A DYNAMIC TIME COURSE OF COGNITIVE MAP DISTORTION

by

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Distortion in cognitive maps has been examined by geographers and psychologists in order to understand the cognitive processes used when spatial knowledge is acquired from maps or images. This past research has lead to multiple, reasonable, descriptions of cognitive mapping. These studies have generally been based on cognitive maps formed at a single time point. This approach may ignore the dynamic nature of cognitive maps. How do cognitive maps change through time? How might an examination of temporal cognitive map distortion enhance our approach to cognitive mapping research? This thesis explores how we can observe the dynamic nature of cognitive maps through time and how the cognitive mapping process may vary depending on the map image and the location of a target. Results suggest a dual processing model of cognitive mapping dependent upon stimulus and task requirements. Two map retention tasks are presented which support the dual processing model.

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CHAPTER I

INTRODUCTION

Cognition refers to the ways in which knowledge is acquired, stored, manipulated, and used. Cognitive mapping is the process of cognition as it applies to spatial information (Downs and Stea 1977; Montello 2001). Research into cognitive mapping has often focused on the storage and use of cognitive maps. Inferences about the encoding process have been made based upon the cognitive map products of research participants. Cognitive map products are the result of research protocols which include tasks such as map sketching tasks, judgment tasks, and memory tasks. However, the cognitive map products used in most studies are temporally static, representing a moment or snapshot of an individual's cognitive mapping process (Downs and Stea 1977). Working from cognitive map products, researchers have built hypotheses about the encoding and storage of cognitive maps based upon qualities of those products (Kosslyn, Ball, and Reiser 1978; Stevens and Coupe 1978; Tversky 1981; Portugali and Omer 2003). The majority of research, with notable exceptions, has focused on the cognitive map product as an object representative of the participants' persistent cognitive map. However, using a singular representation ignores a cognitive map's fluid and temporally dynamic nature.

This temporally limited perspective on cognitive maps leads me to examine the time course of cognitive map distortion in this thesis. I ask the following questions:

- Is there an observable time course of cognitive map distortion?
- How do background and/or target affect cognitive map distortion?
- Do background, target, and time have mediating effects on each other?

I believe that an approach to cognitive map research which attends to cognitive map products as temporally dynamic and task specific will lead to a more nuanced and thorough understanding of cognitive mapping as a process ripe with difference between individuals in both strategy and outcome. In the current research I employ a spatial memory experiment to look at the process of cognitive mapping by observing change in cognitive map distortion through time. I focus on the roles that time, background, and target location play in the expression of cognitive map distortion.

A body of literature which includes spatial abilities, cognitive cartography, behavioral geography, mental imagery, and memory has influenced the direction of this study. The current research is developed on the premise that an examination of the initial stages of cognition will provide insight into how distortions of spatial knowledge occur. In this thesis I investigate the relationship between time and cognitive map distortion and how the change from top down to egocentric perspective affects individual performance in cognitive map tasks. To study this relationship I looked at the short term time course of spatial memory distortion for maps and images using theories from cognitive cartography, spatial cognition, and memory (Kulhavy and Stock 1996; Koriat, Goldsmith, and Pansky 2000; Werner and Diedrichsen 2002).

In the following chapter I describe the theories which make up the foundation of the current research. Some main areas are considered; cognitive mapping/cognitive maps, distortion, memory, and spatial abilities. The development of cognitive map and mapping theory is briefly outlined. I highlight the relationship of cognitive map theory to the development of encoding theories and how encoding theories have affected cognitive map research methods. Previous approaches in cognitive map distortion research are reviewed. Special attention is given to systematic distortions and resulting explanations. Spatial abilities related to orientation are discussed. The effects of Internal and external perspectives on environmental and cognitive spatial abilities may explain variation in performance on virtual and environmental spatial tasks. My research is influenced by the correspondence metaphor for memory, which means that I will consider the veridicality of participants' responses rather than categorize the responses (i.e. correct/incorrect). The correspondence metaphor is discussed in further detail, as is its relevance to the current research. The threads of theory from multiple disciplines described above are synthesized as a basis for this research project.

Following the background chapter, subsequent chapters detail the experimental methodology, analysis, and results. A computer administered test instrument was designed to measure the effects of time, background, and target location on a participant's ability to replicate a point location on a map like stimulus. Following the computer test, several subjects participated in a second session which replicates the first experiment's stimulus in an outdoor setting. The second session was conducted as a pilot study to explore the transition from an external to an internal point of view.

CHAPTER II

THE GEOGRAPHY AND PSYCHOLOGY OF COGNITIVE MAPS

The Cognitive Map

During a talk in 1948 Edward Tolman used the term “cognitive map” to describe the internal representations of space created by rats as they experience a maze (Tolman 1949). Tolman’s influential work has been the jumping off point for cognitive research in fields ranging from psychology to geography to computer science. Beyond just the term cognitive map, Tolman presented a theory of cognition which held that our behavior is not determined only by a stimulus response model, popular at the time, but that the stimulus we receive is regulated and integrated into our knowledge base, manipulated, and used to make behavioral decisions. He writes,

> “The stimuli, which are allowed in, are not connected by just simple one-to-one switches to the outgoing responses. Rather, the incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally release” (Tolman 1949).

Though Tolman was working with rats, it was his contention that we could learn much about human behavior and decision making through an understanding of rats’ behavior in mazes.

Only four years later the discipline of cartography began a persistent expansion of methods and theory sparked by Robinson's "The Look of Maps" (Robinson 1952). Robinson introduced an approach to cartographic research which looks scientifically at visual components of maps. In *The Look of Maps* Robinson looks at variables which he considers, "capable of evaluation from the visual point of view" (Robinson 1952). The three visual components listed by Robinson were lettering, structure, and color. These visual components could be researched using existing psychophysical experimental methodology. At the time, the stimulus-response model still dominated psychology, and work by psychologists like Tolman had not gained popular acceptance. Robinson presented to an American audience what European cartographers had been aware of for years, that research into cartographic techniques would provide scientific basis for the seemingly subjective choices made by the cartographer when designing and creating a map. Robinson argued that scientifically researched techniques would lead to more effective maps. This was a first step towards scientific cartographic theory.

These two works planted the seeds of various sub-disciplines in psychology and geography. Cognitive map design research, map psychology and spatial cognition, and behavioral geography can all find some roots in either Tolman or Robinson. Cognitive map-design research attempts to improve maps through research into mapping and map use (Montello 2002). Map psychology, a sub-field of spatial cognition, endeavors to understand how spatial knowledge is learned, stored, manipulated, and used. Map-psychology focuses on the use of map-like stimuli, while the broader category of spatial cognition research investigates cognition by humans, animals, and even machines

(Montello 2001). Behavioral geography focuses on what processes affect environmental behavior, wayfinding, and environmental learning. These are all factors related to spatial choices people make in the environment. Environmental spatial abilities and individual differences in spatial abilities such as map reading and navigation are focuses of current research in environmental and behavioral geography (Lobben 2007).

The lines between map psychology, map design research, and spatial cognition are not fixed or impenetrable. In recent decades there have been a number of attempts to synthesize and aggregate the developments in these sub-fields into umbrella theories of cognitive cartography (Golledge and Stimson 1987; MacEachren 1995; Lloyd 1997). These are instances where the lineages of research rooted in Tolman and Robinson meet to produce a unique geographical perspective on spatial cognition. My thesis research is at this intersection. This study observes the process of cognitive mapping through distortion in cognitive maps at both survey and egocentric perspectives. I employ the strategies of map-psychology, using a map based stimulus, to make conclusions about cognition and observe environmental behavior.

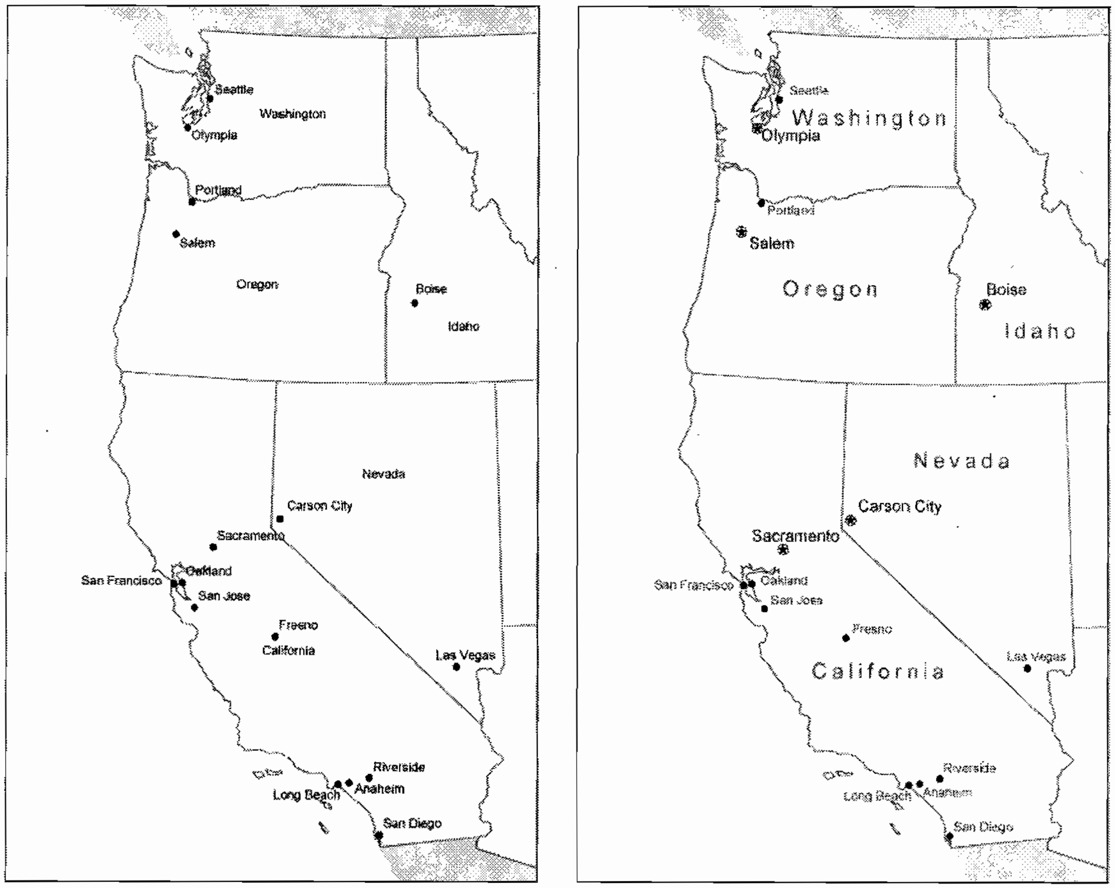
Cognitive Mapping

Studies of cognitive maps have been varied in process, goal, and outcome. They have ranged from approaching cognitive maps as a cartographic problem of projections and data collection (Tobler 1976) to researching image storage through the use of map stimulus (Kosslyn, Ball, and Reiser 1978). A subset of research into cognitive mapping looks specifically at cognitive map distortions in order to clarify the encoding and storage processes involved in cognitive mapping (Kerst and Howard 1978; Thorndyke 1981; Kulhavy and Stock 1996). Distortion has been researched using numerous methods leading to a variety of theories as to why and how distortions happen. The research presented in this thesis approaches cognitive mapping by examining cognitive map distortion. By looking at patterns and forms in cognitive map distortion we can better understand how people perceive, encode, and store spatial information in their minds. First we must understand some of the prevailing theories of image processing and storage as related to maps. Two processes are integral to this discussion, image processing and image storage.

Image Processing

The current experiment has been designed to minimize the requirements of the image processing system. Given this, a review of the assumptions made about image processing informs the design and application of this experiment. Perception is the first part of processing. The Gestalt principles of grouping are particularly germane to cartographic research. Due to the limitations of short term memory, during initial processing of visual stimulus, individuals will group items for more efficient processing (Eastman 1985). Short-term memory (STM) is the transient portion of our memory marked by our awareness of perception (Kosslyn 1985). Kosslyn argues that it is our awareness of perceiving something that defines short term memory. STM is limited by a small capacity for information, which must be moved quickly to long term memory. Kosslyn puts the approximate limit of short term memory at roughly 4-7 units. The units themselves are not necessarily a single feature, but may be a perceptual unit such as a series of dashes making up a dashed line. Cartographers have adopted Gestalt grouping theories and applied them in the development of design principles such as contrast and hierarchy, which make a map easier to read. As an example of the effect of grouping by visual similarity, figure 1 shows two maps. The map on the right more effectively applies the similarity principle resulting in more effective and efficient extraction of the mapped information such as the state names as distinct from city names.

Visual Hierarchy and Discrimination



low hierarchy, difficult discrimination   strong hierarchy, easier discrimination

Figure 1: Visual Hierarchy and Discrimination. Left image represents poor hierarchy, making the levels of information on the map hard to discriminate. The right image presents strong hierarchy, visual discrimination of the levels of text is relatively easy.

Nine Gestalt grouping principles were outlined in *How Maps Work* (MacEachren 1995). Of the nine principles, only proximity, similarity, closure, and experience likely have a significant impact on the retention tasks designed for this research. Figure 2 shows the various stimuli shown to participants in this research. The principle of proximity suggests that objects close together form groups. While this experiment has proximal features in the stimulus, note figure 2 #5, the variation in value should reduce similarity enough so that these features are not grouped. On the other hand, figure 2 #3, shows an example of features which may be grouped due to their similarity, even though they lack proximity. The buildings on either side of the map share similarity in several visual variables leading to strong visual association (Bertin 1967). The principle of closure applies to the walks, figure 2 #4, which are likely grouped due to their appearance as a single polygon.

The principle of experience is one of the more complicated and relevant Gestalt processing principles to this experiment. The principle of experience during perception suggests that previous knowledge or a "knowledge schemata" may affect grouping at the very initial stages of processing (MacEachren 1995). This principle is particularly salient in my research due to the familiarity of the mapped area to students at the University of Oregon. The bottom image in figure 3 shows an air photo of the area represented in the stimulus. The experience principle may allow for easier processing of the more map like stimulus even though it is more complex, containing more features. This principle overlaps with more advanced cognitive processes that operate during image storage addressed in the next section.

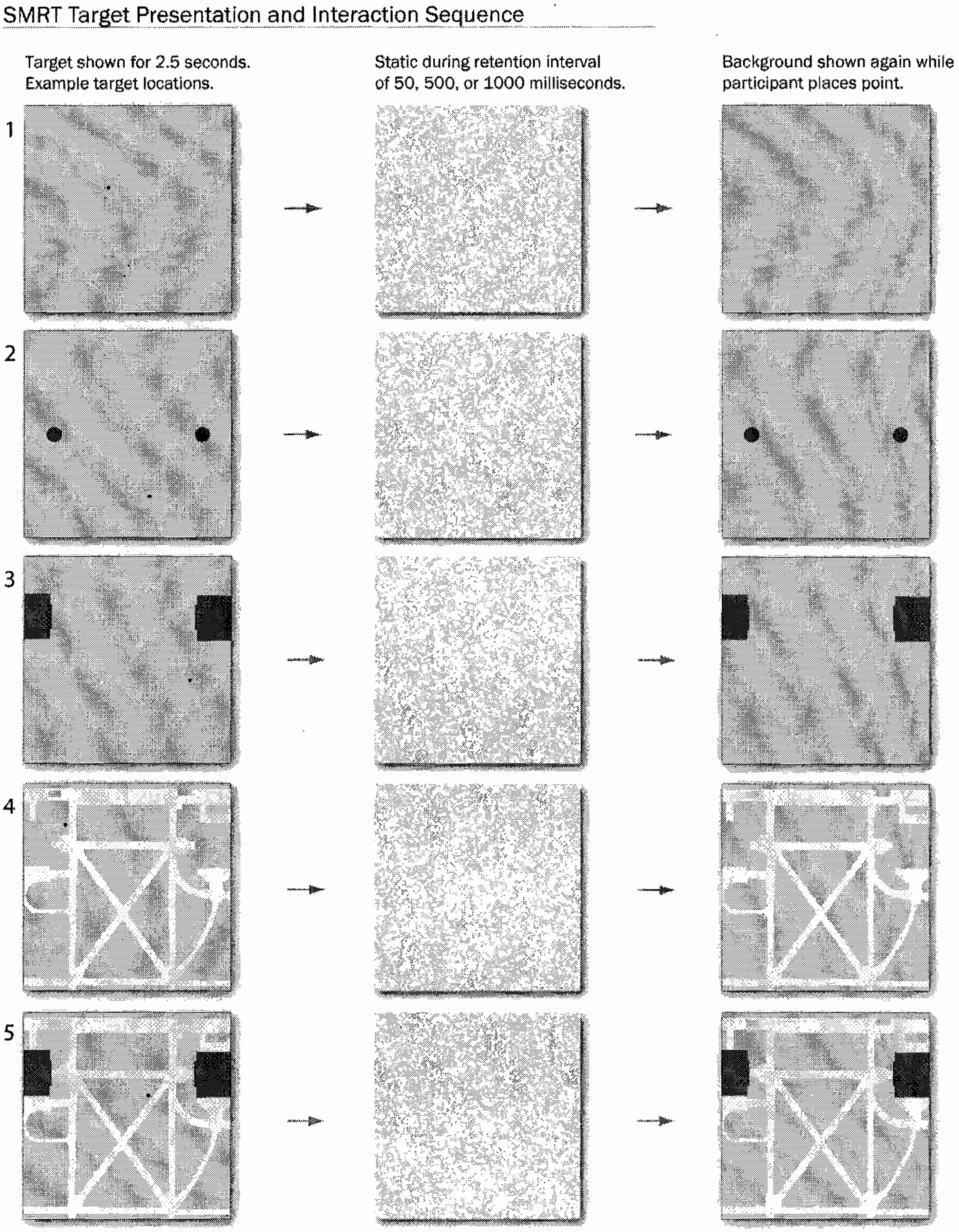


Figure 2: SMRT target presentation and interaction sequence. The first column shows the five backgrounds used in this experiment. The small dots on each background represent example target locations. Column two shows a frame of the static shown during the retention interval. The final column shows the background with no target present, as it is shown during participant interaction.

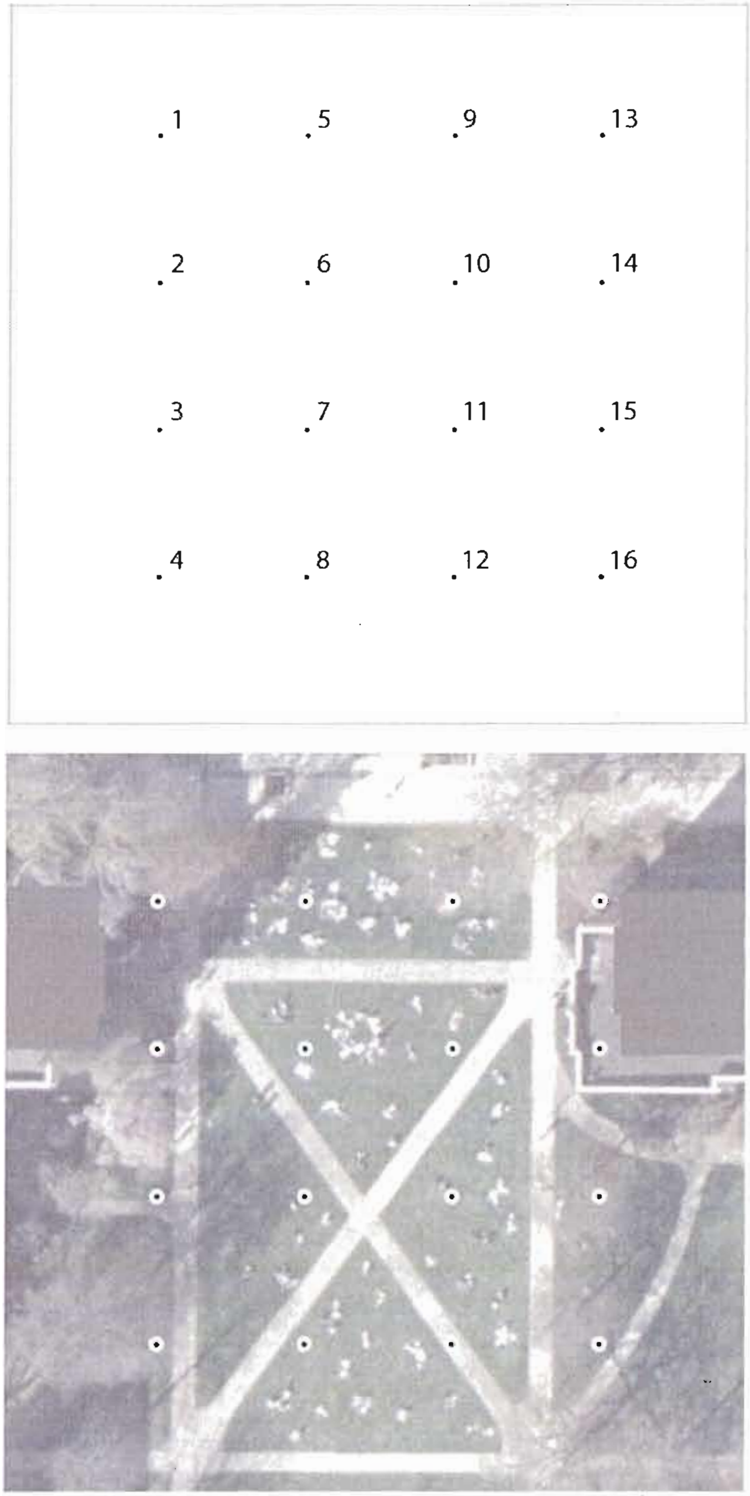
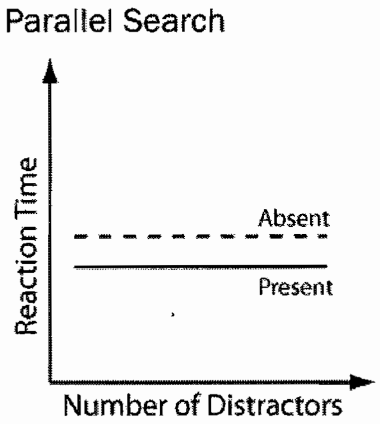


Figure 3: Target locations and air photo. The top image shows the 16 discreet target locations used in this experiment. The bottom image shows an air photo of the area mapped for the experiment with the target locations and building footprints placed on the image.

Another factor operating during image processing in an experiment is the ability of the participant to locate the target. The target in this study is unique in hue and shape. It is also extremely different in shape and size from distractor features. According to parallel search principles the target should be identified in the same amount of time independent of the background type (Lloyd 1988). Figure 4 highlights the effect of parallel search. In this experiment there is no “Absent” condition, so all targets should be identified in the same amount of time. If parallel search principles are present a target can be identified during the very early stages of perception even without focused attention (Lloyd 1997). In the experiment described here the effects of image processing will be controlled by simplifying the processing required by users, thereby limiting the possible causes of systematic distortion to the storage and recall stages during cognitive mapping.



(after Lloyd 1997)

Figure 4: Parallel search suggests that reaction times and number of distracters will be unrelated if there is enough visual distinction between the target and distracters. (Lloyd 1997).

Image Storage

The debate about how we remember images is at least as old as Plato’s wax tablet metaphor (Plato 1990). In Plato’s *Theaetetus* he asks the reader to imagine that there is a block of wax in the mind which preserves mental images. Plato suggests that individual differences can be thought of as differences in the qualities of the wax. Though rejected by the characters Socrates and Theaetetus, this explanation holds a romantic sway over memory research. Research into mental imagery and perception has become more sophisticated since Plato's time. The current debate can be summarized by image theory vs. propositional statement theory (Kosslyn 1977; Pylyshyn 1981). While these positions have been summarized in cognitive cartographic research, their relevance to my thesis warrants some highlights. The image theory holds that viewing an object is the same as imagining that object, and that the object in memory holds similar perceptual properties to the original object (Kosslyn, Ball, and Reiser 1978). In contrast, propositional statement theory argues that there is no image present in memory because memories for spatial relationships are stored as propositional statements. This debate has influenced the direction of cognitive map research and theory (MacEachren 1995; Kulhavy and Stock 1996).

The west coast of the United States is shown as both an image and as a conceptual proposition network in figure 5. The left image displays the image based representation, and the right image displays a propositional network. Psychologists have investigated storage systems using maps as stimuli (Kosslyn, Ball, and Reiser 1978; Tversky 1992). The focus on storage and application has dominated cognitive cartographic research and lead to inferences about how mapped information is learned. Experiments in psychology and geography have reached conclusions reasonably suggesting that either theory best represents the storage of spatial information (Stevens and Coupe 1978; Thorndyke 1981; Tversky 1981; Eastman 1985; MacEachren 1992; Lloyd 1994; Friedman and Brown 2000).

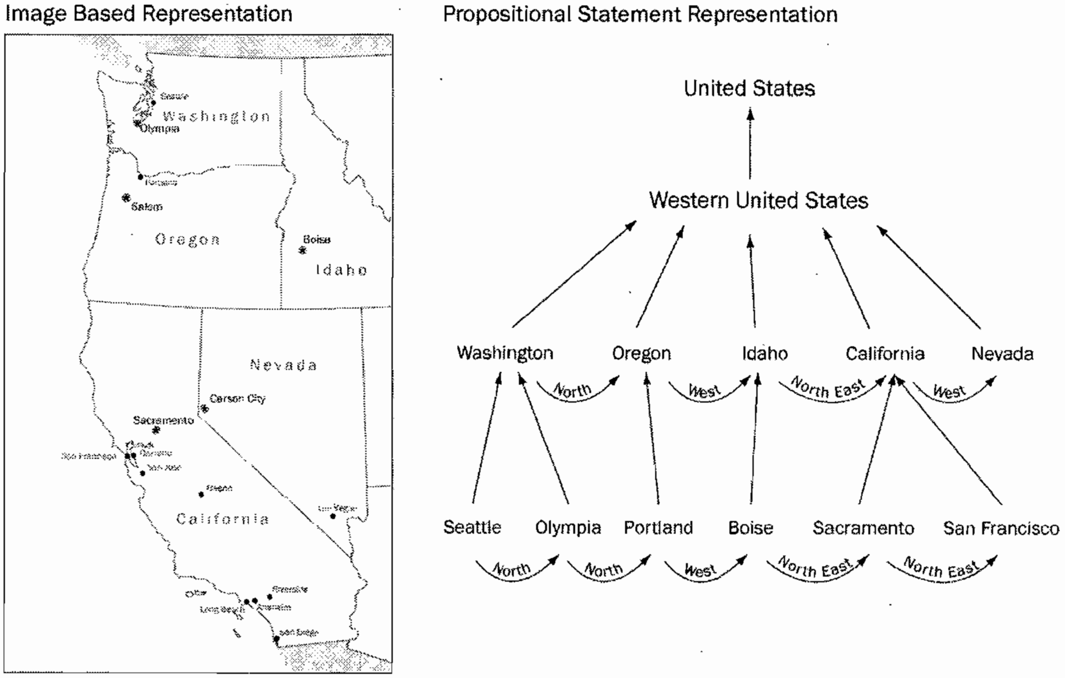


Figure 5: Image and proposition representations. The left image shows an image based representation of the west coast of the United States. The image on the right shows the spatial relationships in a propostional network.

Is there a reason not to accept that many of these researchers have reached accurate conclusions? Dual coding and dual processing theories can account for the overlap and variation in results. Consider again the example in figure 5, some questions can be asked. Which state has the westernmost reach of land? Which state is south of Oregon? Now consider the processes used to answer these questions. Lloyd (1997) employs a similar illustrative tool to discuss dual coding theory. To answer the first question, many would likely picture the map of the three states, or use an imagery based cognitive map of the US west coast. The second question is probably much easier, (at least if asked of someone living on the west coast of the United States). The answer may be reached without imagining a map, but instead answered based on verbally encoded networks in the mind. These facts of spatial relationship are so embedded in our experience and our spatial knowledge that the relationship is known without necessity of referencing an image based cognitive map. This is an example of the dual coding theory (Paivio and Lambert 1981). More specifically this example of multiple encoding and decoding processes highlights race theory, which proposes a system of dual processing, in this case image and proposition, which provides the answer based on the quickest answer received from the cognitive system (Kosslyn et al. 1977). This theory is further explored when considering how cognitive maps change over time, and why our cognitive map may be more image based or proposition based at different times.

My thesis posits that cognitive cartographic research may benefit by focusing less on how mapped information is stored, because such information is most likely stored through multiple processes and in multiple forms. The interesting questions become; what types of spatial problems are solved most efficiently using specific processes, and how much individual variation in strategy is present for a given task? While still utilizing similar methods previously employed to generate hypothesis about the storage of information, cartographic researchers can begin to look at the cognitive mapping strategies that individuals use to solve spatial problems starting from a dual-coding, dual-processing model.

This process of using the task type as a variable for determining mental mapping process has been called "task dependence" (Kulhavy and Stock 1996). Maps as images and verbal propositions contain feature and structure information. Feature information might be described as the attributes of an entity. Structural information refers to the overall framework of the image, including relationships between features and edges. The feature structure argument made by Kulhavy & Stock (1996) is very similar to the assertion by Bertin that displays have an invariant and components (Bertin 1967). Bertin's applies these theories to diagrams, networks, as well as maps. In this way, he suggests that data presented visually, be they on a map or in a chart, may share similar requirements of the user, and by extension, similar cognitive processes. Kulhavy and Stock (1996) argue that depending on the type of task being completed the ways in which information is encoded and decoded will be affected.

This experiment looks at individuals' ability to remember what is referred to as whereness (Downs and Stea 1977). Whereness is about knowing the state of a point's location. Given the short retention interval used in this experiment I hypothesize that a map image will be used by the participants to solve the spatial problems presented in this experiment. Evidence for an image based strategy will be evident in a trend towards increased distortion over time. Results of this experiment will clarify the process used by participants to solve spatial problems of whereness within specific frameworks.

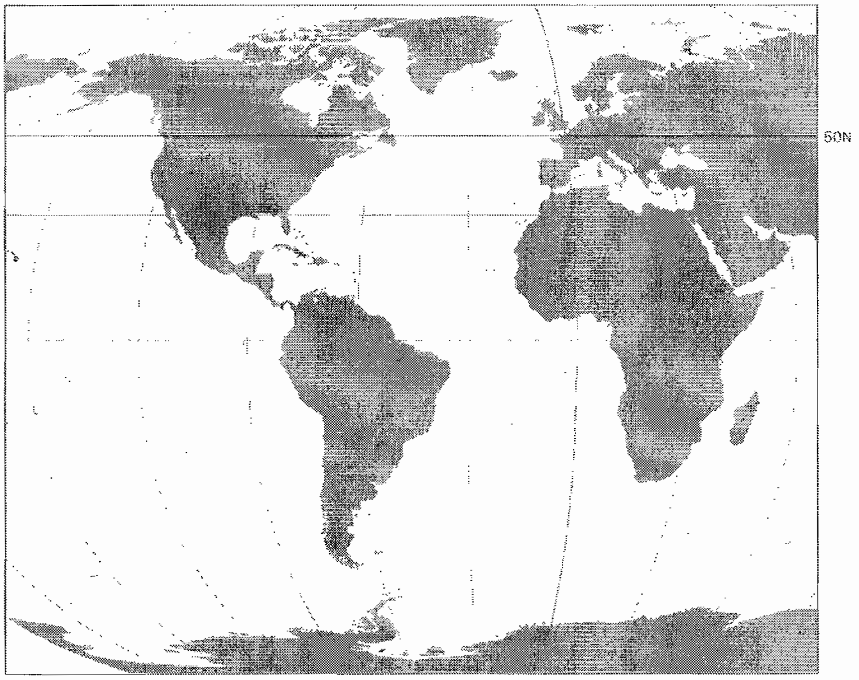
Distortion

The previous sections highlight current theoretical hypothesis central to cognitive cartography such as cognitive mapping, image processing, and image storage. Many of the theories described in the previous sections are built upon results of experiments that examined the correspondence between the experienced world, and individuals' cognitive map. The measure of that correspondence is referred to as cognitive map distortion.

Cognitive map distortion has been a promising route to understanding spatial information processing and is the focus of this research. I am looking at *patterns* in cognitive map distortion, which are distortions which show a consistent pattern, or are predictable and similar across groups of similar location and background. Systematic distortion patterns may suggest the presence of a general cognitive process.

Numerous explanations for systematic distortions are found in spatial cognition literature. One of the most frequently cited explanations of systematic distortions is Gestalt principles. More specifically the heuristics of alignment and rotation (Tversky 1981). Alignment and rotation heuristics suggest that individuals align objects in memory along linear axis, and rotate objects along linear axis as well. This explanation of systematic distortions is based on experiments which examine participant recall of spatial relationships. Systematic distortions have been found at multiple scales suggesting that alignment and rotation have affected spatial memory. The results of the alignment heuristic are shown in figure 6. A Robinson projection of North America, South America, Africa, and Europe is shown on top. The bottom image shows the common result of the alignment and rotation heuristics (Lloyd 1997). Though these results are fairly global for residents of North America, it has also been found that systematic distortions can be perspective dependent. Researchers found that if participants imagined themselves to be in New York they would judge the distance between New York and Pittsburg to be longer than those who imagined themselves to be in San Francisco (Holyoak and Mah 1982).

Accurate Representation, Robinson Projection



Representation of Pervasive Distortions in Cognitive Maps of the World

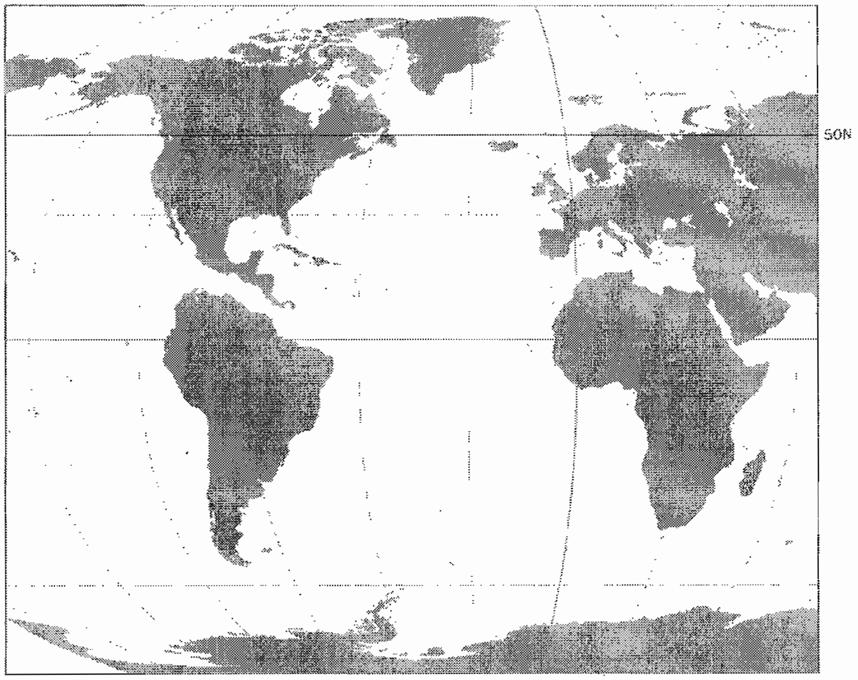


Figure 6: Continental cognitive map distortion (after Lloyd, 1997). The top image shows a Robinson projection of a portion of the earth. The bottom image shows common distortion in cognitive maps of the world. These distortions have been attributed to Gestalt theories of alignment and rotation.

Another explanation for systematic distortion is categorization and hierarchy (Stevens and Coupe 1978). Categorization theories are consistent with the propositional theory of spatial information storage, suggesting that a map is divided into its parts and relationships are described with relational statements as shown previously in figure 5. Stevens and Coupe (1978) published a study which looked at the misalignment of a number of geographical features which are within or relate to a larger category, what they call a superordinate. An example is shown in figure 7. This example illustrates that participants mistakenly suggest that Reno is northeast of San Diego. Stevens and Coupe argue that the consistent inaccuracy is due to the categorization of San Diego as within California and Reno within Nevada and applying the relationship of California and Nevada to the subordinates of San Diego and Reno. Some researchers argue that categorization is an alternative explanation for distortions explained by alignment and rotation (Friedman and Brown 2000). Still others suggest that categorization and Gestalt form are not exclusive, but concomitant encoding processes (Lloyd 1994).

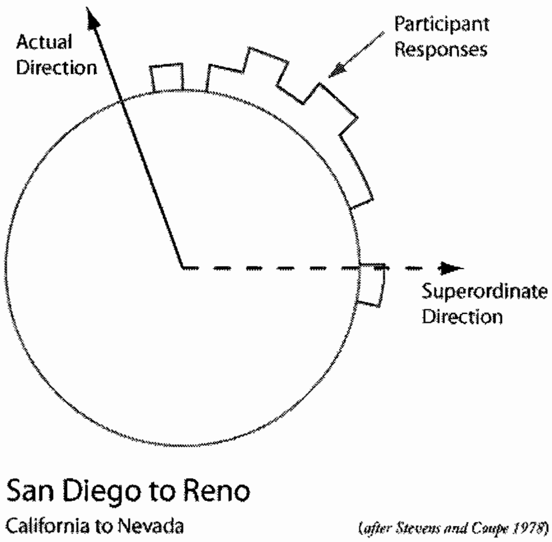


Figure 7: Directional cognitive map distortion. (Stevens and Coupe, 1978). The actual direction from San Diego to Reno is NNW, while the superordinate of Nevada is directly east of the superordinate of California. Responses illustrate the effect of categorization.

The question remains, when are these distortions created? Lloyd (1997) argues that systematic distortions are the result of categorization at the time of encoding, hierarchies created at the time of storage, and reference points perceived at the time of decoding or recall. But the research lacks a temporal component to the investigation of cognitive mapping. Could investigations of the time course of distortions shed some light on the processing and storage of spatial information? The Gestalt psychologists of the early 20th century investigated change over time and found systematic distortion to be present (Werner and Diedrichsen 2002). This result was supported mid century by Crumbaugh (1954) who investigated memory for an image over time at up to 12 second intervals. A more recent article looking at the time course of spatial distortion suggests a quick reduction in memory accuracy for a location, for retention intervals as short as 40 milliseconds, and in some cases an observable error was already present after an interval as short as 50 milliseconds (Werner and Diedrichsen 2002).

Distortion found almost immediately after viewing, as in the Werner and Diedrichsen (2002) example, is likely not due to errors of perception. Rather, the distortion is likely the result of memory processes. For my thesis experiment, and that conducted by Werner & Diedrichsen (2002), the original stimulus is exactly the same as the display when the participant must re-locate the point. An error of perception would result in the same bias in distance estimation during the re-location stage as was present during the original viewing. The results found in Werner and Diedrichsen's (2002) suggest that a short time course of spatial memory distortion is present and that it is the result of memory rather than perceptual processes (Werner and Diedrichsen 2002). A version of the dual processing model may partially explain the time course of spatial memory distortion. The image of the stimulus deteriorates quickly, while the categorical representation remains more intact (Werner and Diedrichsen 2002). As one memory decreases in resolution, it becomes easier to complete the task using the input from the categorical memory system. There is a transition where both the image based and categorical systems are used to solve spatial problems and as confidence in the visual memory gives way, it is replaced by information from the categorical memory. My experiment replicates these results and additionally examines them in the context of map like stimulus. My results provide a unique look at the effects of geographic structure within the visual stimulus, and the affect this has on cognitive map distortion.

Memory

Memory research has been dominated by a quantity oriented approach to experimentation (Koriat, Goldsmith, and Pansky 2000). This approach has given us major theories of processing such as chunks in short term memory and categorical principles (Miller 1956). Spatial memory research does not fit neatly into the quantity oriented approach. What is a chunk of space? How are the non verbal relationships shown on a map grouped and processed? Kulhavy and Stock (1996, 128) write that, “maps contain structural and inferential relationships that are virtually impossible to represent accurately using verbal descriptions alone”. For this reason, spatial memory research has favored an accuracy oriented approach rather than the more traditional quantity based approach. The accuracy oriented approach is represented by a focus on the correspondence between the stimulus and the memory for the stimulus, and referred to as the correspondence metaphor for memory (Koriat, Goldsmith, and Pansky 2000). The focus on the quality of memory is evident in the studies discussed in the previous section, which use the qualities of the distortion to make conclusions about cognitive processes. The current experiment uses the correspondence metaphor for memory by examining the change in accuracy over time.

Werner and Diedrichsen (2002) use a discrimination task in the majority of their experiments. A discrimination task asks the respondent to decide whether the current image is the same as, or different than an original image. Their decision to use this type of task is based on their findings that it similarly represents the distortion present in a replication task where the participant is asked to replicate a point location. Though it may capture a certain level of spatial memory distortion, a discrimination task loses the connection to the correspondence between the original point and the remembered point. Distortion may be observable, but the nature or quality of the distortion is mostly hidden by the multiple choice response paradigm. For this reason I am using a point replication task in this experiment. The nature of the distortions will be more clearly represented by the scatter of responses rather than limited by the discrimination method.

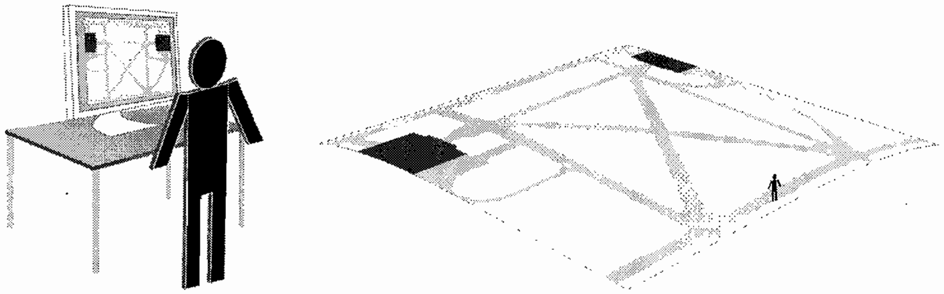
Spatial Abilities

Spatial abilities at an environmental or human scale are a central concern for geographers. Generally, geographers differ from psychologists in their scale of interest. For geographers the focus often is on the scale of human/earth relations with the goal of explaining human spatial behavior through the understanding of the processes humans use to “acquire, represent, and use spatial information” (Lloyd 1997). To an extent, spatial abilities research has been dominated by psychology with some notable geographic exceptions (Golledge et al. 1992; MacEachren 1995; Lloyd 1997). Geographers have borrowed methods and theories from psychology, which have been adapted and modified in an effort to understand spatial behavior within the framework of prevailing cognitive and perceptual theories. In the last few decades, however, geographers have made an effort to establish geography-specific theories of spatial abilities and cognition (Golledge, Dougherty, and Bell 1995; Golledge and Stimson 1997; Lobben 2007).

Environmental spatial abilities are examined in part two of this experiment where I am looking at the ways in which spatial information learned from a survey perspective is distorted when attempting to replicate it in an environmental setting. Participants will gather information from a printed map, or "bird's eye view" perspective (Lobben 2004). They will then need to replicate that information in an environmental setting that matches the mapped location. This dichotomy of learning through survey or environmental experience is also referred to as internal and external spatial perspective (Bryant, Tversky, and Franklin 1992). These two perspectives are integral to the larger map reading and wayfinding spatial abilities (Lloyd 1998). Figure 8 illustrates the external and internal perspectives. A figure views the stimulus from external (left) and internal (right) perspectives. The individual participants' spatial abilities are expected to relate in different ways to the participants' performance on the lab vs. the environmental based experiment.

Current Study

The dispersed but related body of literature drawn upon for this research is not unlike that used by many cognitive cartographers. The integration of existing theory facilitates growth in the field of geography as we attempt to understand cognitive mapping, and the uniquely geographical problems that go along with this pursuit. Since the introduction of the cognitive map and the birth of academic cartographic research in the 1940s there has been a perpetual crossing of paths of many disciplines examining similar phenomena but with different goals. My research aims to highlight the effect of cognitive mapping as a process on our internal representations of space. I wish to contribute a method of looking at cognitive mapping as temporally dynamic and task specific. I emphasize the effect of time and the concept of a cognitive map as a dynamic and constantly changing representation.



External and Internal Perspective

Figure viewing a map from an external or survey perspective.

Figure viewing a space from an internal or egocentric perspective.

Figure 8: External and internal perspectives. Part one of the experiment requires participants to view and replicate a location from a survey perspective. Part two asks the participant to view the stimulus from a survey perspective and transfer that information into an internal perspective to replicate a location.

CHAPTER III

METHODS AND PROCEDURE

Three instruments were combined to measure distortion of mental maps over time as well as predictors, which may influence or vary with performance on a spatial recall test. The Spatial and Map Retention Test (SMRT) was designed to measure the extent and direction of cognitive map distortion over a short retention interval from an external perspective, and is applied in a lab setting. The Environmental Map Retention Test (EMRT) was created to measure the same effects from an internal and environmental perspective. Geographical and psychological researchers have investigated map distortions and provided explanations for the manifestations of those distortions (Downs and Stea 1977; Kosslyn, Ball, and Reiser 1978; Tversky 1981,1992). However, little research has investigated the process of this distortion, and the time-course of distortion. The SMRT is designed to trace distortion that appears in just the first second of the cognitive mapping process. The Santa Barbara Sense of Direction questionnaire (SBSOD) was included to examine the relationship between spatial abilities and both computer based and environmental measures of spatial recall. The SBSOD provides a measure of environmental spatial abilities (Hegarty et al. 2002). In addition to the SMRT, EMRT, and SBSOD other data were collected. Information on age and gender of participants was collected. In order to compare multiple groups and combinations of stimuli a within-subjects design was used. Each participant viewed all conditions. The following subsections provide a more detailed description of each instrument's design and implementation, the experimental design, procedure, and participants.

Participants

The experiment was divided into two parts. Part one included the SBSOD and SMRT, part two included the EMRT. Forty participants were recruited from the University of Oregon student and staff population for part one. Participants learned about the project through in-class announcements or from flyers posted throughout campus. Twenty females and twenty males participated in the experiment. Ages ranged from eighteen to thirty-nine for males and eighteen to thirty-seven for females. Participants were each paid $5 in addition to a coupon for ice cream ($2.50 value). Participants were each provided with an informed consent form. The consent form briefly explained the experiment and the amount of time involved and provided the participants with information about their rights as participants (Appendix A). One or two participants completed the experiment during each administration. After completing the consent form and being given the opportunity to ask questions the participants were seated at a computer to begin the experiment. Forty participants who participated in part one were invited back to participate in part two. A total of ten participants returned. Participants were each paid $8 for their time and effort.

Instruments

Three instruments were used in this experiment. Each participant completed a series of two instruments on a Personal Computer for part one. The instruments used in part one were administered using an Adobe Flash interface. In addition to some demographic questions, the instruments used were the Santa Barbara Sense of Direction Questionnaire (SBSOD) and the Spatial and Map Retention Test (SMRT). Part two included the Environmental Map Retention Test (EMRT) and was administered approximately one month after the initial testing.

Santa Barbara Sense of Direction (SBSOD)

The SBSOD is a standardized instrument developed at UC Santa Barbara (Hegarty et al. 2002). This fifteen question instrument has been validated as a measure of environmental spatial abilities, such as way-finding and learning the layout of a new environment. The SBSOD uses a seven choice Likert scale. See Appendix B for a complete list of SBSOD questions. The fifteen questions are aggregated into a sense of direction scale score. The SBSOD measure of sense of direction was chosen to highlight the similarities and differences between top-down, map based spatial abilities being examined in experiment 1 and the environmental spatial abilities examined in experiment two. Based upon results reported in Hegarty (Hegarty et al. 2002) it is expected that participants' SBSOD scores will more accurately predict performance in part two, an environmental experiment, than performance in part one. The development of an accurate measure of spatial abilities and the refinement of such an instrument is beneficial to the advancement of cognitive cartography and behavioral geography.

Spatial and Map Retention Test (SMRT)

The SMRT is designed to capture distortion through spatial and temporal variation. To accomplish this, the instrument was designed to present the participants with varying distractors, targets, and retention intervals. The design was based upon existing experiments in spatial distortion (Werner and Diedrichsen 2002). During the SMRT participants were shown a series of graphics at a 700 x 700 pixel size. There are three stages for each trial; the target presentation stage, the retention interval stage, and the participant interaction stage (figure 2). The target is shown in one of sixteen specific locations with one of five backgrounds for 2500 milliseconds. This is followed by a retention interval which lasts 50, 500, or 1000 milliseconds. During the retention interval, a static screen is shown to eliminate any visual trace of the target location. The background is then shown again, and the mouse cursor now has the appearance of the target. At this point the participant moves the mouse and clicks their mouse button with the cursor as close as possible to the target location presented in the initial display. There are sixteen target locations, five backgrounds, and three retention

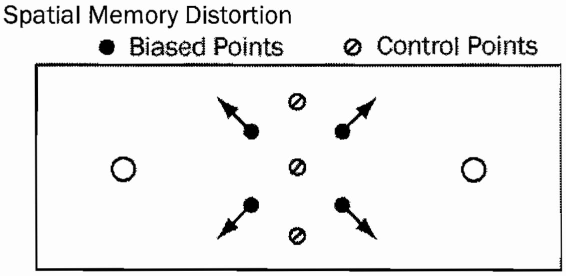


Figure 9: Spatial memory distortion. Redrawn from Werner and Diedrichsen (2002). Arrows indicate the direction of distortion from target locations. The open circles are the distractors.

intervals, for a total of 240 trials. Each participant received all trials in random order. The order was unique for each participant. This provided a way, through experimental design, to control for fatigue. Rather than later examining the fatigue as a variable, by using a random order the effect of fatigue is dispersed across the dataset.

The target locations are displayed in an evenly spaced grid (Figure 3, top). Only one target location is shown per trial. This arrangement was chosen to allow for a consistent pattern displayed across the five backgrounds. Informal participant feedback suggested that the target locations did not appear to be in sixteen specific locations due to the variation of spatial relationships across the five backgrounds.

The first background is blank (figure 2, #1). The second background (figure 2, #2) is similar in design to that presented in Werner and Diedrichsen's research regarding the time course of spatial memory distortions (Werner and Diedrichsen 2002). The layout of their stimulus is shown in figure 3. The three other backgrounds include more map like backgrounds (Figure 2, #3-5). The backgrounds displayed for 2.5 seconds. This amount of time was sufficient to give the participants the opportunity to locate the target on the screen. Visual search literature suggests that when a target is unique in color and shape, there is no change in visual search time with increased distracters, a result of the parallel search cognitive process (Lloyd 1988). The map like backgrounds represent real world features on the University of Oregon campus (figure 3, bottom). This specific location was chosen for a number of reasons. It was important to have a stimulus similar to that in Werner & Diedrichsen (2002). The graphic background (figure 2, #2) is visually similar to the Werner & Diedrichsen background. The building only background (figure 2, #3) is similar in visual layout to the graphic background (figure 2, # 1). Backgrounds 4 and 5 (figure 2, #4 and 5) include a linear feature as well as a polygon. The walks were included in order to compare the effects of a polygon background and linear background; the walks add a linear reference. The five backgrounds allow global comparison of map like, and non map like distractor effects, graphic complexity effect, and presence/absence effects of specific features. The specific target location and subject response can also be looked at with respect to feature proximity and feature type of the background distractor.

Following the display of the target and background for 2.5 seconds there was a retention interval of 50, 100, or 1000 milliseconds (figure 2, center column). The intervals are based on published results which suggest an observable directional distortion after the first 40 milliseconds (Werner and Diedrichsen 2002). During the retention interval a dynamic screen was displayed to remove any visual trace of the target location. The screen was randomly generated in Adobe Photoshop using the mosaic filter. Output images were put together in Adobe Flash at 24 frames per second to create the appearance of animated static. The animated static screen was loaded into the SMRT and displayed during the retention interval. A screen shot of one frame of the static is shown in figure 2, center column. The length of the retention interval is hypothesized to have a predictable effect on participant target replication; as the retention interval increases, the XY offset of the participant point replication will also increase.

After the retention interval the background reappeared without the target. At that point the participant could control the target location with their mouse. The mouse cursor was been replaced with the target graphic. The participant was assigned the task of clicking the mouse button with their cursor in the target location presented before the retention interval. Upon pressing the mouse button, the X, Y location of the participant point was recorded as well as the time it took the participant to respond. The absolute distance from the original target location to the participant position was calculated from the X, Y location. It is hypothesized that response time will have less to do with the participant performance than the retention interval. However, there is expected to be an interaction between the background and target location. The location of the target and its proximity to features in the background is hypothesized to have an observable effect on XY offset and XY offset angle. This graphic representation shows the data collected and calculated from the participant (figure 10).

Environmental Map Retention Test (EMRT)

Participants in part 2 had already completed the SMRT and SBSOD during part 1. The only new task in part 2 was the Environmental Map Retention Test (EMRT). The EMRT consists of only background 5 from the SMRT (Figure 2, #5), and 12 of the 16 unique target locations (Figure 3). The EMRT does not include locations 1,4,13, or 16. Figure 3 also shows the building footprints for reference due to the offset of

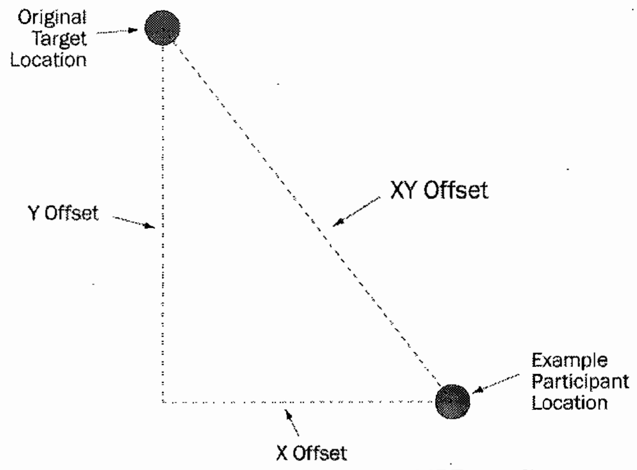


Figure 10: Data derived during the SMRT and EMRT.

building roofs. The EMRT shows the participants one point at a time for 12 total trials. To complete the task participants were seated outside at the south end of the mapped area. They were given a folder which included paper maps the same size and color as those shown on the computer screen. Participants viewed a single map and point location for 4 seconds, after which they were given a marker and asked to place the marker in the environment as close to the mapped location as possible. The use of a 4 second viewing time was necessary after early pilot testing revealed that it was too hard to complete with any less viewing time. Participants returned to the south end of the mapped area after placing their marker. During that time the point location was measured and recorded, and the marker removed. After removal of the marker the participant would begin the next trial. The participants repeated this for each of the 12 point locations.

Procedure

The first part of the experiment was administered entirely on a PC. After completing the consent form participants sat down at a computer. Each participant had the opportunity to adjust the vertical angle of the screen for their height. The screen was located 12” from the edge of the table. The questions were displayed using an Adobe Flash interface delivered through Microsoft Internet Explorer at a display resolution of 1024x800. Participants took approximately 30-35 minutes to complete the tasks. The data were collected in Adobe Flash and sent through an ASP.NET server page to a Microsoft Access Database where further data management is automated. The data were then manipulated into formats suitable for analysis in ArcMap, R, and SPSS.

CHAPTER IV

RESULTS AND ANALYSIS

Analysis was completed using various statistical methods including ANOVA and the General Linear Model for categorical predictors and linear regression. ANOVA was used to examine the effects of gender and age. Linear regression was used to examine the relationship between the predictor variables, SBSOD scores and response times, and response variable of XY offset. Within and between subjects methods were used to examine the predictor variables of background, retention interval, and target location. In the following analyses the observations are broken up by experimental condition. I will refer to the with walks and without walks groups. These refer to the background during the observation. The without walks group includes cases where the background did not include walks (figure 2, #1-3). The with walks group includes cases when the background did include walks (figure 2, #4-5).

The points clicked on by participants are shown in appendix C. These maps of participant points are shown for the entire SMRT and are then broken down by retention interval and background. With retention intervals as short as 50 milliseconds, and the longest being 1 second, it was expected that there would be a high level of accuracy. This is the case, however, there is distortion. The pattern and amount of that distortion differs among backgrounds. The participant points shown for backgrounds with walks (appendices C.11 –C.16) and those without walks (appendices C.2 –C.10) reveal a pattern of both similarity within those categories and difference between those categories. While the clearest differences in offset pattern exist between the with walks and without walks groups, the without walks group has significantly different patterns of distortion between without walk conditions. The buildings background plots show strong linear alignment of points with the edges of the buildings. The graphic background plots reveal a pattern of distortion similar to those found by Werner & Diedrechsen (2002). In both cases there is an expansion of space at the center, with replicated points trending away from the center of the plot. Statistical analysis of the results reveals the presence or absence of walks in the background of the image to be an important factor in participant performance, however other patterns and interactions are also revealed by a closer look at the data.

The SMRT asks participants to roll over a "button" to continue to the next trial. Participants had the occasional reflex to press the button with their mouse rather than just rolling over it, which in those cases led to spurious results. Of the 9600 resulting data points less than 1% represent extreme outliers which were removed. Outliers were identified through analysis of z scores. Those scores with a z score greater than 4, or less than -4 were considered extreme outliers. Extreme outliers, which most likely resulted from the function or format of the task, were removed. In the series of 240 trials each participant had approximately two outliers. The removed outliers were replaced with the median score for all participants of the variable from which the outlier was removed.

The positive skewness expected in a response accuracy test such as the SMRT was present in this task. The mild skewness of each of the 240 variables was reduced using a square root transformation. The square root transformation was applied to all 9600 observations, which eliminated the skewness in over 90% of the observations using a criterion of the skewness values being less than twice their standard errors. The following results report statistics based on this recoding of the data.

TABLE 1

Internal reliability of SMRT subscales for background by retention interval.

Scale	Description		alpha*	N
G1	Graphic Background, Figure 4 # 2	Retention Interval 1	.808	16
G2	Graphic Background, Figure 4 # 2	Retention Interval 2	.823	16
G3	Graphic Background, Figure 4 # 2	Retention Interval 3	.816	16
B1	Building Background, Figure 4 # 3	Retention Interval 1	.789	16
B2	Building Background, Figure 4 # 3	Retention Interval 2	.688	16
B3	Building Background, Figure 4 # 3	Retention Interval 3	.612	16
01	Blank Background, Figure 4 # 1	Retention Interval 1	.805	16
02	Blank Background, Figure 4 # 1	Retention Interval 2	.799	16
03	Blank Background, Figure 4 # 1	Retention Interval 3	.754	16
W1	Walks Background, Figure 4 # 4	Retention Interval 1	.794	16
W2	Walks Background, Figure 4 # 4	Retention Interval 2	.705	16
W3	Walks Background, Figure 4 # 4	Retention Interval 3	.593	16
A1	Buildings and Walks Background, Figure 4 # 5	Retention Interval 1	.784	16
A2	Buildings and Walks Background, Figure 4 # 5	Retention Interval 2	.714	16
A3	Buildings and Walks Background, Figure 4 # 5	Retention Interval 3	.662	16
EMRT	Environmental Task	No Retention Interval	.615	12

*Cronbach's Alpha based on standardized items.

The SMRT is a new instrument and some analysis of the instrument itself is useful before we examine results of the task. One standard test of a new instrument is Cronbach's Alpha as a measure of internal reliability (Cronbach 1951). The design of the study includes subscales within the SMRT. The 240 trials are classified by five backgrounds and three retention intervals. This leads to the 15 subscales of background by retention interval. The 15 subscales are listed and described in Table 1 along with the alpha score for standardized items. Reliability analysis performed on these subscales showed high internal reliability for standardized items on most subscales, with only one subscale falling below the alpha = 0.6 level.

A factor analysis provided further insight into the performance of the SMRT, indicating the extent to which all the subscales are related to one or many conceptual constructs. Table 2 shows the rotated factor analysis using an orthogonal varimax rotation for the SMRT subscales representing each background by retention interval. This analysis is also an approach to assess the content validity of the scales (Cronbach and Meehl 1955). The results suggest that those subscales representing trials without walks are in one factor and those subscales with walks load strongly on a second factor.

An analysis of variance with average XY offset as the dependent variable and gender as the independent variable revealed no significant difference in average XY offset based on gender, $F(1,38) = 1.12$, $p = 0.297$. There was also no significant between-group differences in gender for SBSOD score, $F(1,38) = 1.04$, $p = 0.250$. Gender was found to be insignificant in relation to both the SBSOD score and the XY offset. This lack of difference suggests that gender is not related to constructs measured by the SBSOD or SMRT. An examination of the relationship between age and XY offset also revealed no significant relationship. A regression was run with participant age as the independent variable and average XY offset as the dependent variable. The analysis of variance for this regression was not significant, $F(1,38) = 1.12$, $p = .297$.

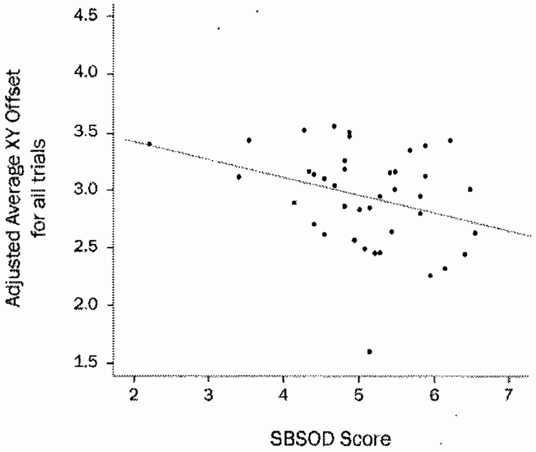
TABLE 2

Rotated Factor Matrix for SMRT

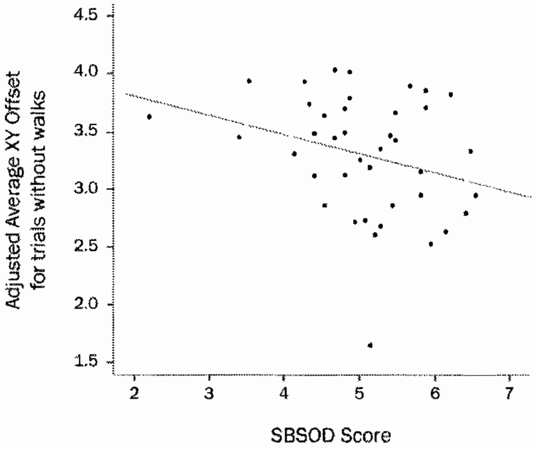
	Loading	
Scale	Factor 1	Factor 2
B1	**.886**	.348
O1	**.850**	.357
O2	**.792**	.332
G3	**.766**	.481
O3	**.766**	.363
G2	**.756**	.424
B3	**.749**	.343
G1	**.747**	.522
B2	**.674**	.583
A1	.336	**.855**
A2	.392	**.813**
W2	.323	**.774**
W1	.542	**.689**
W3	.323	**.671**
A3	.349	**.650**

The relationship between SBSOD score and various dependent variables is shown in figure 11. All plots show the SBSOD score on the x axis. The top plot shows XY offset for all trials on the y axis. The second shows the XY offset for trials without walks, and the last shows the XY offset for trials with walks on the y axis. It is apparent from the scatter plots that a weak linear relationship exists between the SBSOD score and the average XY offset for all trials. The SBSOD significantly predicted a small amount of the average XY offset, $\beta = -0.322$, $t(38) = -2.1$, $p = 0.042$. The SBSOD score also explained a significant portion of the variance of XY offset, adjusted $R^2 = 0.104$, $F(1,38) = 4.408$, $p = 0.042$. This significant relationship is somewhat weaker when looking at the relationship between the SBSOD score and the XY offset for trials without walks. The relationship is not significant at the 95% confidence interval, $\beta = -0.282$, $t(38) = 1.81$, $p = 0.078$. While this result is marginally significant, it suggests that the lack of walks in the image affects performance. This is further suggested by the relationship between the SBSOD score and XY offset for trials with walks. The SBSOD was found to be significantly related to the XY offset for trials with walks, $\beta = -0.369$, $t(38) = -2.47$, $p = 0.019$. A significant portion of the variance in XY offset for trials with walks was explained, adj. $R^2 = 0.136$, $F(1,38) = 5.988$, $p = 0.019$.

Scatter Plot of XY offset for all trials by SBSOD score.



Scatter Plot of XY offset for trials without walks by SBSOD score.



Scatter Plot of XY offset for trials with walks by SBSOD score.

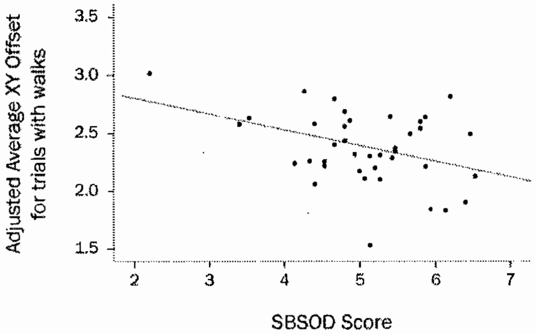
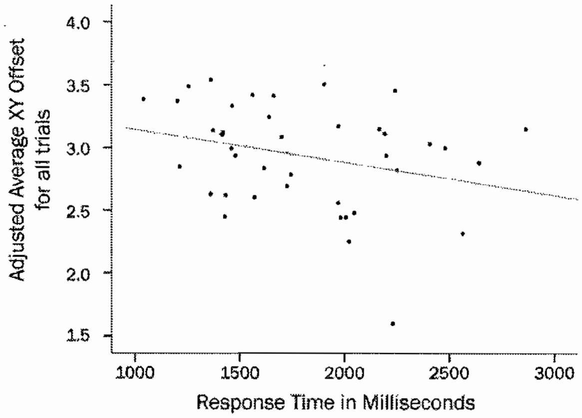


Figure 11: SBSOD score and XY offset shown for all trials and broken up by with/without walk conditions.

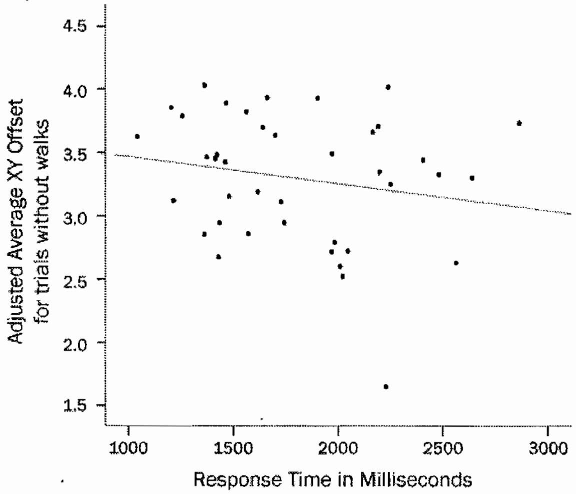
Exploration of the relationship between response latency and XY offset was done in the same way as the SBSOD scale score and XY offset. Scatter plots are shown in figure 12. Response latency has a significant relationship with XY offset for all trials, $\beta = -0.283$, $t(38) = -1.82$, $p = 0.019$. Response latency showed no significant relationship with XY offset for trials without walks, but was found to be strongly related to XY offset for trials with walks, $\beta = -0.476$, $t(38) = -3.34$, $p < 0.01$. This explains a significant amount of the variance in XY offset for trials with walks, adj. $R^2 = 0.206$, $F(1,38) = 11.137$, $p < 0.01$. This result further highlights the difference between those trials with walks and those without walks.

The null hypothesis that time is not a factor in cognitive map accuracy can be examined through an analysis of variance of the average offset by retention interval using a repeated measures design. Figure 13 shows the plot of average XY offset by each retention interval level. The 3 within subject variables making up the levels of the within subject factor of retention interval are average XY offset for retention interval 1(50 ms), average XY offset for retention interval 2(500 ms), and average XY offset for retention interval 3(1000 ms). The within subject effect of the retention interval was found to be significant, $F(2,78) = 49.71$, $p < 0.01$. Post hoc tests of pairwise difference using Bonferroni contrasts revealed that XY offset for retention interval 1, mean = 2.81, SE = .073, is significantly lower than XY offset for retention interval 2, mean = 2.91, SE = .068, $p < 0.01$ and retention interval 3, mean = 3.08, SE = .063, $p < 0.01$. XY offset for retention interval 2 is significantly smaller than XY offset for retention interval 3, $p < 0.01$. As the retention interval increased, response accuracy decreased.

Scatter Plot of XY offset for all trials by Response Time.



Scatter Plot of XY offset for trials without walks by Response Time.



Scatter Plot of XY offset for trials with walks by Response Times.

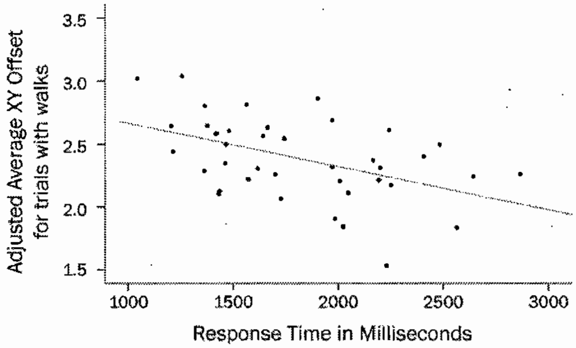


Figure 12: Response latency and XY offset shown for all trials and broken up by with/without walk conditions.

A similar within subjects test of the effect of background on subject performance was conducted to test the null hypothesis that background is not a factor in cognitive map accuracy. Figure 14, top image, shows the plot of average XY offset by each background condition split by retention interval. The 5 variables making up the within subjects factor of Background are average XY offset for the blank background (figure 2 #1), average XY offset for the graphic background (figure 2 #2), average XY offset for the building background (figure 2 #3), average XY offset for the walks background (figure 2 # 4), and average XY offset for the walks and buildings background (figure 2 #5). The within subject effect of background is found to be significant, $F(4,156) = 198.25$, $p < 0.01$.

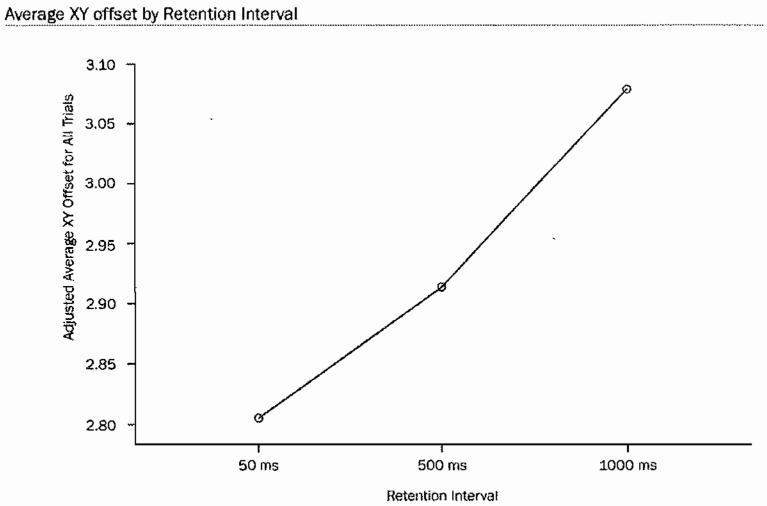


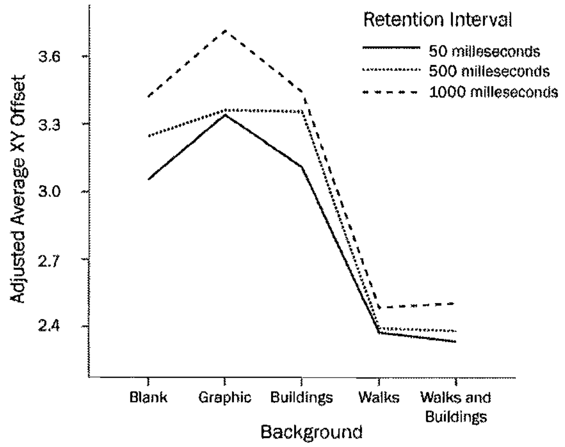
Figure 13: Plot of average XY offset for all trials by retention interval. This figure indicates the significant increase in offset, or error, at each retention interval.

The largest average XY offset occurs with the graphic background, mean = 3.43, SE = .09. This is significantly worse than all other background conditions. The average XY offset for the building background, mean = 3.26, SE = .08, is significantly lower than the average XY offset for the graphic background, $p < 0.01$. The average XY offset for the blank background, mean = 3.198, SE = .08, is significantly lower than the average XY offset for the graphic background, $p < 0.01$, but only slightly lower, and not significantly different from the average XY offset for the building background. The blank, graphic, and building backgrounds all represent backgrounds without walks.

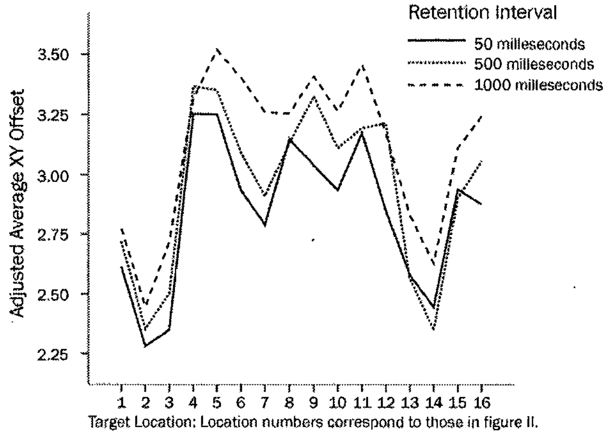
The average XY offset for the walks background, mean = 2.39, SE = .05, and the walks and buildings background, mean = 2.38, SE = .05, are virtually identical. The average XY offset for these two background conditions are not significantly different from each other, but are both significantly lower than all other background conditions at the $p < 0.01$ level. The best performance, the lowest XY offset, occurred during trials with backgrounds containing walks. The presence of such a significant difference in performance suggests that the presence of the linear reference of walks is helpful to accurate memory for a point location.

To examine the main and interaction effects of background, retention interval, and target location the data were examined using the average XY offset by trial as the dependent variable. Independent categorical variables of background, retention interval, target location, and interactions of those variables were used as predictors of XY offset in a General Linear Model. The same background and retention interval categories were used as in the previous analysis. The target location variable is a 16 category variable. The target location category corresponds to the numbers of the target locations shown in figure 3.

Interaction of Background and Retention Interval



Interaction of Target Location and Retention Interval



Interaction of Target Location and Background

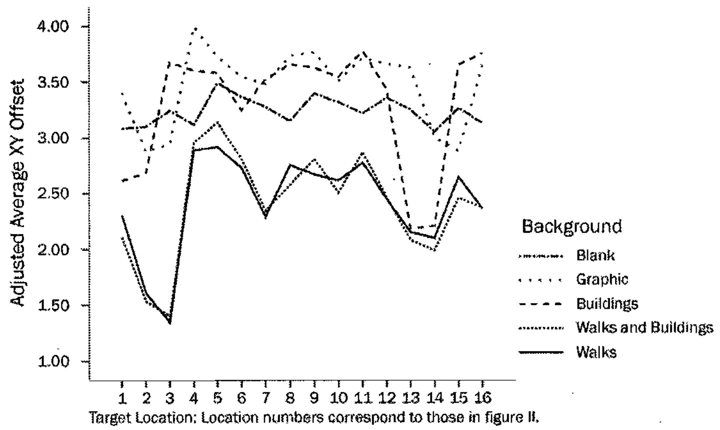


Figure 14: Interaction Effects. Each graph shows a unique interaction plotted against XY offset.

The full model was found to be significant, adj. $R^2 = 0.929$, $F(1,239) = 27.459$, $p < 0.01$. The main effects of background and retention interval on participant XY offset found in previous analyses are present in this analysis by trial. Table 3 shows the results of the General Linear Model analysis. Pairwise comparisons for background and retention interval reveal almost identical results to those found using the repeated measures design by participant (appendix D.1 and D.2). The average XY offset by target location reveals significant differences exist based on the target location, $F(15, 120) = 52.949$, $p = < 0.01$. Pairwise comparisons of the 16 target locations can be seen in appendix D.3.

TABLE 3

Test of main effects and interaction effects of target location, background, and retention interval

Dependent Variable: Average XY Offset

Source	SS	df	Mean Square	F	Sig.
Corrected Model	95.518(a)	119	.803	27.459	.000
Intercept	2112.314	1	2112.314	72261.259	.000
Target Location	23.217	15	1.548	52.949	.000
Retention INterval	3.009	2	1.505	51.476	.000
background	51.055	4	12.764	436.646	.000
Target * Retention	1.076	30	.036	1.227	.218
Target * Background	16.347	60	.272	9.320	.000
Retention * Background	.814	8	.102	3.479	.001
Error	3.508	120	.029		
Total	2211.340	240			
Corrected Total	99.025	239			

a R Squared = .965 (Adjusted R Squared = .929)

Interaction effects were found to be significant. Figure 14 shows plots of average XY offset by trial on the y axis. The x axis shows a predictor variable with plots that are categorized by an interaction variable. The interaction between retention interval and target location (figure 14, center) is not significant, $F(30, 120) = 1.23$. $p = .22$. This indicates that the affect produced by target location is independent of retention interval, and that the effect of retention interval is independent of target location. A small effect was found in the interaction between retention interval and background, $F(8,120) = 3.48$, $p < 0.01$, figure 14, top. An examination of this interaction revealed that the change in XY offset at each retention interval is significantly different depending on background. Appendix D.4 shows Bonferroni comparisons of these interactions.

There is also a significant interaction effect on XY offset of target location by background, $F(60, 120) = 9.32$, $p < 0.01$. As with the interaction between target location and background, this interaction indicates a change in XY offset for each background depending on the location of the target. The bottom plot in figure 14 shows this interaction. A similar pattern is apparent depending on the target location; however some backgrounds have very different patterns for some of the target locations (figure 14, bottom graph). The comparison of interaction effects is shown in appendix D.5.

Part two of this experiment, the Environmental Map Retention Test, was conducted to explore the relationship between survey and egocentric perspectives in cognitive map tasks. A small N and difficulties in creating similar indoor and outdoor experiences make this comparison elusive, but some interesting results are still revealed from this pilot study. Much like with the SMRT, it is worth looking at the internal reliability of the EMRT. Table I shows the results of internal reliability test for the EMRT. The EMRT falls at the low end of reliable, but is still above the .6 threshold for Cronbach's alpha.

Two of the most interesting interactions found in the SMRT were the relationships between SBSOD score, response latency, and XY offset. Using the same framework with the EMRT, no significant relationship between either SBSOD score, *r*(10) = -.327, p = 0.36, or response time, *r*(10) = -.18, *p* = 0.61, to EMRT XY offset was found. Though no statistically significant relationship is found between SBSOD score and EMRT XY offset, the scatter plot of the relationship in figure 15 shows the relationship between SBSOD score and EMRT XY offset. The small N of the EMRT limits the strength of this analysis, but the presence of small slope suggests that further testing is reasonable. The scatter plot of response time with EMRT XY offset shows no apparent relationship.

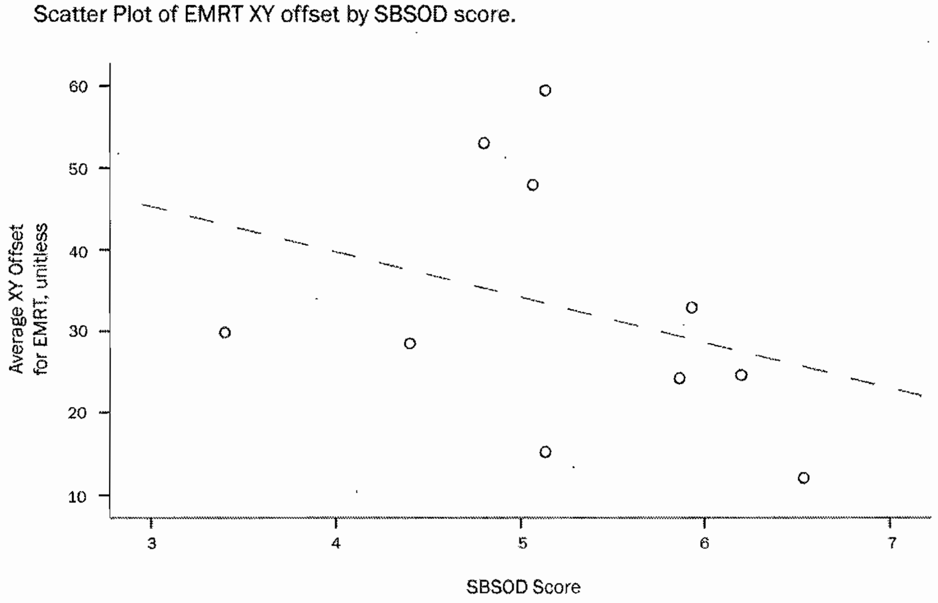


Figure 15: Scatter plot of EMRT XY offset by SBSOD score.

Retention interval and background are not factors in the EMRT as they were in the SMRT. However, it is interesting to look at the EMRT XY offset by target location. The 12 target locations used in the EMRT are plotted in figure 16. This pattern differs from that found during the SMRT. The small sample of the EMRT prevents some analysis, but the within subjects effects of location can be tested using a repeated measures design. A significant within subjects effect of target location was found, $F(11,99) = 2.38$, $p = 0.01$. This suggests that even in an environmental setting the location of a target relative to reference objects may affect memory for location. A plot of participant placed points for the EMRT is shown in appendix C.17.

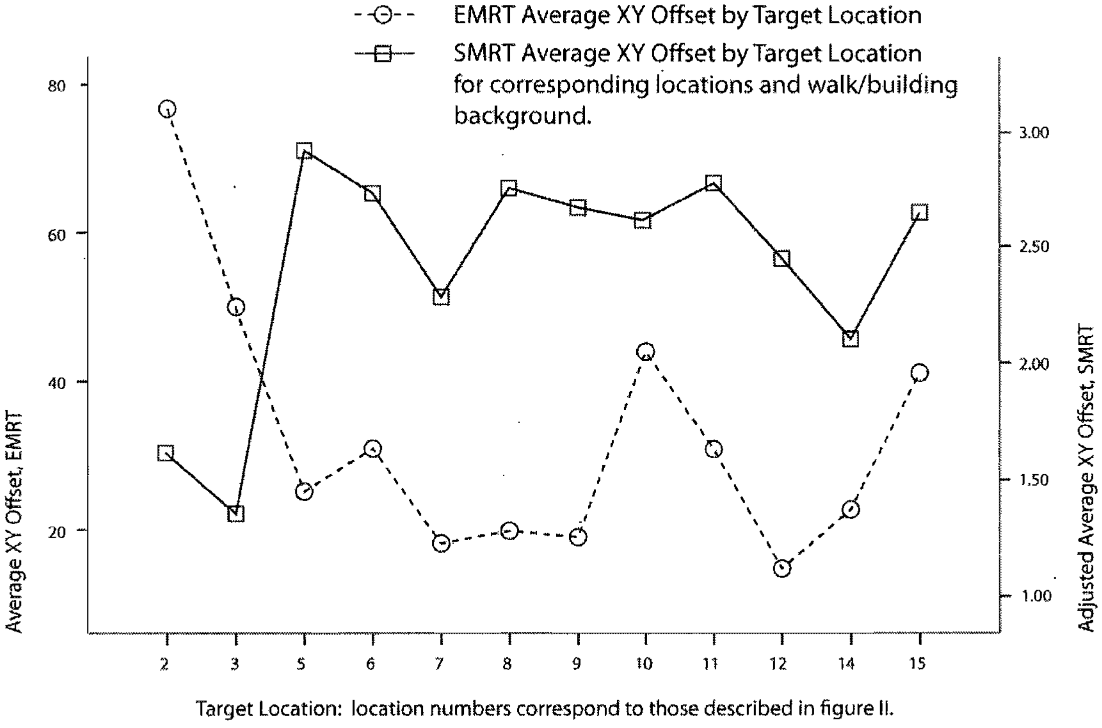


Figure 16: SMRT and EMRT XY offset by target location.

Observing the participants placing their points during the EMRT revealed a consistent use by participants of reference locations to judge their own location. Participants would often walk to the approximate location they believed the point to be, and then would look at building corners and walks and use their arms to make imaginary lines from their location to the reference point. These gestures seem consistent with a categorical memory for the structure of the spatial relationships rather than an image based storage system. The results of the EMRT suggest that further experimentation using environmental rather than lab based spatial tasks could reveal much about the process of spatial cognition and environmental spatial abilities.

CHAPTER V

DISCUSSION AND CONCLUSIONS

This study was designed to examine the presence of change over time in cognitive maps. The null hypothesis that there is no effect of time on the cognitive map has been rejected. The null hypothesis that background has no effect on the cognitive map has also been rejected. The results also suggest that target location plays an important role in memory for specific location, and that this effect is mediated by what the background of an image includes. The results of this study reveal that the examination of the cognitive map as a static object may disguise the dynamic nature of the cognitive mapping process. The argument for a dual processing model of cognitive mapping is supported by the results, which show unique processes acting that depend upon the demands of particular tasks.

The time course of distortion revealed by the results presented here highlights an untapped research method for the understanding of cognitive mapping. The presence of a time course of cognitive map distortion was evaluated through the observation of increased distortion at each of the three retention intervals used during the Spatial and Map Retention Test. The presence of observable increase over time shows that there is a nearly immediate and persistent degradation of memory for location following initial viewing of an image. The short duration of the retention intervals used in this experiment resulted in a continuing increase in distortion; however, the progression of distortion could be further investigated through the use of longer retention intervals.

The relative weakness in both magnitude and systematic directionality of the time course of distortion during observations with backgrounds that included walks compared to those that did not include walks suggests a difference in spatial problem solving strategy between the two conditions. These results are consistent with dual coding theory. In the with walks trials there is such a strong visual reference system, it may be easier and more accurate to answer the questions based upon propositional relationships. A strategy based on propositional statements would be less likely to exhibit the same pattern of spatial compression and expansion present when an image based strategy is employed. Further research using extended retention intervals could also strengthen the apparent dichotomy between the with walks and without walks trials.

The relationship between the SBSOD and XY offset and the relationship between response latency and XY offset both underscore the difference between the with walks and without walks conditions. Both the SBSOD score and response latency are significantly related to the XY offset for trials with walks. This is not the case for XY offset for trials without walks. These results further suggest a difference in strategy being employed by participants during the two types of tasks. The results of the factor analysis also support the uniqueness of the with walks and without walks trials.

Caution should be taken when making conclusions about cognitive processes used when examining the results of the SMRT. The difference found between the with walks and without walks tasks may be based on something other than the presence of the linear reference of walks. The participant points found for target locations nearest the buildings for background 3, appendix C. 8-10, where the points fall into a somewhat linear pattern along the axis running from building edge to building edge show some similarity to participant points found when the background includes walks. I would suggest that a similar strategy is used here as that used when the background included walks. The linear pattern of the distortion suggests that participants used the linear relationship between the buildings as a reference for point replication. Perhaps the ambiguity of these specific locations suggests that the combination of point location and background found for points at the top half of appendices C.8-10 represent multiple spatial problem solving strategies being employed by participants. This could be an example of either image or propositional strategies being employed depending upon participant.

This study, which examines the time course of cognitive map distortion, has revealed a dynamic pattern of distortion over time and across background and target locations. The presence of task and background dependent distortion suggests that the literature on cognitive map distortion may be evaluated in terms of task dependent spatial problem solving strategy in addition to spatial information storage. Existing cognitive mapping research has generally focused on distortion in cognitive maps as arguments for one or another form of spatial information storage. A more significant understanding of the spatial problem solving strategies used by individuals through time and across tasks may well be revealed through the employment of time series based cognitive mapping research methods.

APPENDIX A

CONSENT TO PARTICIPATE

Consent to Participate:

Spatial and Map Cognition Research Lab

You are invited to participate in a research study conducted by Nick Martinelli, from the University of Oregon, Department of Geography. I hope to learn about how we remember locations. You were selected as a possible participant in this study because you expressed interest during an information session or contacted the researcher.

If you decide to participate, you will complete a series of computer based tasks which ask you questions about yourself. You will also complete a series of tasks in which you will be asked to remember the location of a point on the computer screen. The entire experiment will take approximately one hour.

The tasks may be difficult, don't worry if you do not know an answer, simply answer the questions as best you can. You will receive $5 and a gift certificate for ice cream in appreciation of your time and effort after you complete the tasks.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept. The tasks will only be associated with a number, not your name. No record will be kept associating your name with your answers

Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the University of Oregon. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions, please feel free to contact Nick Martinelli at 346-4870, or in room #160 of Condon Hall, in the Department of Geography. You may also contact Nick's academic advisor, Amy Lobben, at 346-4566. If you have questions regarding your rights as a research subject, contact the Office for Protection of Human Subjects, University of Oregon, Eugene, OR 97403, (541) 346-2510. This Office oversees the review of the research to protect your rights and is not involved with this study.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights or remedies.

Print Name____

Signature____
Date____________________

APPENDIX B

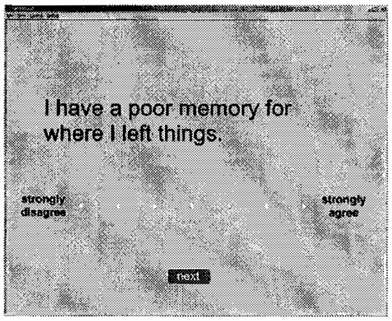
SBSOD

SBSOD-(Hegarty et al. 2002)

This Questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle check "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree that the statement applies to you. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.
2. I have a poor memory for where I left things.
3. I am very good at judging distances.
4. My "sense of direction" is very good.
5. I tend to think of my environment in terms of cardinal directions (North, South, East, West).
6. I very easily get lost in a new city.
7. I enjoy reading maps.
8. I have trouble understanding directions.
9. I am very good at reading maps.
10. I don't remember routes very well while riding as passenger in car.
11. I don't enjoy giving directions.
12. It's not important to me to know where I am.
13. I usually let someone else do the navigational planning for long trips.
14. I can usually remember a new route after I have traveled it only once.
15. I don't have a very good "mental map" of my environment.

SCREENSHOT FROM COMPUTER BASED INSTRUMENT:



I have a poor memory for where I left things.

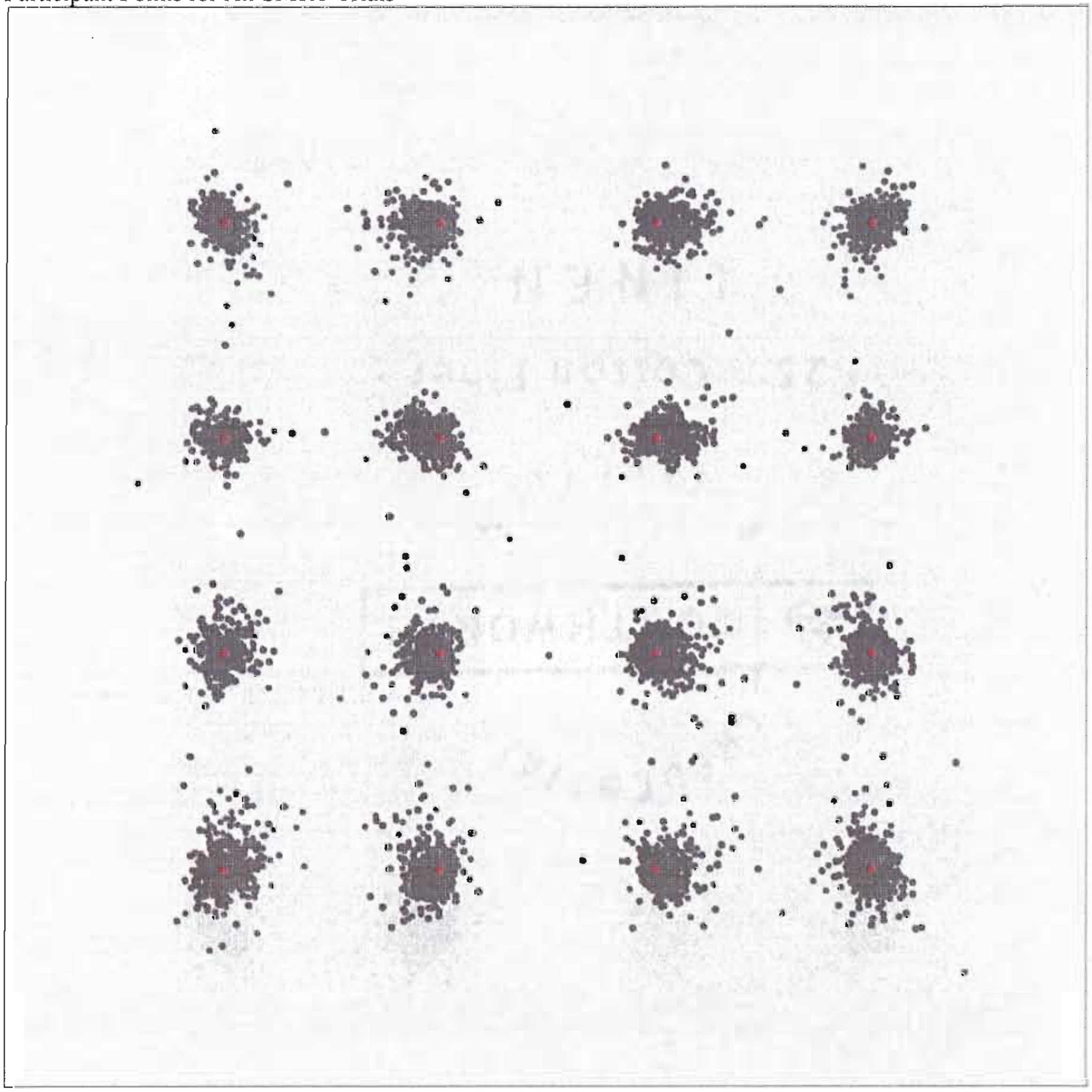
APPENDIX C

PLOTS OF PARTICIPANT POINTS FOR SMRT AND EMRT

Original target locations are shown in red. Participant points are plotted in black.

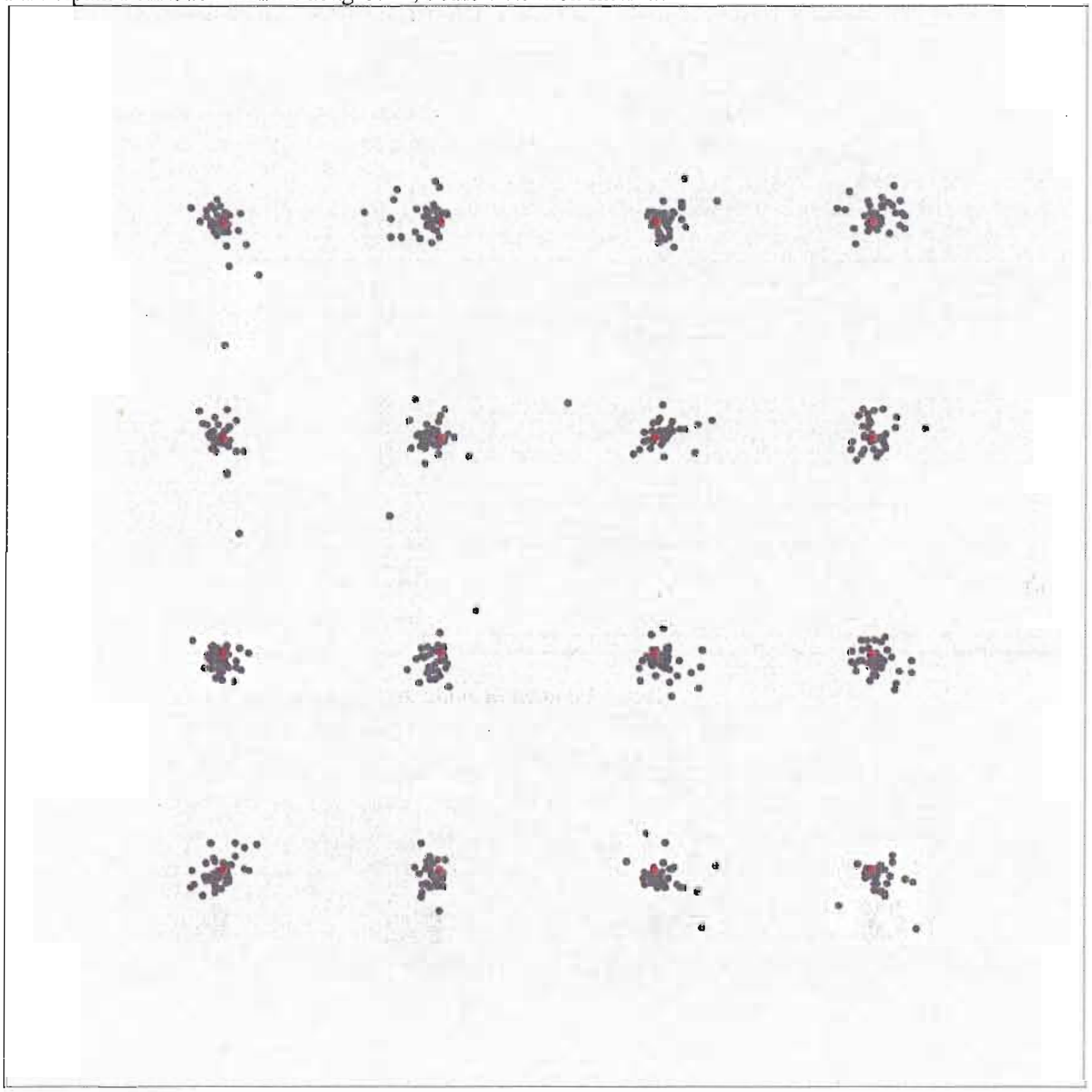
Appendix C.1

Participant Points for All SMRT Trials



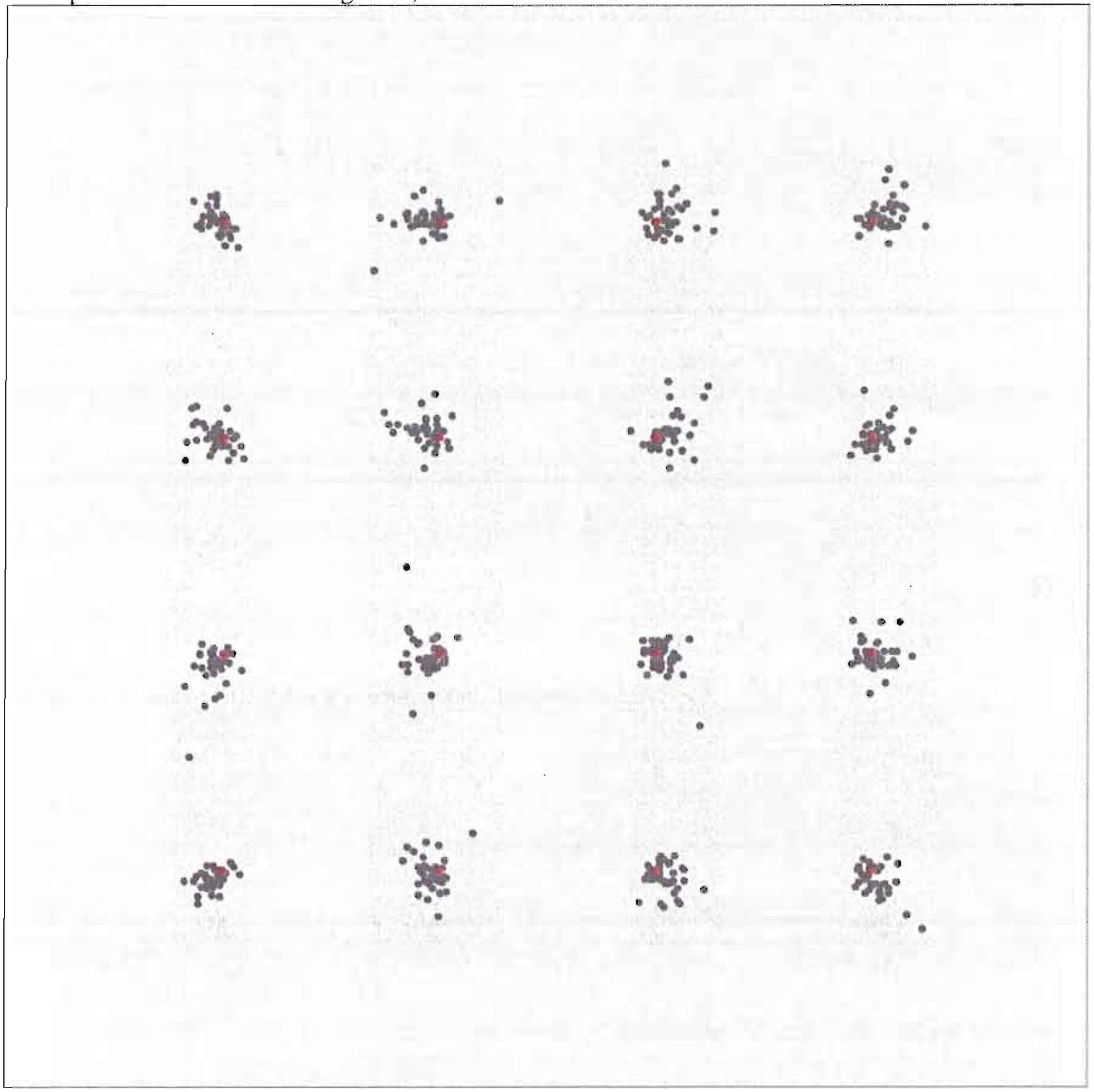
Appendix C.2

Participant Points for Blank Background, 50ms Retention Interval



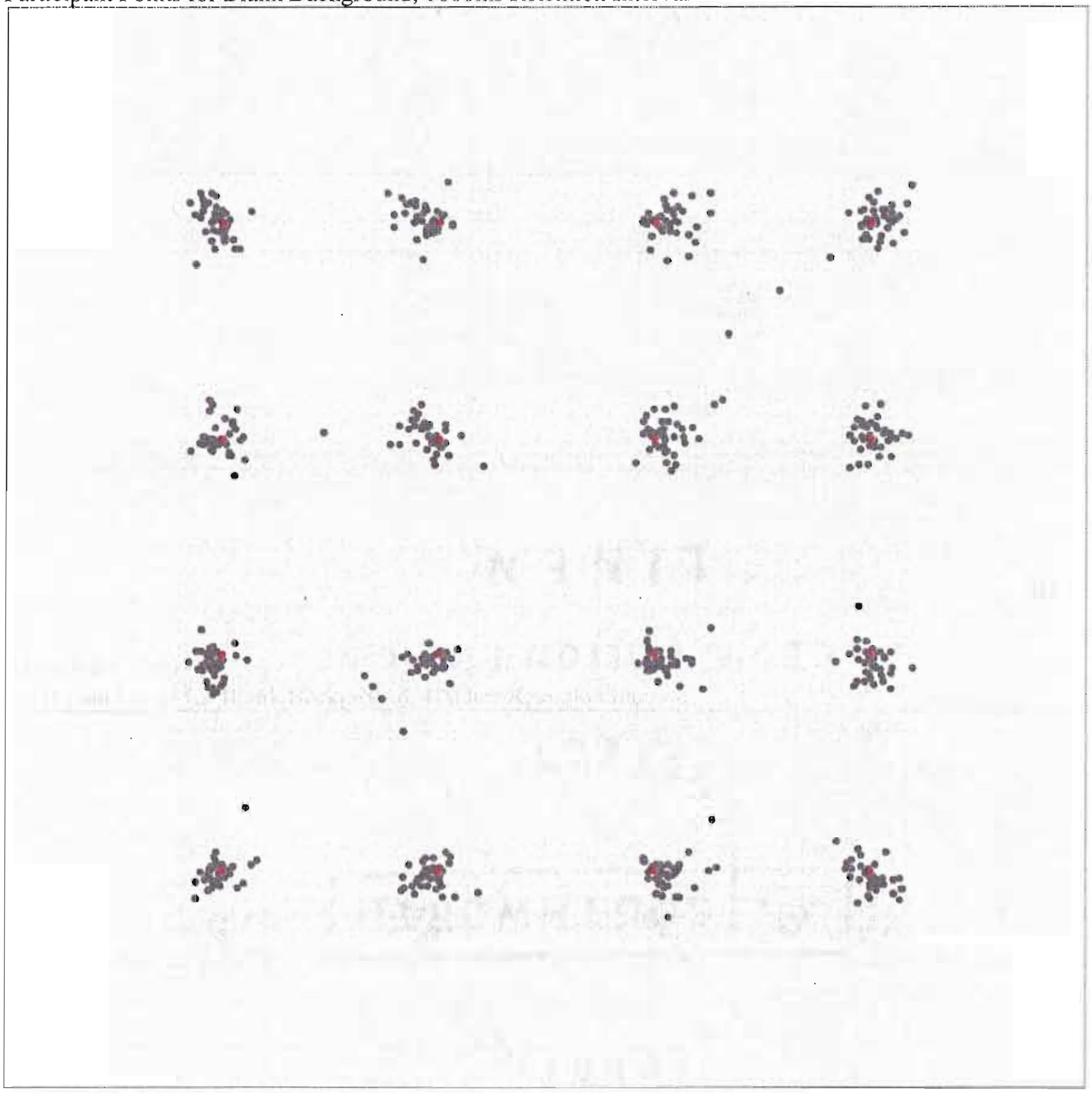
Appendix C.3

Participant Points for Blank Background, 500ms Retention Interval



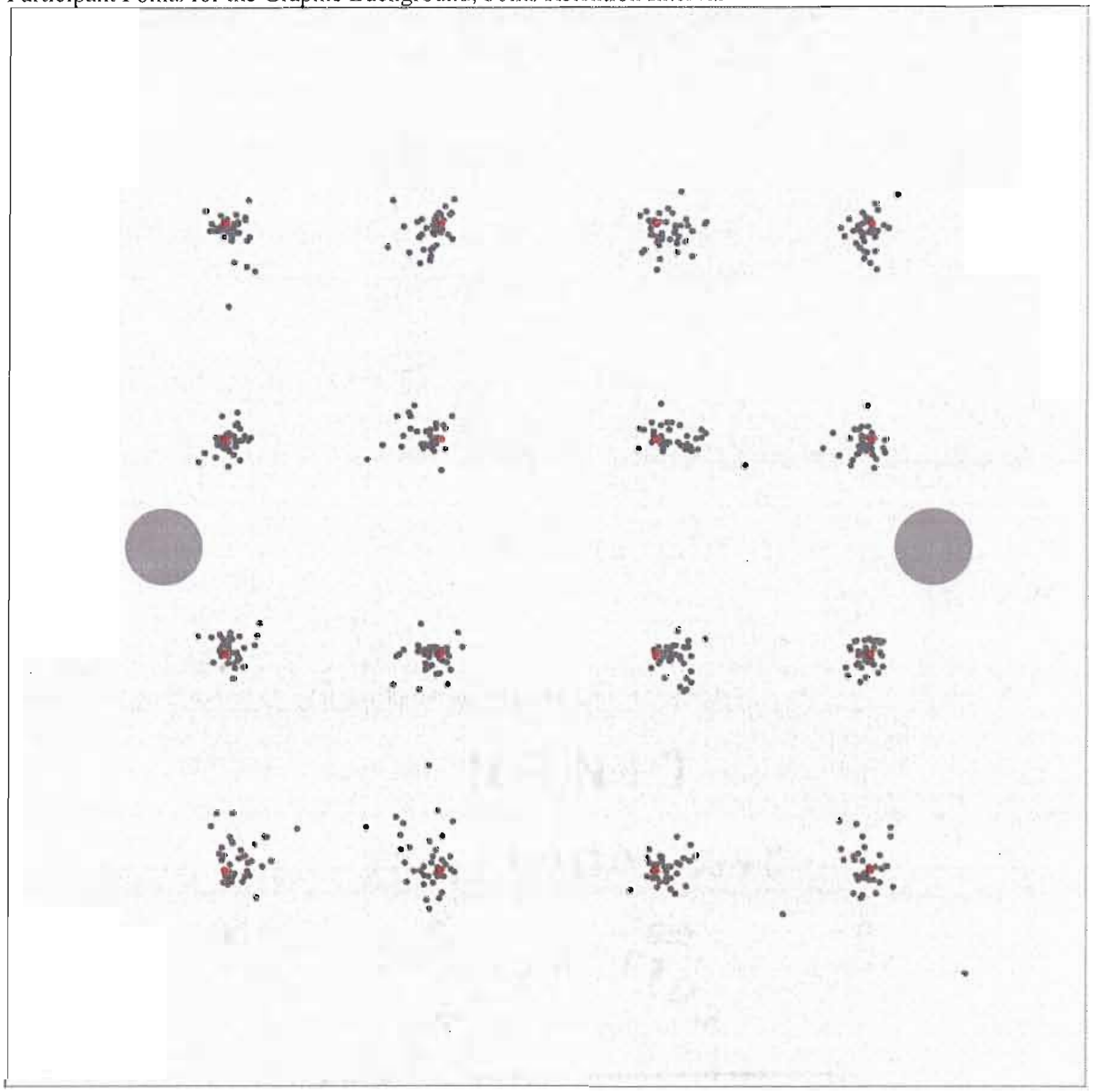
Appendix C.4

Participant Points for Blank Background, 1000ms Retention Interval



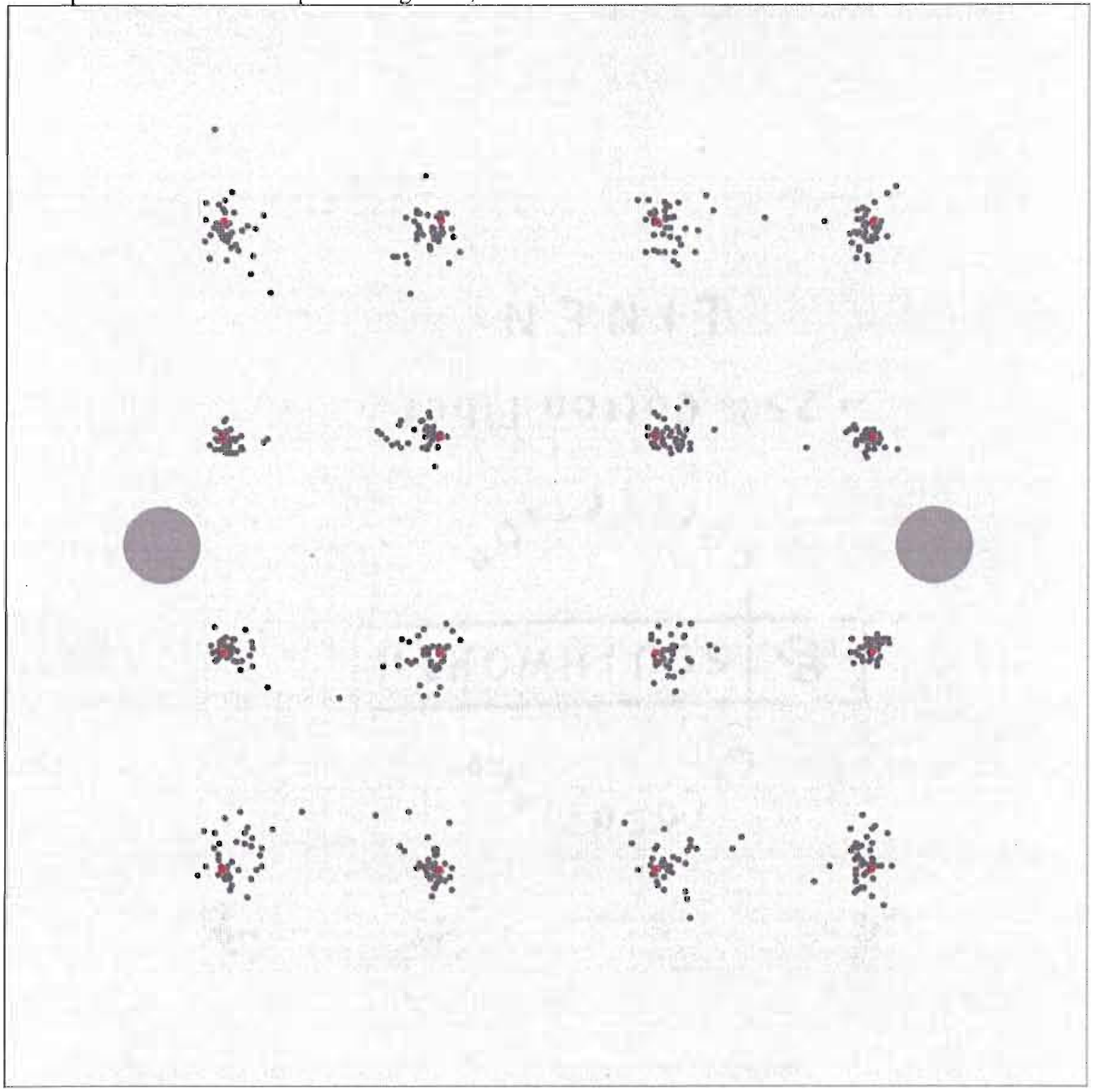
Appendix C.5

Participant Points for the Graphic Background, 50ms Retention Interval



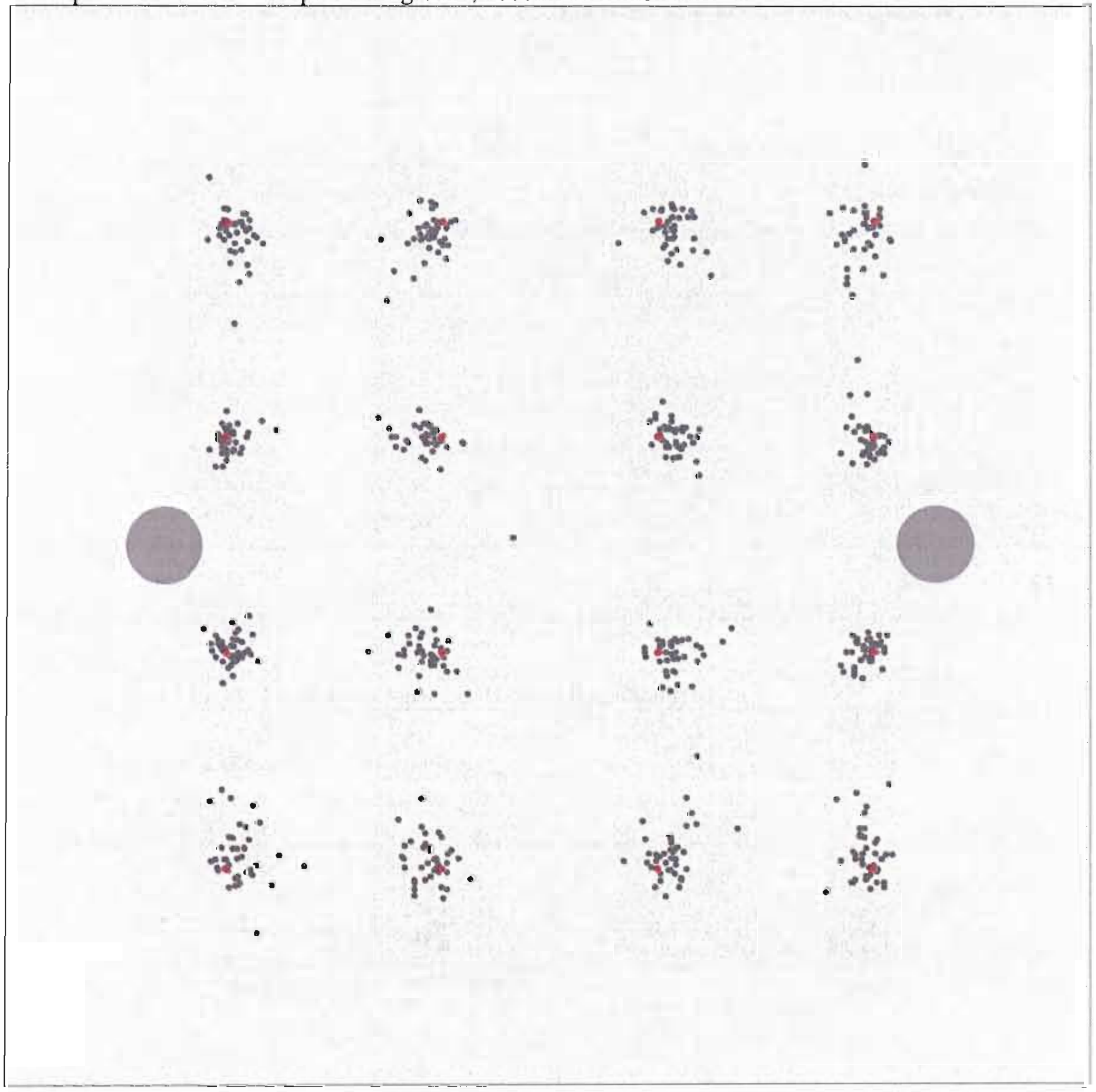
Appendix C.6

Participant Points for the Graphic Background, 500ms Retention Interval



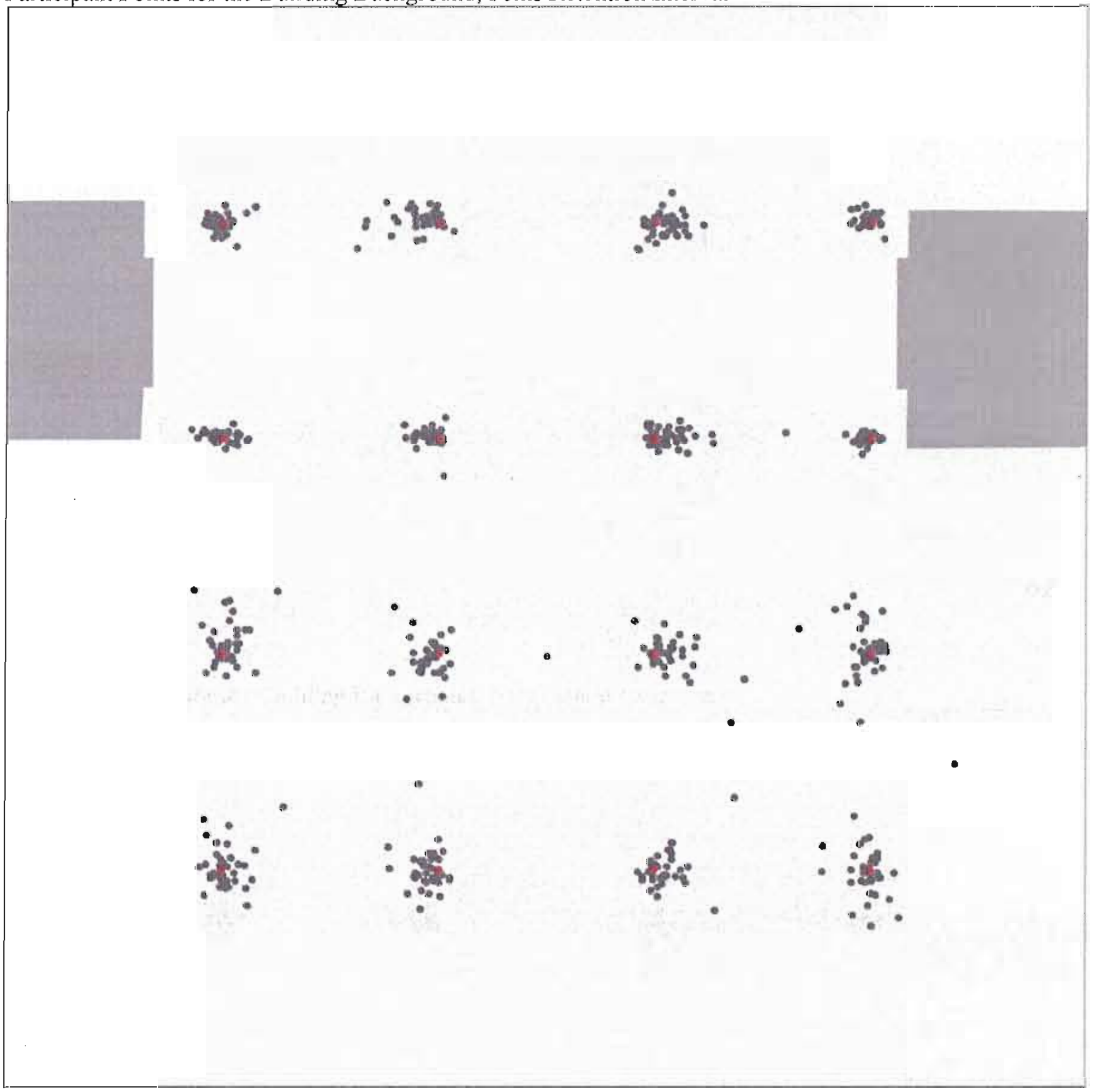
Appendix C.7

Participant Points for the Graphic Background, 1000ms Retention Interval



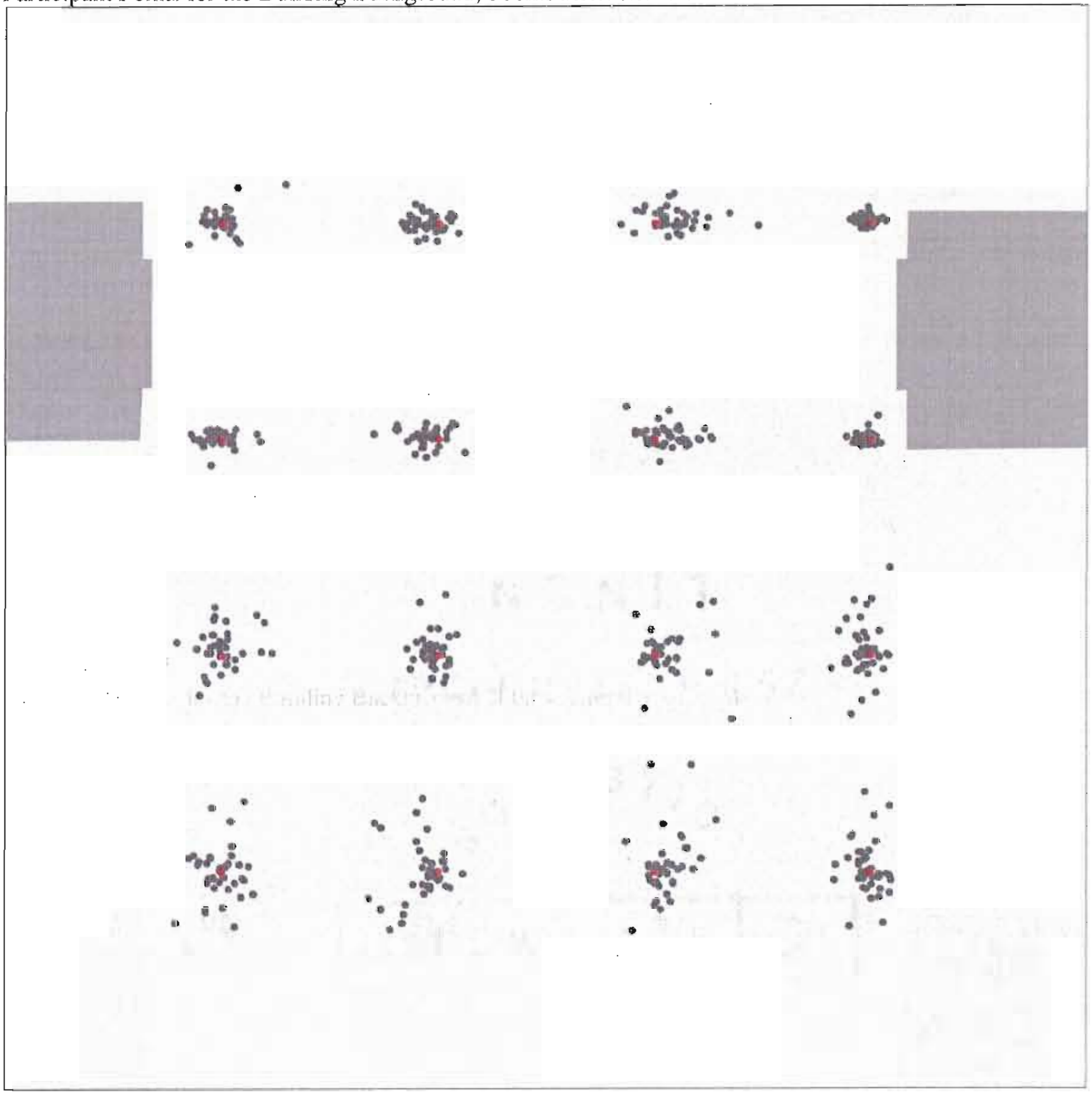
Appendix C.8

Participant Points for the Building Background, 50ms Retention Interval



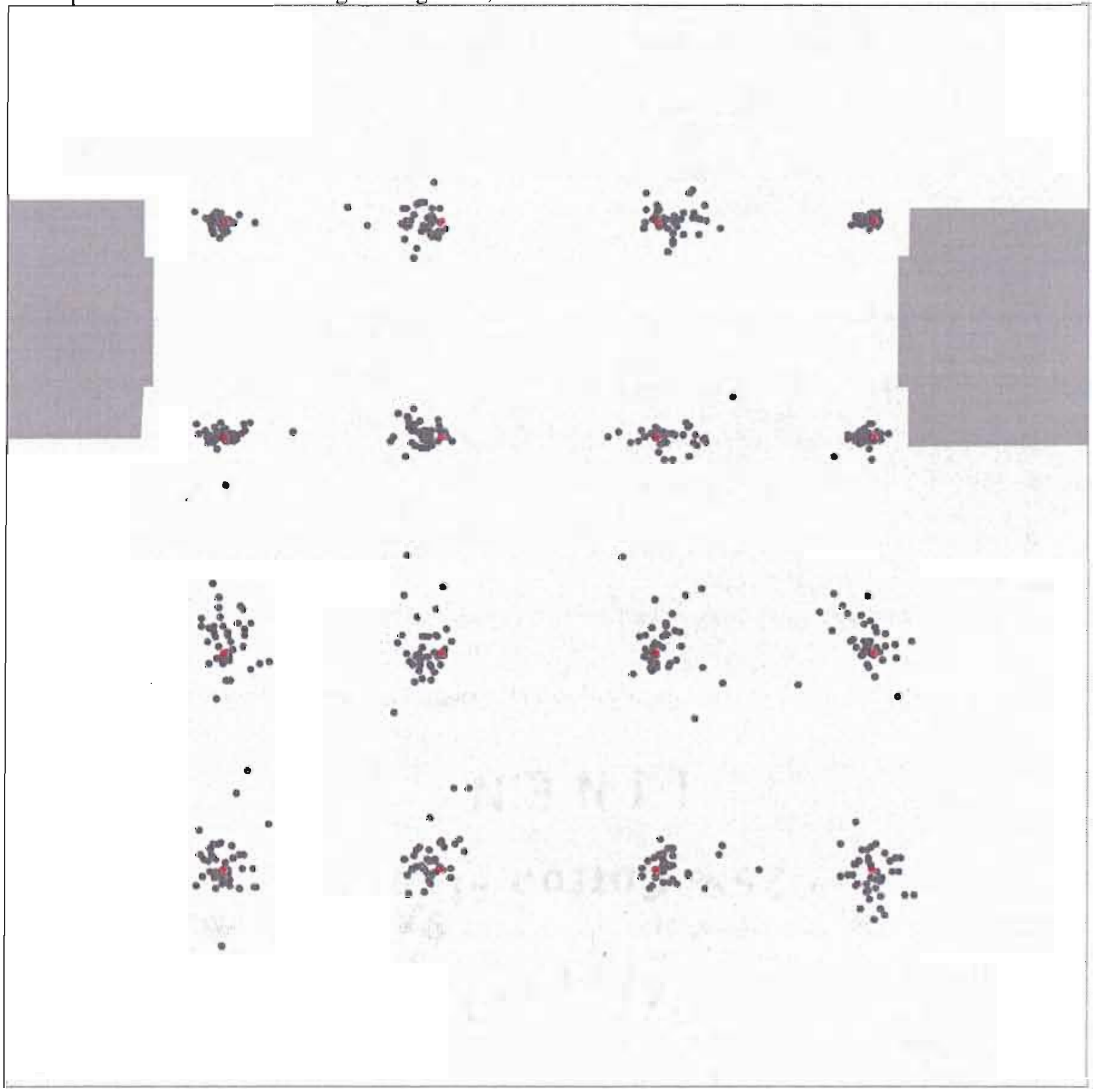
Appendix C.9

Participant Points for the Building Background, 500ms Retention Interval



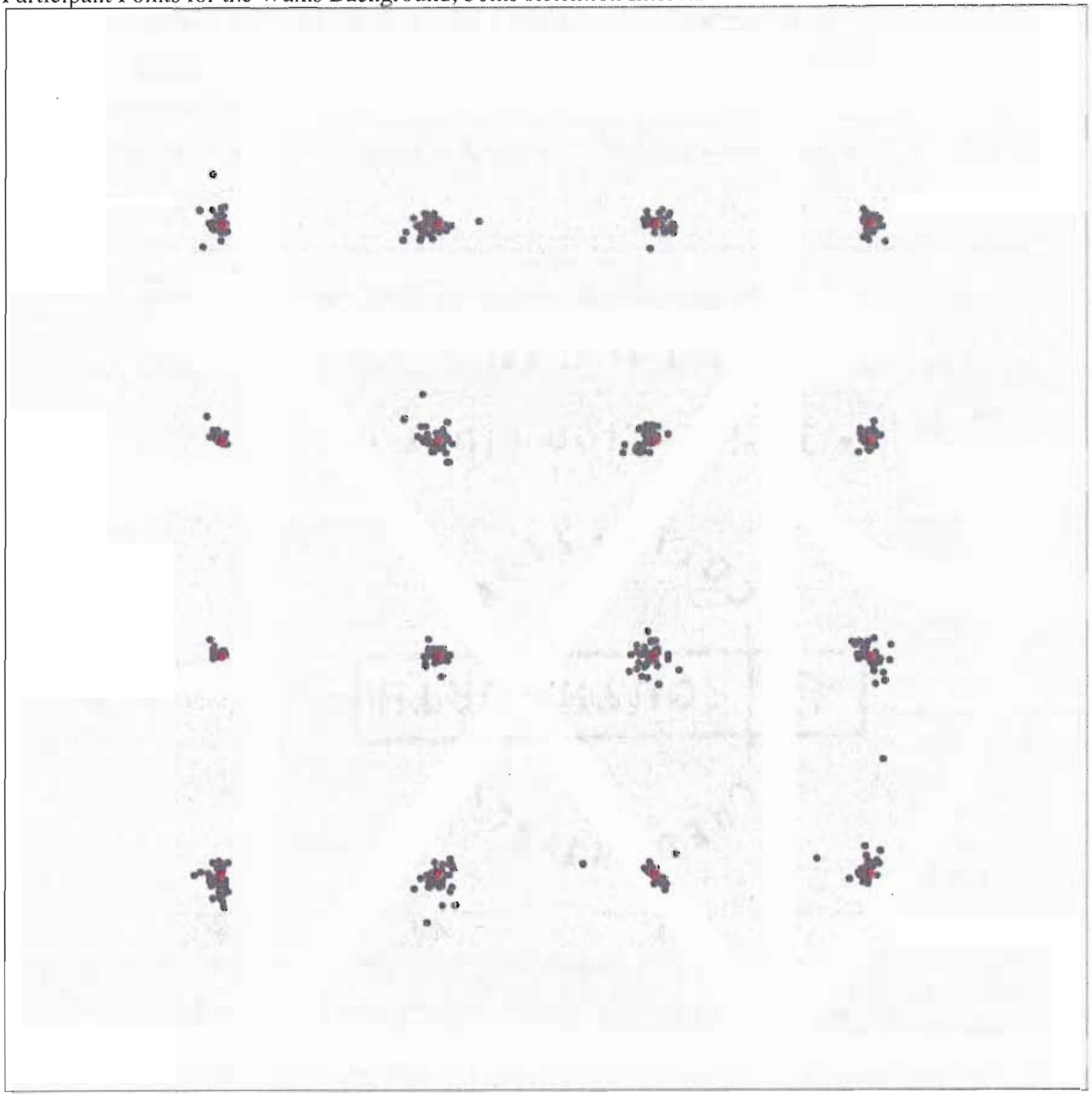
Appendix C.10

Participant Points for the Buildings Background, 1000ms Retention Interval



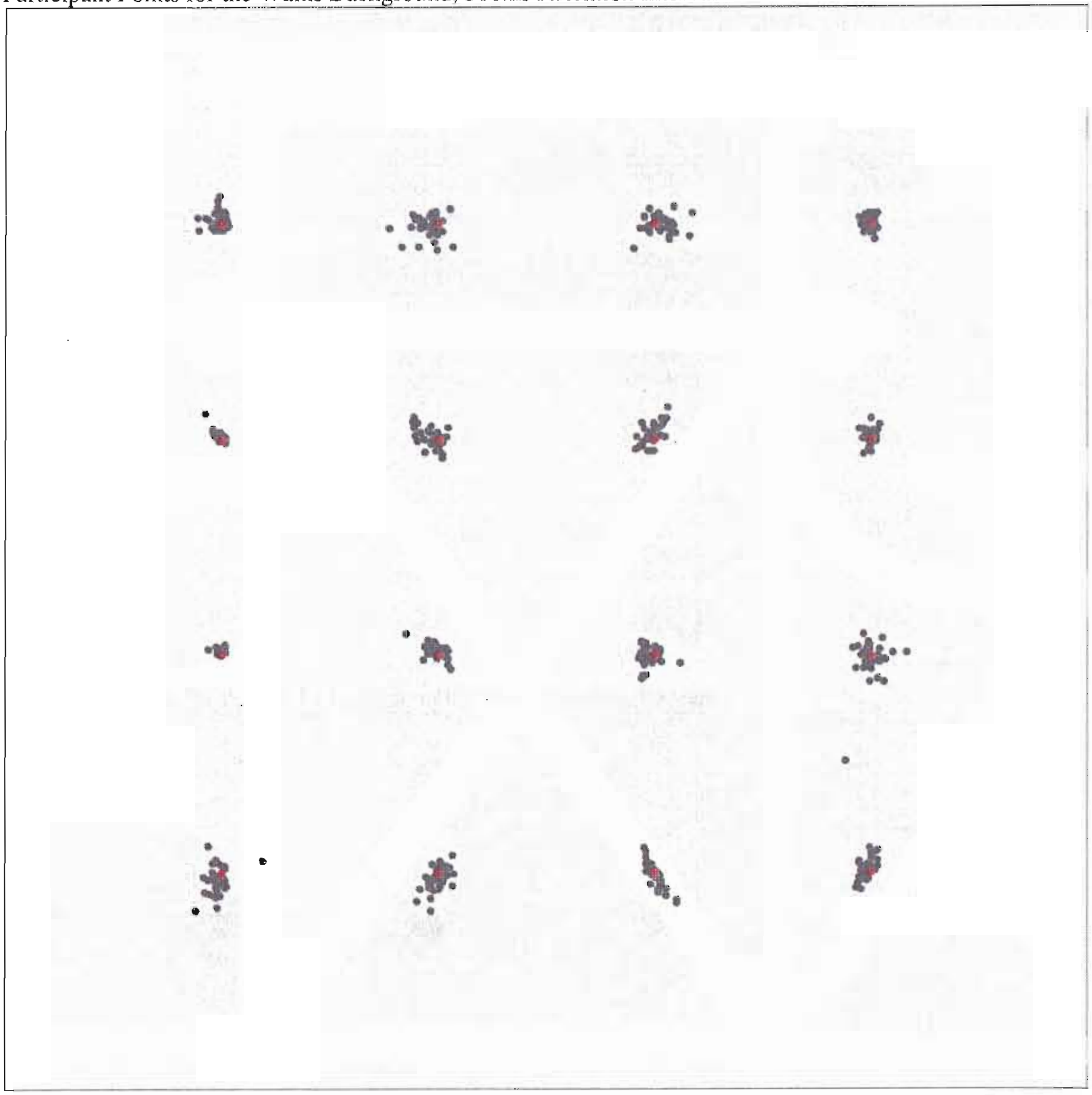
Appendix C.11

Participant Points for the Walks Background, 50ms Retention Interval



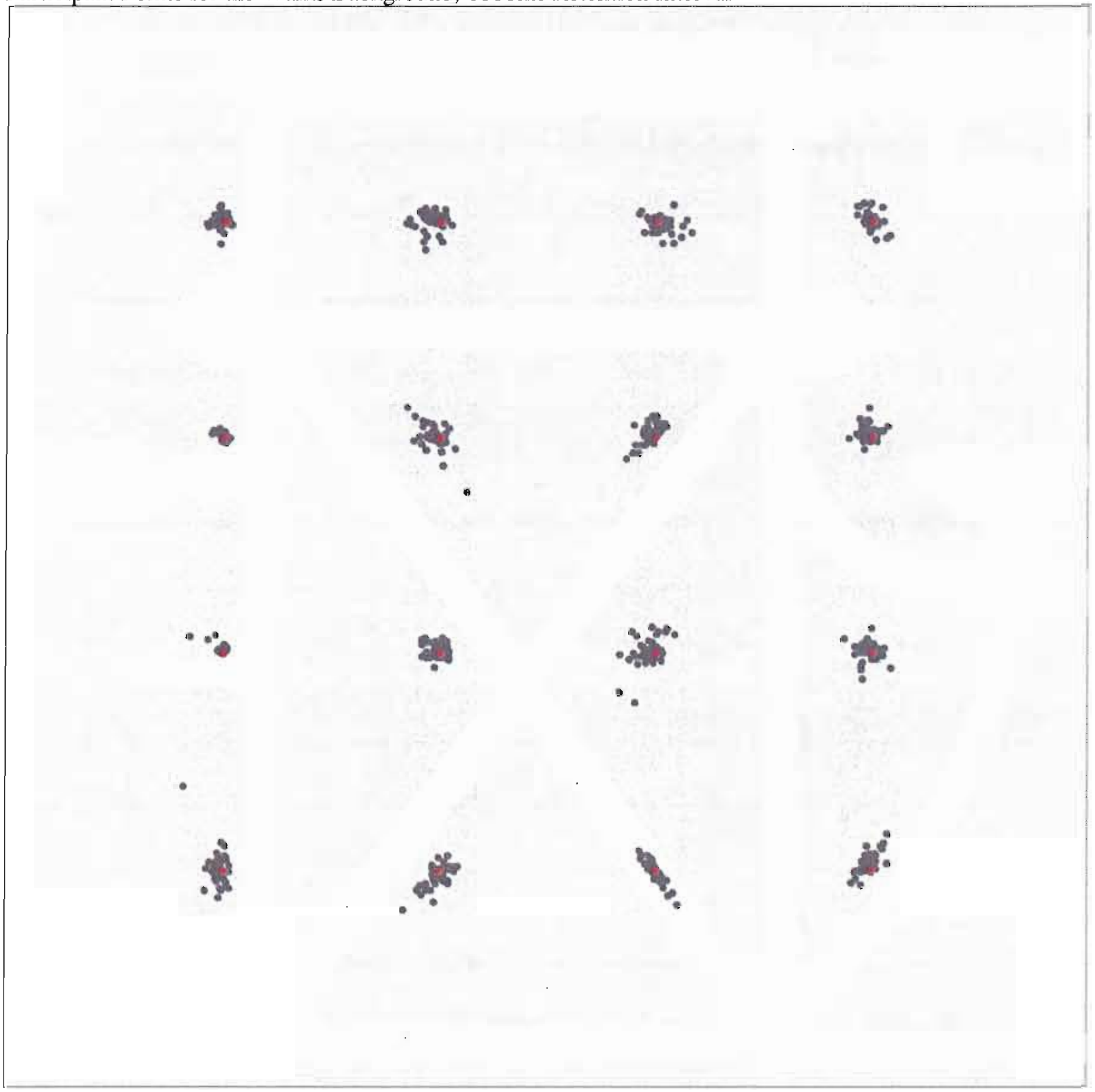
Appendix C.12

Participant Points for the Walks Background, 500ms Retention Interval



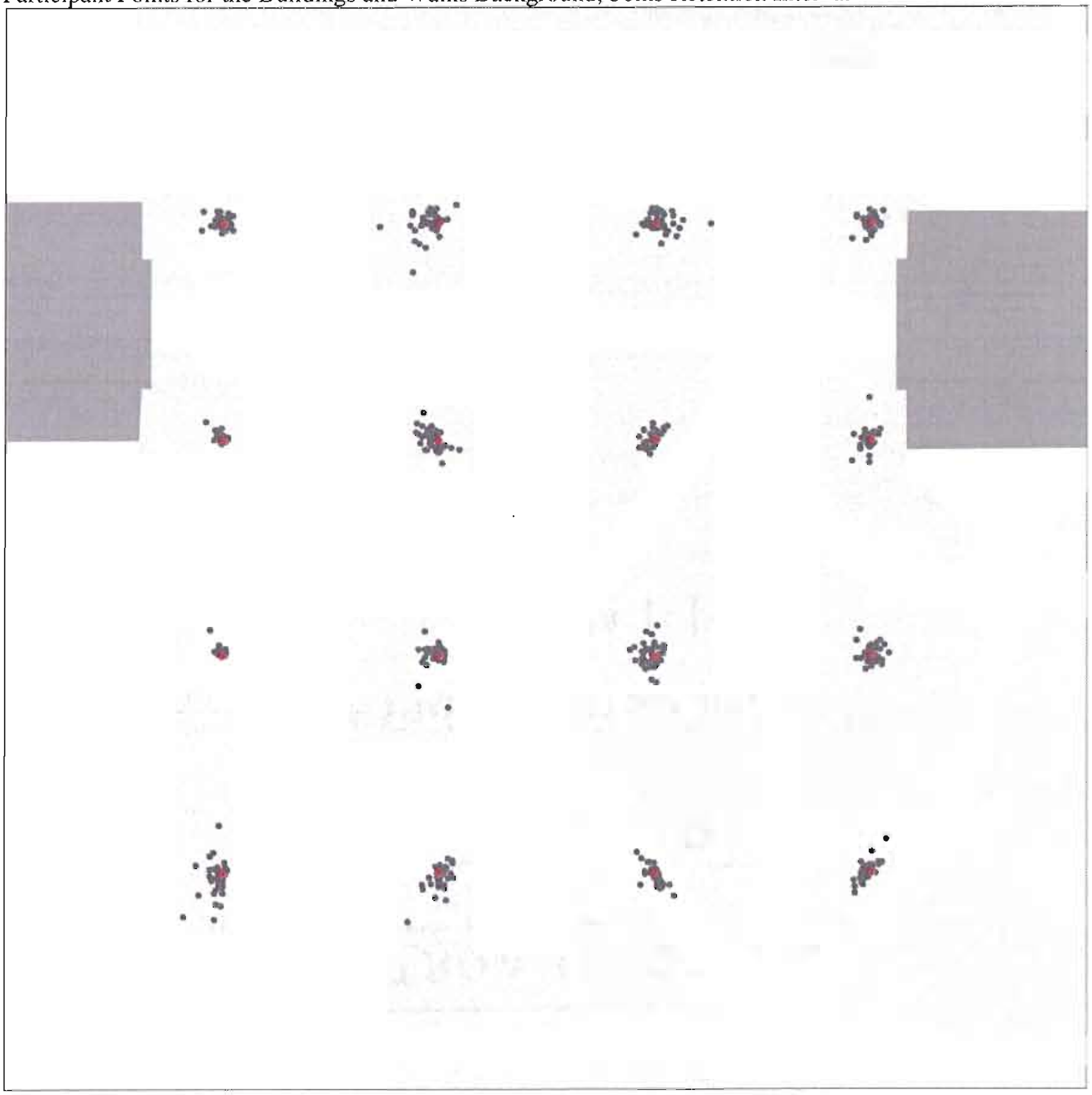
Appendix C.13

Participant Points for the Walks Background, 1000ms Retention Interval



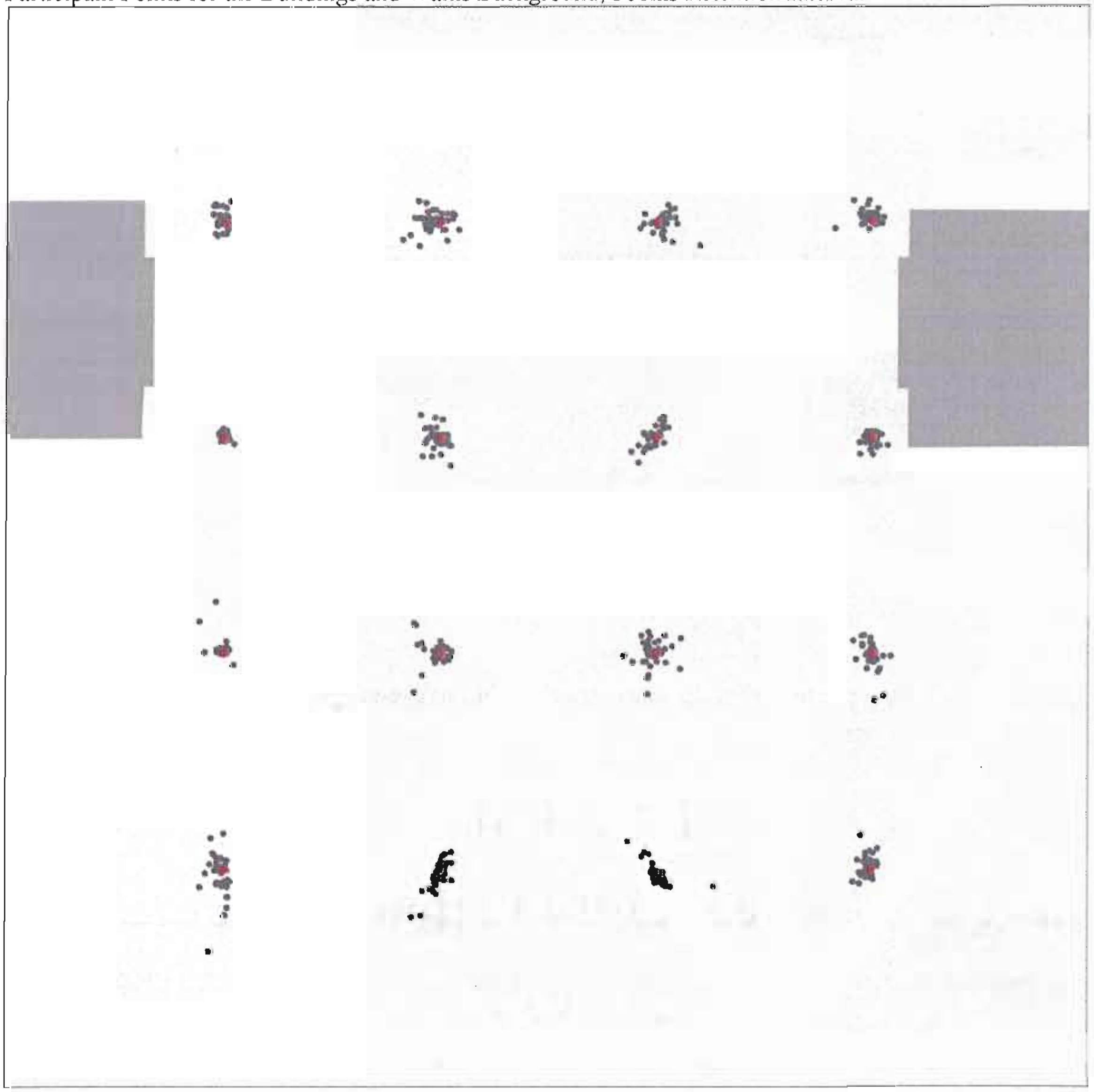
Appendix C.14

Participant Points for the Buildings and Walks Background, 50ms Retention Interval



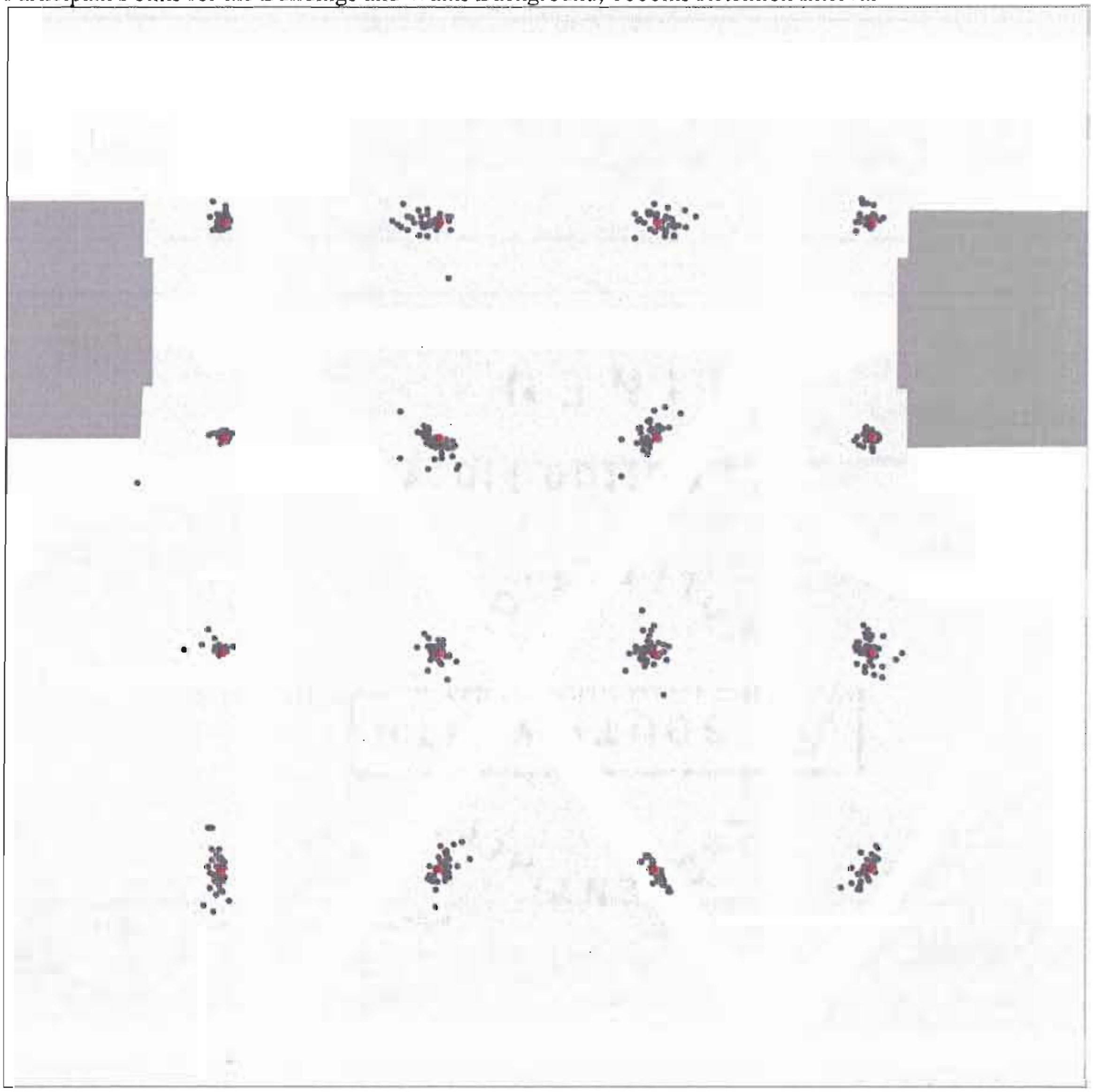
Appendix C.15

Participant Points for the Buildings and Walks Background, 500ms Retention Interval

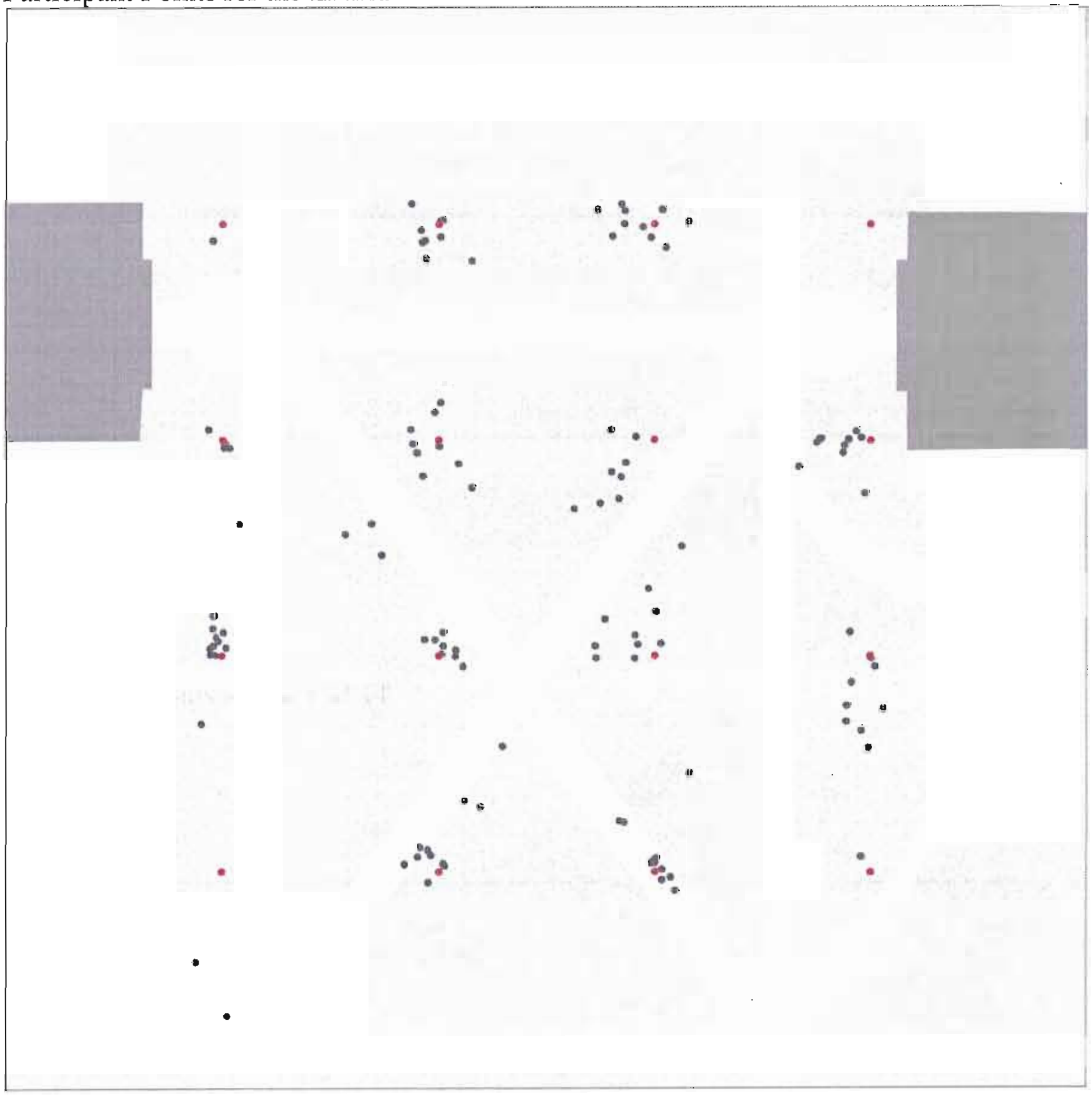


Appendix C.16

Participant Points for the Buildings and Walks Background, 1000ms Retention Interval



Appendix C.17
Participant Points for the EMRT



APPENDIX D

BONFERRONI COMPARISONS

Appendix D.1

Bonferroni Comparisons of SMRT average XY offset by background.

Dependent Variable: Average XY Offset

(I) Background	(J) Background	Mean Difference (I-J)	Std. Error	P
Blank	Graphics	-.231	0.03	0.00
	Buildings	-0.06	0.03	0.90
	Walks	.826	0.03	0.00
	Buildings and Walks	.838	0.03	0.00
Graphic	Buildings	.171	0.03	0.00
	Walks	1.057	0.03	0.00
	Buildings and Walks	1.069	0.03	0.00
Buildings	Walks	.885	0.03	0.00
	Buildings and Walks	.897	0.03	0.00
Walks	Buildings and Walks	0.01	0.03	1.00

Appendix D.2

Bonferroni Comparisons of SMRT average XY offset by retention interval.

Dependent Variable: Average XY Offset

(I) Retention INterval	(J) Retention Interval	Mean Difference (I-J)	Std. Error	P
50 ms	500 ms	-.105	0.03	0.00
	1000 ms	-.272	0.03	0.00
500 ms	1000 ms	-.167	0.03	0.00

Appendix D.3

Bonferroni Comparisons of SMRT average XY offset by target location.

Dependent Variable: Average XY Offset

(I) Target	(J) Target	Mean Difference (I-J)	Std. Error	p
1.00	2.00	0.34	0.06	0.00
	3.00	0.18	0.06	0.56
	4.00	-0.61	0.06	0.00
	5.00	-0.67	0.06	0.00
	6.00	-0.44	0.06	0.00
	7.00	-0.28	0.06	0.00
	8.00	-0.47	0.06	0.00
	9.00	-0.55	0.06	0.00
	10.00	-0.40	0.06	0.00
	11.00	-0.57	0.06	0.00
	12.00	-0.37	0.06	0.00
	13.00	0.04	0.06	1.00
	14.00	0.23	0.06	0.04
	15.00	-0.28	0.06	0.00
	16.00	-0.36	0.06	0.00
2.00	3.00	-0.16	0.06	1.00
	4.00	-0.95	0.06	0.00
	5.00	-1.01	0.06	0.00
	6.00	-0.78	0.06	0.00
	7.00	-0.63	0.06	0.00
	8.00	-0.82	0.06	0.00
	9.00	-0.90	0.06	0.00
	10.00	-0.74	0.06	0.00
	11.00	-0.91	0.06	0.00
	12.00	-0.72	0.06	0.00
	13.00	-0.30	0.06	0.00
	14.00	-0.11	0.06	1.00
	15.00	-0.62	0.06	0.00
	16.00	-0.70	0.06	0.00
3.00	4.00	-0.79	0.06	0.00
	5.00	-0.85	0.06	0.00
	6.00	-0.62	0.06	0.00
	7.00	-0.46	0.06	0.00
	8.00	-0.65	0.06	0.00
	9.00	-0.73	0.06	0.00
	10.00	-0.58	0.06	0.00
	11.00	-0.75	0.06	0.00
	12.00	-0.55	0.06	0.00
	13.00	-0.14	0.06	1.00
	14.00	0.05	0.06	1.00
	15.00	-0.46	0.06	0.00
	16.00	-0.53	0.06	0.00
4.00	5.00	-0.06	0.06	1.00

	6.00	0.17	0.06	0.85
	7.00	0.33	0.06	0.00
	8.00	0.14	0.06	1.00
	9.00	0.06	0.06	1.00
	10.00	0.21	0.06	0.12
	11.00	0.04	0.06	1.00
	12.00	0.24	0.06	0.03
	13.00	0.65	0.06	0.00
	14.00	0.84	0.06	0.00
	15.00	0.33	0.06	0.00
	16.00	0.25	0.06	0.01
5.00	6.00	0.23	0.06	0.04
	7.00	0.39	0.06	0.00
	8.00	0.20	0.06	0.25
	9.00	0.12	0.06	1.00
	10.00	0.27	0.06	0.00
	11.00	0.10	0.06	1.00
	12.00	0.30	0.06	0.00
	13.00	0.71	0.06	0.00
	14.00	0.90	0.06	0.00
	15.00	0.39	0.06	0.00
	16.00	0.31	0.06	0.00
6.00	7.00	0.16	0.06	1.00
	8.00	-0.03	0.06	1.00
	9.00	-0.12	0.06	1.00
	10.00	0.04	0.06	1.00
	11.00	-0.13	0.06	1.00
	12.00	0.06	0.06	1.00
	13.00	0.48	0.06	0.00
	14.00	0.67	0.06	0.00
	15.00	0.16	0.06	1.00
	16.00	0.08	0.06	1.00
7.00	8.00	-0.19	0.06	0.34
	9.00	-0.27	0.06	0.00
	10.00	-0.12	0.06	1.00
	11.00	-0.29	0.06	0.00
	12.00	-0.09	0.06	1.00
	13.00	0.32	0.06	0.00
	14.00	0.51	0.06	0.00
	15.00	0.00	0.06	1.00
	16.00	-0.07	0.06	1.00
8.00	9.00	-0.08	0.06	1.00
	10.00	0.07	0.06	1.00
	11.00	-0.10	0.06	1.00
	12.00	0.10	0.06	1.00
	13.00	0.51	0.06	0.00
	14.00	0.70	0.06	0.00
	15.00	0.19	0.06	0.30

	16.00	0.12	0.06	1.00
9.00	10.00	0.16	0.06	1.00
	11.00	-0.02	0.06	1.00
	12.00	0.18	0.06	0.55
	13.00	0.60	0.06	0.00
	14.00	0.78	0.06	0.00
	15.00	0.27	0.06	0.00
	16.00	0.20	0.06	0.21
10.00	11.00	-0.17	0.06	0.81
	12.00	0.03	0.06	1.00
	13.00	0.44	0.06	0.00
	14.00	0.63	0.06	0.00
	15.00	0.12	0.06	1.00
	16.00	0.04	0.06	1.00
11.00	12.00	0.20	0.06	0.24
	13.00	0.61	0.06	0.00
	14.00	0.80	0.06	0.00
	15.00	0.29	0.06	0.00
	16.00	0.22	0.06	0.09
12.00	13.00	0.42	0.06	0.00
	14.00	0.60	0.06	0.00
	15.00	0.09	0.06	1.00
	16.00	0.02	0.06	1.00
13.00	14.00	0.19	0.06	0.38
	15.00	-0.32	0.06	0.00
	16.00	-0.40	0.06	0.00
14.00	15.00	-0.51	0.06	0.00
	16.00	-0.58	0.06	0.00
15.00	16.00	-0.07	0.06	1.00

Appendix D.4

Bonferroni Comparisons of SMRT average XY offset by retention interval and background.

Dependent Variable: Average XY Offset

Ret Interval	(I) Back ground	(J) Back ground	Mean Difference (I-J)	Std. Error	Sig.(a)
50 ms	Blank	Graphic	-.285(*)	.060	.000
		Buildings	-.052	.060	1.000
		Walks	.684(*)	.060	.000
		Walks and Buildings	.726(*)	.060	.000
	Graphic	Blank	.285(*)	.060	.000
		Buildings	.233(*)	.060	.002
		Walks	.969(*)	.060	.000
		Walks and Buildings	1.011(*)	.060	.000
	Buildings	Blank	.052	.060	1.000
		Graphic	-.233(*)	.060	.002
		Walks	.736(*)	.060	.000
		Walks and Buildings	.778(*)	.060	.000
	Walks	Blank	-.684(*)	.060	.000
		Graphic	-.969(*)	.060	.000
		Buildings	-.736(*)	.060	.000
		Walks and Buildings	.042	.060	1.000
	Walks and Buildings	Blank	-.726(*)	.060	.000
		Graphic	-1.011(*)	.060	.000
		Buildings	-.778(*)	.060	.000
		Walks	-.042	.060	1.000
500 ms	Blank	Graphic	-.115	.060	.590
		Buildings	-.108	.060	.770
		Walks	.855(*)	.060	.000
		Walks and Buildings	.867(*)	.060	.000
	Graphic	Blank	.115	.060	.590
		Buildings	.007	.060	1.000
		Walks	.970(*)	.060	.000
		Walks and Buildings	.982(*)	.060	.000
	Buildings	Blank	.108	.060	.770
		Graphic	-.007	.060	1.000
		Walks	.963(*)	.060	.000
		Walks and Buildings	.975(*)	.060	.000
	Walks	Blank	-.855(*)	.060	.000
		Graphic	-.970(*)	.060	.000
		Buildings	-.963(*)	.060	.000
		Walks and Buildings	.012	.060	1.000
	Walks	Blank	-.867(*)	.060	.000

	and Buildings	Graphic	-.982(*)	.060	.000
		Buildings	-.975(*)	.060	.000
		Walks	-.012	.060	1.000
1000 ms	Blank	Graphic	-.293(*)	.060	.000
		Buildings	-.019	.060	1.000
		Walks	.939(*)	.060	.000
		Walks and Buildings	.920(*)	.060	.000
	Graphic	Blank	.293(*)	.060	.000
		Buildings	.274(*)	.060	.000
		Walks	1.232(*)	.060	.000
		Walks and Buildings	1.213(*)	.060	.000
	Buildings	Blank	.019	.060	1.000
		Graphic	-.274(*)	.060	.000
		Walks	.958(*)	.060	.000
		Walks and Buildings	.939(*)	.060	.000
	Walks	Blank	-.939(*)	.060	.000
		Graphic	-1.232(*)	.060	.000
		Buildings	-.958(*)	.060	.000
		Walks and Buildings	-.019	.060	1.000
	Walks and Buildings	Blank	-.920(*)	.060	.000
		Graphic	-1.213(*)	.060	.000
		Buildings	-.939(*)	.060	.000
		Walks	.019	.060	1.000

* The mean difference is significant at the .05 level.

Appendix D.5

Bonferroni Comparisons of SMRT average XY offset by target location and background.

Dependent Variable: Average XY Offset

Dot	(I) BG	(J) BG	Mean Difference (I-J)	Std. Error	Sig.(a)
1	Blank	Graphic	-.315	.140	.260
		Buildings	.471(*)	.140	.010
		Walks	.780(*)	.140	.000
		Walks and Buildings	.975(*)	.140	.000
	Graphic	Blank	.315	.140	.260
		Buildings	.786(*)	.140	.000
		Walks	1.095(*)	.140	.000
		Walks and Buildings	1.290(*)	.140	.000
	Buildings	Blank	-.471(*)	.140	.010
		Graphic	-.786(*)	.140	.000
		Walks	.309	.140	.289
		Walks and Buildings	.504(*)	.140	.004
	Walks	Blank	-.780(*)	.140	.000
		Graphic	-1.095(*)	.140	.000
		Buildings	-.309	.140	.289
		Walks and Buildings	.195	.140	1.000
	Walks and Buildings	Blank	-.975(*)	.140	.000
		Graphic	-1.290(*)	.140	.000
		Buildings	-.504(*)	.140	.004
		Walks	-.195	.140	1.000
2	Blank	Graphic	.222	.140	1.000
		Buildings	.415(*)	.140	.036
		Walks	1.488(*)	.140	.000
		Walks and Buildings	1.564(*)	.140	.000
	Graphic	Blank	-.222	.140	1.000
		Buildings	.193	.140	1.000
		Walks	1.266(*)	.140	.000
		Walks and Buildings	1.341(*)	.140	.000
	Buildings	Blank	-.415(*)	.140	.036
		Graphic	-.193	.140	1.000
		Walks	1.073(*)	.140	.000
		Walks and Buildings	1.148(*)	.140	.000
	Walks	Blank	-1.488(*)	.140	.000
		Graphic	-1.266(*)	.140	.000
		Buildings	-1.073(*)	.140	.000
		Walks and Buildings	.075	.140	1.000
	Walks and	Blank	-1.564(*)	.140	.000

	Buildings	Graphic	-1.341(*)	.140	.000
		Buildings	-1.148(*)	.140	.000
		Walks	-.075	.140	1.000
3	Blank	Graphic	.302	.140	.325
		Buildings	-.434(*)	.140	.023
		Walks	1.896(*)	.140	.000
		Walks and Buildings	1.837(*)	.140	.000
	Graphic	Blank	-.302	.140	.325
		Buildings	-.736(*)	.140	.000
		Walks	1.594(*)	.140	.000
		Walks and Buildings	1.535(*)	.140	.000
	Buildings	Blank	.434(*)	.140	.023
		Graphic	.736(*)	.140	.000
		Walks	2.330(*)	.140	.000
		Walks and Buildings	2.272(*)	.140	.000
	Walks	Blank	-1.896(*)	.140	.000
		Graphic	-1.594(*)	.140	.000
		Buildings	-2.330(*)	.140	.000
		Walks and Buildings	-.058	.140	1.000
	Walks and Buildings	Blank	-1.837(*)	.140	.000
		Graphic	-1.535(*)	.140	.000
		Buildings	-2.272(*)	.140	.000
		Walks	.058	.140	1.000
4	Blank	Graphic	-.881(*)	.140	.000
		Buildings	-.485(*)	.140	.007
		Walks	.231	.140	1.000
		Walks and Buildings	.163	.140	1.000
	Graphic	Blank	.881(*)	.140	.000
		Buildings	.396	.140	.053
		Walks	1.112(*)	.140	.000
		Walks and Buildings	1.044(*)	.140	.000
	Buildings	Blank	.485(*)	.140	.007
		Graphic	-.396	.140	.053
		Walks	.715(*)	.140	.000
		Walks and Buildings	.647(*)	.140	.000
	Walks	Blank	-.231	.140	1.000
		Graphic	-1.112(*)	.140	.000
		Buildings	-.715(*)	.140	.000
		Walks and Buildings	-.068	.140	1.000
	Walks and Buildings	Blank	-.163	.140	1.000
		Graphic	-1.044(*)	.140	.000
		Buildings	-.647(*)	.140	.000

		Walks	.068	.140	1.000
5	Blank	Graphic	-.237	.140	.921
		Buildings	-.093	.140	1.000
		Walks	.575(*)	.140	.001
		Walks and Buildings	.357	.140	.118
	Graphic	Blank	.237	.140	.921
		Buildings	.144	.140	1.000
		Walks	.812(*)	.140	.000
		Walks and Buildings	.594(*)	.140	.000
	Buildings	Blank	.093	.140	1.000
		Graphic	-.144	.140	1.000
		Walks	.668(*)	.140	.000
		Walks and Buildings	.450(*)	.140	.016
	Walks	Blank	-.575(*)	.140	.001
		Graphic	-.812(*)	.140	.000
		Buildings	-.668(*)	.140	.000
		Walks and Buildings	-.219	.140	1.000
	Walks and Buildings	Blank	-.357	.140	.118
		Graphic	-.594(*)	.140	.000
		Buildings	-.450(*)	.140	.016
		Walks	.219	.140	1.000
6	Blank	Graphic	-.182	.140	1.000
		Buildings	.122	.140	1.000
		Walks	.636(*)	.140	.000
		Walks and Buildings	.557(*)	.140	.001
	Graphic	Blank	.182	.140	1.000
		Buildings	.304	.140	.311
		Walks	.818(*)	.140	.000
		Walks and Buildings	.739(*)	.140	.000
	Buildings	Blank	-.122	.140	1.000
		Graphic	-.304	.140	.311
		Walks	.514(*)	.140	.003
		Walks and Buildings	.434(*)	.140	.023
	Walks	Blank	-.636(*)	.140	.000
		Graphic	-.818(*)	.140	.000
		Buildings	-.514(*)	.140	.003
		Walks and Buildings	-.080	.140	1.000
	Walks and Buildings	Blank	-.557(*)	.140	.001
		Graphic	-.739(*)	.140	.000
		Buildings	-.434(*)	.140	.023
		Walks	.080	.140	1.000
7	Blank	Graphic	-.204	.140	1.000

		Buildings	-.246	.140	.807
		Walks	.989(*)	.140	.000
		Walks and Buildings	.934(*)	.140	.000
	Graphic	Blank	.204	.140	1.000
		Buildings	-.042	.140	1.000
		Walks	1.193(*)	.140	.000
		Walks and Buildings	1.138(*)	.140	.000
	Buildings	Blank	.246	.140	.807
		Graphic	.042	.140	1.000
		Walks	1.235(*)	.140	.000
		Walks and Buildings	1.180(*)	.140	.000
	Walks	Blank	-.989(*)	.140	.000
		Graphic	-1.193(*)	.140	.000
		Buildings	-1.235(*)	.140	.000
		Walks and Buildings	-.055	.140	1.000
	Walks and Buildings	Blank	-.934(*)	.140	.000
		Graphic	-1.138(*)	.140	.000
		Buildings	-1.180(*)	.140	.000
		Walks	.055	.140	1.000
8	Blank	Graphic	-.588(*)	.140	.000
		Buildings	-.511(*)	.140	.004
		Walks	.394	.140	.055
		Walks and Buildings	.573(*)	.140	.001
	Graphic	Blank	.588(*)	.140	.000
		Buildings	.077	.140	1.000
		Walks	.982(*)	.140	.000
		Walks and Buildings	1.161(*)	.140	.000
	Buildings	Blank	.511(*)	.140	.004
		Graphic	-.077	.140	1.000
		Walks	.906(*)	.140	.000
		Walks and Buildings	1.084(*)	.140	.000
	Walks	Blank	-.394	.140	.055
		Graphic	-.982(*)	.140	.000
		Buildings	-.906(*)	.140	.000
		Walks and Buildings	.179	.140	1.000
	Walks and Buildings	Blank	-.573(*)	.140	.001
		Graphic	-1.161(*)	.140	.000
		Buildings	-1.084(*)	.140	.000
		Walks	-.179	.140	1.000
9	Blank	Graphic	-.373	.140	.086
		Buildings	-.233	.140	.978
		Walks	.726(*)	.140	.000

		Walks and Buildings	.586(*)	.140	.001
	Graphic	Blank	.373	.140	.086
		Buildings	.140	.140	1.000
		Walks	1,099(*)	.140	.000
		Walks and Buildings	.959(*)	.140	.000
	Buildings	Blank	.233	.140	.978
		Graphic	-.140	.140	1.000
		Walks	.959(*)	.140	.000
		Walks and Buildings	.819(*)	.140	.000
	Walks	Blank	-.726(*)	.140	.000
		Graphic	-1.099(*)	.140	.000
		Buildings	-.959(*)	.140	.000
		Walks and Buildings	-.140	.140	1.000
	Walks and Buildings	Blank	-.586(*)	.140	.001
		Graphic	-.959(*)	.140	.000
		Buildings	-.819(*)	.140	.000
		Walks	.140	.140	1.000
10	Blank	Graphic	-.189	.140	1.000
		Buildings	-.227	.140	1.000
		Walks	.704(*)	.140	.000
		Walks and Buildings	.811(*)	.140	.000
	Graphic	Blank	.189	.140	1.000
		Buildings	-.038	.140	1.000
		Walks	.893(*)	.140	.000
		Walks and Buildings	1.000(*)	.140	.000
	Buildings	Blank	.227	.140	1.000
		Graphic	.038	.140	1.000
		Walks	.931(*)	.140	.000
		Walks and Buildings	1.038(*)	.140	.000
	Walks	Blank	-.704(*)	.140	.000
		Graphic	-.893(*)	.140	.000
		Buildings	-.931(*)	.140	.000
		Walks and Buildings	.108	.140	1.000
	Walks and Buildings	Blank	-.811(*)	.140	.000
		Graphic	-1.000(*)	.140	.000
		Buildings	-1.038(*)	.140	.000
		Walks	-.108	.140	1.000
11	Blank	Graphic	-.497(*)	.140	.005
		Buildings	-.557(*)	.140	.001
		Walks	.445(*)	.140	.018
		Walks and Buildings	.352	.140	.130

	Graphic	Blank	.497(*)	.140	.005
		Buildings	-.060	.140	1.000
		Walks	.942(*)	.140	.000
		Walks and Buildings	.849(*)	.140	.000
	Buildings	Blank	.557(*)	.140	.001
		Graphic	.060	.140	1.000
		Walks	1.002(*)	.140	.000
		Walks and Buildings	.909(*)	.140	.000
	Walks	Blank	-.445(*)	.140	.018
		Graphic	-.942(*)	.140	.000
		Buildings	-1.002(*)	.140	.000
		Walks and Buildings	-.093	.140	1.000
	Walks and Buildings	Blank	-.352	.140	.130
		Graphic	-.849(*)	.140	.000
		Buildings	-.909(*)	.140	.000
		Walks	.093	.140	1.000
12	Blank	Graphic	-.304	.140	.312
		Buildings	-.081	.140	1.000
		Walks	.910(*)	.140	.000
		Walks and Buildings	.893(*)	.140	.000
	Graphic	Blank	.304	.140	.312
		Buildings	.223	.140	1.000
		Walks	1.214(*)	.140	.000
		Walks and Buildings	1.198(*)	.140	.000
	Buildings	Blank	.081	.140	1.000
		Graphic	-.223	.140	1.000
		Walks	.991(*)	.140	.000
		Walks and Buildings	.975(*)	.140	.000
	Walks	Blank	-.910(*)	.140	.000
		Graphic	-1.214(*)	.140	.000
		Buildings	-.991(*)	.140	.000
		Walks and Buildings	-.016	.140	1.000
	Walks and Buildings	Blank	-.893(*)	.140	.000
		Graphic	-1.198(*)	.140	.000
		Buildings	-.975(*)	.140	.000
		Walks	.016	.140	1.000
13	Blank	Graphic	-.374	.140	.084
		Buildings	1.073(*)	.140	.000
		Walks	1.101(*)	.140	.000
		Walks and Buildings	1.171(*)	.140	.000
	Graphic	Blank	.374	.140	.084
		Buildings	1.447(*)	.140	.000

		Walks	1.475(*)	.140	.000
		Walks and Buildings	1.545(*)	.140	.000
	Buildings	Blank	-1.073(*)	.140	.000
		Graphic	-1.447(*)	.140	.000
		Walks	.028	.140	1.000
		Walks and Buildings	.098	.140	1.000
	Walks	Blank	-1.101(*)	.140	.000
		Graphic	-1.475(*)	.140	.000
		Buildings	-.028	.140	1.000
		Walks and Buildings	.070	.140	1.000
	Walks and Buildings	Blank	-1.171(*)	.140	.000
		Graphic	-1.545(*)	.140	.000
		Buildings	-.098	.140	1.000
		Walks	-.070	.140	1.000
14	Blank	Graphic	.051	.140	1.000
		Buildings	.842(*)	.140	.000
		Walks	.951(*)	.140	.000
		Walks and Buildings	1.063(*)	.140	.000
	Graphic	Blank	-.051	.140	1.000
		Buildings	.791(*)	.140	.000
		Walks	.900(*)	.140	.000
		Walks and Buildings	1.012(*)	.140	.000
	Buildings	Blank	-.842(*)	.140	.000
		Graphic	-.791(*)	.140	.000
		Walks	.109	.140	1.000
		Walks and Buildings	.221	.140	1.000
	Walks	Blank	-.951(*)	.140	.000
		Graphic	-.900(*)	.140	.000
		Buildings	-.109	.140	1.000
		Walks and Buildings	.113	.140	1.000
	Walks and Buildings	Blank	-1.063(*)	.140	.000
		Graphic	-1.012(*)	.140	.000
		Buildings	-.221	.140	1.000
		Walks	-.113	.140	1.000
15	Blank	Graphic	.389	.140	.062
		Buildings	-.386	.140	.066
		Walks	.619(*)	.140	.000
		Walks and Buildings	.805(*)	.140	.000
	Graphic	Blank	-.389	.140	.062
		Buildings	-.775(*)	.140	.000
		Walks	.230	.140	1.000
		Walks and Buildings	.416(*)	.140	.035

	Buildings	Blank	.386	.140	.066
		Graphic	.775(*)	.140	.000
		Walks	1.005(*)	.140	.000
		Walks and Buildings	1.191(*)	.140	.000
	Walks	Blank	-.619(*)	.140	.000
		Graphic	-.230	.140	1.000
		Buildings	-1.005(*)	.140	.000
		Walks and Buildings	.186	.140	1.000
	Walks and Buildings	Blank	-.805(*)	.140	.000
		Graphic	-.416(*)	.140	.035
		Buildings	-1.191(*)	.140	.000
		Walks	-.186	.140	1.000
16	Blank	Graphic	-.518(*)	.140	.003
		Buildings	-.625(*)	.140	.000
		Walks	.769(*)	.140	.000
		Walks and Buildings	.760(*)	.140	.000
	Graphic	Blank	.518(*)	.140	.003
		Buildings	-.107	.140	1.000
		Walks	1.287(*)	.140	.000
		Walks and Buildings	1.277(*)	.140	.000
	Buildings	Blank	.625(*)	.140	.000
		Graphic	.107	.140	1.000
		Walks	1.394(*)	.140	.000
		Walks and Buildings	1.385(*)	.140	.000
	Walks	Blank	-.769(*)	.140	.000
		Graphic	-1.287(*)	.140	.000
		Buildings	-1.394(*)	.140	.000
		Walks and Buildings	-.010	.140	1.000
	Walks and Buildings	Blank	-.760(*)	.140	.000
		Graphic	-1.277(*)	.140	.000
		Buildings	-1.385(*)	.140	.000
		Walks	.010	.140	1.000

* The mean difference is significant at the .05 level.

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