 Summary

The prevalent results of this study involve the distinction between path 2 and path 3. The difference between these two paths is the number of turns. The number of turns then becomes a critical value in distinguishing ‘efficient’ navigators from ‘non-efficient’ navigators. Efficient navigators seem to be able, regardless of the number of turns, to maintain an accurate orientation to their origin as well as an accurate tally of metric distance traveled than non-efficient navigators. Efficient navigators are also better able to mentally manipulate and maintain complex figures and tend to be more confident in their own skill set to get around.

CHAPTER 4
DISCUSSION AND CONCLUSION

4.1 Introduction

The purpose of this experiment was to investigate the relationship among actual navigational shortcutting behaviour, specific spatial abilities tests (MRT, PFT, and OLMT), self-rated SOD and preferred learning strategies in a novel environment. There are several hypotheses that were tested in order to evaluate the extent of these relationships.

- Higher scores on MRT, PFT, and SOD and choosing the 'explore' learning preference will be more positively related to appropriate shortcutting regardless of their sex

The first hypothesis that was examined stated that participants who demonstrate higher scores on MRT, PFT, and SOD and prefer to learn new environments with an 'exploratory' method will be more likely to shortcut on any given path. This hypothesis was found to be partially supported. It was demonstrated that a higher likelihood of efficient decision making was found with higher scores in the MRT. It was also determined that there was a higher percentage of individuals choosing the most efficient paths that prefer the 'exploratory' learning preference compared to those choosing either a map or being shown around as their learning preference. Discrepancies are shown within the PFT and SOD, in that they do not indicate a higher incidence of efficiency.

- Given the similarity of solving strategies of MRT and PFT and the previously shown male advantage for these tests; males will be more likely to shortcut on any given path

The second hypothesis states that males are more likely to shortcut than females. Overall, a larger proportion of males (53.1%) were efficient than females (23.5%) in their path choices. When looking at each path separately, it was found that for path 2 87.5% of males shortcutted compared to only 58.8% of females shortcutted. The other three paths did not support this hypothesis. The distinction between path 2 and the other paths is interesting and will be discussed further in this chapter.

- OLMT performance will be negatively correlated to shortcutting and efficient navigation choice, higher scores on this test will be more likely to rely on available landmarks and retrace the path they were shown

This hypothesis states that higher scores on the OLMT will be more likely to return on the known path rather that shortcut. This was not supported in this study. The main sex difference usually found using this test was not duplicated here and may have been a contributing factor to the non-significant values on all subsequent analyses involving this test. There are several other explanations for this which will be discussed in depth in this chapter.

- Replication of all spatial ability test sex differences (MRT, PFT, OLMT, & SOD)

A final hypothesis was to replicate the standard sex differences found by each of the spatial abilities tests. This study replicates the findings for the MRT and the SOD sex differences. The PFT is non-significant, although it follows a similar trend to the published research. As stated in the previous hypothesis, the OLMT was not replicated. These are discussed further in the next sections.

4.2 High Scores on MRT, PFT, SOD, and Prefer 'Explore' will Shortcut

The premise of this hypothesis was that an individual deciding whether to try a novel path or return along a known path would involve similar cognitive processes to those utilized in both the MRT and the PFT. Participants may also be more confident in their own ability to find their way (SOD score) and may have the more adventurous 'exploratory' learning preference. MRT, PFT, and SOD tested as being significantly positively correlated to one another, which validates the use of similar scores on these tests in comparison to shortcutting behaviour.

Efficient participants (i.e. those choosing the shortest decision for each path) were shown to have higher scores on the MRT and an 'exploratory' learning preference. This indicates that participants who are able to maintain and manipulate complex patterns and prefer to learn novel environments in a more adventurous way choose the shortest metric distance solution path more often. These participants are able to maintain the correct metric distance traveled in relation to the overall route (Lawton, 1994; Ishikawa & Montello, 2006). It is possible that confidence in exploring novel environments provides increased ability in further novel navigation situations (Bryant, 1982; Linn & Peterson, 1985).

There are two components in this hypothesis that did not provide significant results. The PFT, although positively correlated with MRT, does not seem to be related to any ability to make efficient navigational decisions in this environment. The nature of the PFT is to reverse multiple steps to form the original shape. Intuitively this still should be useful in mentally maintaining, reversing, and predicting spatial patterns that are needed for efficient navigating. It is possible though that this navigation task was too simplistic to require a solving strategy involving multiple step retention and reversal (McGee, 1979). It is also possible that the reversal strategy of the PFT was confounded with the reversal strategy of the return decision. This would result in higher PFT scores loading on return decisions instead of the expected shortcut decision.

Self-rated SOD was also found to be different between the efficient and non-efficient groups. This comparison is curious as there may be other factors involved. While the overall test yielded no significant main effects, testing males against females in the efficient/non-efficient groups resulted in a significant difference where males scored higher than females and non-efficient females scored lower than their efficient counterparts. SOD has been compared to other spatial abilities tests (Hegarty et al., 2002; Hegarty et al., 2006) and navigation (Montello & Pick., 1993; Heth et al., 2002). Kozloski and Bryant (1977) suggested that their method of leading participants may have encouraged poor SOD participants to rely on the experimenter or be passive participants. They also suggest that forcing these poor SOD individuals to 'explore' may have improved their performance by forcing them to attend to their environment. In the current study participants were not prompted with what to attend to in the environment and some may have neglected to attend to the greater environment. It is then possible that some participants neglected to note their environment while being led along the path. This neglect would bias decisions towards the return choice. Distribution of the decisions would be then biased as well.

4.3 Males more likely to Shortcut

This hypothesis stated that males would be more likely to shortcut overall. This was supported when 53.1% of males made the most efficient decision for all of the paths compared to only 23.5% of females. This distinction was maintained in individual path analysis for only path 2 where 87.5% of males shortcutted and only 58.8% of females shortcutted. All other paths (1, 3, and 4) showed no significant sex difference.

Males seem to have a better sense of traversed metric distance from an origin and are able to utilize this information to make efficient navigational decisions. Lawton (1994) found that males use metric information to update their position in an orienting strategy. This is not to say that females do not have these specific skills (several females were efficient in their decision making in this environment), only that the majority may rely on alternative information and/or strategies to make decisions or that shortest metric distance is not their default decision strategy. Males and females have been noted to attend to different types of spatial information in novel environments (Holding & Holding, 1989; Galea & Kimura, 1993) which supports the difference in efficient navigational decisions.

Previous research has shown that males tend to score higher on MRT, PFT, and SOD (Kozlowski & Bryant, 1977; McGee, 1979; Bell & Saucier, 2004) and therefore should have a more efficient set of skills for navigating in novel environments, if the latter skills are related to the former. In order to make efficient decisions in this novel context, with few distinct objects or points to be used as landmarks, an individual that is able to monitor and maintain accurate metric distances, retain multiple steps and reverse them, and may have a bit more adventurous personality or maybe more experience in novel navigation situations would have an advantage in this task. Higher scores on the MRT and an ‘exploratory’ learning preference appear to be indicators of efficient navigational decision making.

4.4 High OLMT less likely to Shortcut

In this study, the OLMT failed to yield a significant main sex difference. This had the potential to influence subsequent comparisons made involving this test. Several previous studies have found a significant main effect. Research has suggested that there may be a negative correlation between scores on the OLMT and MRT (Silverman & Eals, 1992; Eals & Silverman, 1994). There are several possible reasons for this failure.

Silverman and Eals (1992), the originators of the OLMT, made the distinction between implicit and explicit memory in administering this task. The authors found that the difference was maintained only in using implicit memory whereas the difference disappeared when explicit memory was utilized (Silverman & Eals, 1992). The discussion at the beginning of the testing session may have been enough to cue the participants as to the nature of the test and therefore removing the implicit component. There is not enough information available in the current study to determine whether this is a critical factor and will need to be examined further to understand whether general introductions to the session influence implicit versus explicit nature of the task for the participants.

Another possible consideration is that, due to low total participant numbers, all individuals were left in the analysis even if they had previous experience in any of the spatial abilities tests. Out of a total of 66 participants, 12 indicated that they had some experience with at least one of the tests. If these 12 were taken out of the analysis it would have left not enough participants in each of the 4 path orders for proper analysis. Ideally, these participants would have been taken out and replaced by new participants with no previous experience, but due to time and total number constraints on testing these were not able to be redone. This will need to be addressed in any subsequent studies.

4.5 Replication of Spatial Abilities Tests

Replication was confirmed in both the MRT and SOD tasks. This follows previous research using these tests (Vandenberg & Kuse, 1978; Linn & Peterson, 1985; Geary, Gilger, & Elliot-Miller, 1992; Galea & Kimura, 1993; Hegarty et al., 2006). The MRT showed significantly higher scores for males as compared to females. Even though this study administered only half of the original test (MRT), as utilized in previous research (Gouchie & Kimura, 1991; Saucier, McCreary et al., 2002), this difference was maintained. This demonstrates the strength of the sex difference found with this test. The SOD scores also indicated a significant sex difference.

Research using the PFT shows a male advantage for this task (McGee, 1979). The present study follows with this trend. There have been studies that did not find a significant difference when using both sections yet similar sample size as the present study (Watson & Kimura, 1991). One possibility for this test not providing statistical significance is that only half the test was given; this was due to time constraints during the testing phase. Although other studies have used half of the test (Gouchie & Kimura, 1991), they also reported confirming trends instead of significant differences. Another explanation could be that the participants who had previous experience with any of these tests remained in the analysis due to relatively low participant numbers (see section 4.4). Linn and Petersen (1985) have stated that spatial visualization tests (involving both visual and non-visual strategies) are equally difficult for both males and females which may help explain the inconsistency among studies using this test.

The OLMT fails to show any sex difference in scores. This test has shown stable significant sex difference in many previous studies (Silverman & Eals, 1992; Eals & Silverman, 1994), on the other hand some studies have not found a significant sex difference for this test (Eals & Silverman, 1994; James & Kimura, 1997). There has been continued debate on the applicability of this test, what exactly it is measuring, and what solving strategy gives females an advantage.

There is a strong correlation between all of the spatial ability tests, except OLMT. It is not surprising to see a significant relationship between MRT and PFT as they both favour males and have comparable mental manipulation requirements and have been significantly correlated previously (Blajenkova et al., 2006). What is interesting is that SOD is highly correlated to both MRT and PFT. Previous research has found weak, if any, relation between MRT and other psychometric spatial abilities and measures of SOD (Bryant, 1982; Sholl, 1988; Hegarty et al., 2002). On the other hand there has been a recent study that has found a significant relationship between factors involving SOD and spatial ability (including MRT) (Hegarty et al., 2006). The divergence of these studies may have to do with the different ways that SOD was measured. Some have used single question scalar responses (Sholl, 1988; Montello & Pick., 1993; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000) where others have used multi-item scales (Bryant, 1982; Vandenberg et al., 1985; Lorenz & Neisser, 1986; Bryant, 1991). This leaves the question of which method is the most useful in comparison to navigation. It seems that both methods may have pros and cons associated with them when trying to match mental processes or strategies in navigation and care should be taken when choosing one over the other for a study.

One would expect the opposite relationship with the OLMT (female advantage) to yield a negative relationship between itself and the other tests as it has in previous studies (Silverman & Eals, 1992; Eals & Silverman, 1994). In this study there was no significant sex difference found regarding the OLMT, as well there was no correlation found among the OLMT and other spatial abilities tests. Further testing should be done in order to examine this relationship and the possible cuing from the other spatial tests. (See section 4.4 for explanations.)

4.6 Navigation

This navigation task was designed to be simple in order to control for as many environmental and confounding variables as possible. Participants had very little distinct visual information and therefore needed to focus more on the physical properties of the route (e.g. number of turns and which direction as well as metric distance traveled) to make their decisions.

A total of 37.9 percent (n = 25/66) of participants chose the most efficient path combination of returning on path 1 and shortcutting on paths 2, 3, and 4. This demonstrates that a majority of participants were capable of making accurate metric distance judgments in order to make the efficient decision. There were 17 males and 8 females within this group. Almost twice as many males chose the 'most efficient' path combination.

Path 2 stands out with regards to providing distinct decision patterns among participants. This path was longer than half of the total hallway distance with only two corners. Rather than a skill deficit in terms of correctly estimating elapsed metric distances the decision to return on path 2 might indicate a strategy that relied on the explicit cues of total number of corners passed as a ratio of total number of corners in the environment to evaluate their environmental decisions. In another study of wayfinding in a novel environment, routes with more turns were estimated as being longer than those with less turns (Jansen-Osmann & Wiedenbauer, 2004). The path complexity used here is relatively simplistic in comparison, with the total path being rectangular. The current study supports this suggestion with participants having more difficulty maintaining accurate metric distance traveled on path 2 unless they have high SOD, MRT and 'explore' tendencies.

MRT and PFT both yielded significant differences in scores between shortcutters and returnees on path 2. Shortcutters scored higher on both tests indicating a higher competence in situations where multiple steps and maintaining the whole environment in relational perspective. SOD also shows higher scores for shortcutters and is very close to being significant. It is likely that with a higher number of participants would settle this difference into being statistically significant.

4.7 Limitations of Research

The study has a few limitations from which there should be care taken in generalizing the conclusions. As in most studies, adjustments were made from an ideal template in order to make testing more available to participants and keep their time commitments reasonable yet maintain enough of the idea to be able to test the hypotheses.

There were a total of 67 participants tested for this study. One was rejected due to an answer to the SOD being more than three standard deviations from the mean. Another participant did not complete the question on SOD or learning preference and was subsequently not included in analyses involving those measures. This is a relatively low total number of participants for a study using MRT. This particular test is usually administered in mass testing sessions which yields hundreds of participants. This study does duplicate the significant difference found with the MRT since there tends to be a substantial difference.

With the relatively short time period that was imposed on the spatial abilities tests phase of this experiment, it was necessary to cut out half of both the PFT and the MRT. There is precedent for doing so with both tests. The MRT maintains the main sex difference (Saucier, McCreary et al., 2002; Bell & Saucier, 2004) whereas the PFT retains the basic trends without a significant difference (Gouchie & Kimura, 1991). This trend should be examined further to compare part 1 and part 2 of the test as well as increasing the number of participants in order to evaluate the validity of using only half the full test.

This study failed to duplicate previous research findings for OLMT. Several possible reasons for this were discussed in the earlier section regarding hypothesis three (see section 4.4). It is also possible that the sample of participants in this study just do not show any differences as found with some other studies (James & Kimura, 1997). The nature of this study as a whole is spatial in nature and may have cued a location based strategy for this test. The cuing may have detracted from the implicit nature of the test (Silverman & Eals, 1992) possibly making it a deliberate strategy which could have levelled out the scores.

4.8 Conclusions

This study has demonstrated that efficient navigators have distinct characteristics over non-efficient navigators. Efficient navigators have a higher proficiency with rotating complex objects in their head and are more likely to use an 'exploratory' method of novel environmental navigation. Males are most likely to be efficient navigators, with only a few females exhibiting these characteristics. This difference may highlight a distinction in skill sets between individuals and sexes that contribute to successful navigation strategies in this novel environment.

The nature of this environment was such that there were no reliably distinct landmarks available and subsequently focused solving strategies on metric distance and each participant's cognitive map of the traversed environment. Individuals with strong mental manipulation skills and an adventurous personality proved to be indicators of efficient navigational decision making. This distinct pattern of behaviour was observed with Path 2. This path required the individual to be able to accurately decipher the metric distance that had been covered as well as update their current position with reference to the origin. Metric distance is the most salient feature in making this decision as compared to the other paths with similar distance with more turns.

4.9 Directions for Future Research

There are several questions that are not answered in this study. There needs to be further analysis comparing the salient features of paths 2 and 3. This study makes the assertion that correct determination of metric distance is critical in making the correct navigational decision. With more specific data comparing metric distance with number of turns, it may be possible to draw a more specific conclusion.

The OLMT needs to be examined in more rigorous circumstances to evaluate the possibility of spatial location strategy cuing that may have occurred in this study. Although it is possible that this sample simply had no difference, priming cannot be ruled out as a factor from the available information. Spatial location strategies as well as general navigation strategies need to be analyzed for contribution to this phenomenon.

An additional analysis should be conducted to evaluate the validity of using only half of the PFT. The analyses conducted in this study showed that there are some significant results with half the test. For example, the PFT showed a significant difference between shortcutters and returnees for path 2. Unfortunately, there was no main sex difference found. This replication issue needs to be validated in order to make any direct conclusions using this test.

Some previous studies have indicated that anxiety concerning navigation has a correlation to other spatial abilities tests and navigation (Lawton, 1994; Lawton & Kallai, 2002). This may have had an influence in this study concerning the subjects that returned on all four paths. Some participants stated a tendency to know for sure that they would succeed in the task if they returned and an uncertainty with the novel choice. This factor surfaced during testing and past inclusion in this study but bears investigation.

CHAPTER 5
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APPENDIX A: CONSENT FORM – PHASE 1
Consent Form 1

You are invited to participate in a study entitled Sex Differences in Spatial Abilities and Navigation. Please read this form carefully, and feel free to ask any questions you might have.

Researcher(s): A. J. Goodall Department of Geography, Phone: 966-5675
Dr. S. Bell, Department of Geography, Phone: 966-5676

Purpose and Procedure: Research has demonstrated a difference in the spatial abilities and navigation execution of males and females. This study is an investigation of whether the previous findings can be extended to other areas of navigation. The participant will be asked to complete a navigation task, a few physical measurements (made on your hands), and a short questionnaire. The entire session should take less than a ½ hour.

Potential Risks: There are no known risks associated with the tasks or procedure.

Potential Benefits: This project should be valuable in expanding the understanding of the real-world applicability of the spatial abilities tests. The participant will be given the opportunity to learn about this area of Geographic research and also about the results of this study and their implications in the area. The participant will also receive one research credit for participation.

Confidentiality: The data will be coded and no personal information will be recorded parallel to these codes. The findings will be presented in a research paper, geographic conferences, and journal articles. Only group scores will be reported.

Right to Withdraw: *You may withdraw from the study for any reason, at any time, without penalty of any sort (and without loss of credit for the session, without loss of relevant entitlements, without affecting academic or employment status, without losing access to relevant services, etc.). If you withdraw from the study at any time, any data that you have contributed will be destroyed.*

Questions: *If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided above if you have questions at a later time. This study has been approved on ethical grounds by the University of Saskatchewan Behavioral Sciences Research Ethics Board on February 23, 2004. Any questions regarding your rights as a participant may be addressed to that* *committee through the Office of Research Services (966-2084). Out of town participants may call collect.*

Consent to Participate: *I have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study and described above, understanding that I may withdraw this consent at any time. A copy of this consent form has been given to me for my records.*

__________________________ ________________________________

Signature of Participant

____

Signature of Researcher

APPENDIX B: QUESTIONNAIRE PHASE 1

<u>Questionnaire - 1</u>

1. How well do you know this building and/or floor?

1	2	3	4	5
Not at all				Very well

2. When asked to go to the X, did you consider not following the path on which you were led?

3. What strategy(s) did you use to solve this navigational problem?

APPENDIX C: CONSENT FORM – PHASE 2

Consent Form 2

You are invited to participate in a study entitled Sex Differences in Spatial Abilities and Navigation. Please read this form carefully, and feel free to ask any questions you might have.

Researcher(s): A. J. Goodall Department of Geography, Phone: 966-5675
Dr. S. Bell, Department of Geography, Phone: 966-5676

Purpose and Procedure: Research has demonstrated a difference in the spatial abilities and navigation execution of males and females. This study is an investigation of whether the previous findings can be extended to other areas of navigation. The participant will be asked to complete three spatial abilities tasks, and a short questionnaire. The entire session should take less than a ½ hour.

Potential Risks: There are no known risks associated with the tasks or procedure.

Potential Benefits: This project should be valuable in expanding the understanding of the real-world applicability of the spatial abilities tests. The participant will be given the opportunity to learn about this area of Geographic research and also about the results of this study and their implications in the area. The participant will also receive one research credit for participation.

Confidentiality: The data will be coded and no personal information will be recorded parallel to these codes. The findings will be presented in a research paper, geographic conferences, and journal articles. Only group scores will be reported.

Right to Withdraw: *You may withdraw from the study for any reason, at any time, without penalty of any sort (and without loss of credit for the session, without loss of relevant entitlements, without affecting academic or employment status, without losing access to relevant services, etc.). If you withdraw from the study at any time, any data that you have contributed will be destroyed.*

Questions: *If you have any questions concerning the study, please feel free to ask at any point; you are also free to contact the researchers at the numbers provided above if you have questions at a later time. This study has been approved on ethical grounds by the University of Saskatchewan Behavioral Sciences Research Ethics Board on February 23, 2004. Any questions regarding your rights as a participant may be addressed to that committee through the Office of Research Services (966-2084). Out of town participants may call collect.*

Consent to Participate: *I have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study and described above, understanding that I may withdraw this consent at any time. A copy of this consent form has been given to me for my records.*

___________________________ __________________________________

Signature of Participant

____

Signature of Researcher

APPENDIX D: QUESTIONNAIRE PHASE 2

Questionnaire – 2

1. Age? ______ Sex? ______

2. What hand do you write with? Right Left

3. What is your dominant/first language? ______________

4. What year of University are you in? _______ Major? ________________

5. Have you ever injured your hands/fingers? Yes No.
   If yes, briefly explain injury

6. Have you ever seen or completed any of these tasks before? Yes No
   If yes, which?

4. Do you think you know the purpose of this experiment? Yes No
   If yes, explain.

5. How easy did you find the mental rotations task?

1	2	3	4	5
Hard				Easy

6. What strategy(s) did you use to solve the mental rotations task?

7. What strategy(s) did you use to solve the memory task?

8. What strategy(s) did you use to solve the paper folding task?

9. Rate your sense of direction on a scale from 0 to 100 (0 being very poor, 100 being excellent).

10. How do you prefer to learn a new building?

    a. Use a map.

    b. Have someone show you around.

    c. Explore on your own.

    d. Get someone to describe the building to you.

APPENDIX E: DEBRIEFING FORM

Sex Differences in Spatial Abilities and Navigation

Thank you for participating in this study! In this study we were interested in how and why males and females are different in the execution of spatial abilities tasks and navigation tasks. For example, men are better at learning mazes and reading maps, whereas females have been shown to be better at remembering the location of objects in an array. This study was an attempt to analyze the factors used in these specific tasks in contributing to choices made in real-world navigation.

In recent studies there have been attempts to understand more clearly what the spatial abilities tasks are measuring and how they relate to natural behaviour. There have been comparisons done with sense of direction, wayfinding, navigational strategy, and type of environment. This study attempts to compare navigational behaviour with mental rotations (3-D cubed objects), object location memory (array of common objects), mental paper folding, and prenatal testosterone levels (finger measurements). All these tasks and measures may be contributing in different combinations to an individual's decisions in everyday navigation. Similar mental strategies have been reported in both the navigation and mental rotations. Both tasks require the ability to mentally rotate an object or environment to be able to complete the task. With this parallel strategy, there should be a strong relationship between scores on these tasks. Also, there should be an opposite relationship between navigation and object location memory. Object location memory requires being able to remember an object's location relative to other objects, which is a very different strategy than the one usually employed for mental rotations. Being able to remember the path that has been just traveled would be better associated with object location memory. Paper folding strategies are generally associated with complex mental manipulations where each step is required to be maintained in memory for successful completion. The ability to hold each turn or section of a path and maintain a clear picture of the current path may be a factor being used in choosing a novel path in navigation. Differing levels of testosterone have been shown to be a factor involved in the execution of spatial tasks and may have a positive influence on the choices made in navigation. By comparing the results of these tasks, we hope to be able to get a clearer picture of the factors and strategies certain individuals are using in real-world navigation.

Thanks again for participating in this study!

If you have any questions or concerns about this study, do not hesitate to contact me by phone or email (A. J. Goodall, phone: 966-5675; e-mail: ajg132@mail.usask.ca). Alternatively you can contact my supervisor (Dr. S. Bell, phone: 966-5676; e-mail: scott.bell@usask.ca), the Head of the Department of Geography at 966-5654, or the Office of Research Services at 966-4053.

APPENDIX F: ETHICS APPROVAL

UNIVERSITY OF SASKATCHEWAN
BEHAVIOURAL RESEARCH ETHICS BOARD
http://www.usask.ca/research/ethics.shtml

NAME: Scott Bell (Amy Goodall) Beh 04-20
Department of Geography

DATE: February 23, 2004

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the Application for Ethics Approval for your study "Sex Differences in Spatial Abilities and Navigation" (Beh 04-20).

1. Your study has been APPROVED.

2. Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Committee consideration in advance of its implementation.

3. The term of this approval is for 5 years.

4. This approval is valid for one year. A status report form must be submitted annually to the Chair of the Committee in order to extend approval. This certificate will automatically be invalidated if a status report form is not received within one month of the anniversary date. Please refer to the website for further instructions http://www.usask.ca/research/behavrsc.shtml

I wish you a successful and informative study.

Dr. David Hay, Acting Chair
University of Saskatchewan
Behavioural Research Ethics Board

DH/ck

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