ANIMATED AND STATIC CARTOGRAPHY: COMPARING USER ABILITY AND
CONFIDENCE IN INFORMATION ACQUISITION

by

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(Under the Direction of Thomas W. Hodler)

ABSTRACT

Previous research has demonstrated that in some circumstances, animated maps are more
effective than equivalent static maps, while in other situations the opposite is true. An
experiment was conducted in which users were divided into three groups and shown either static
maps, animated maps, or a mix of static and animated maps. Originally based on land use/land
cover data, the maps were abstract, very complex, and nominally categorized, and they depicted
the same areas at five successive points in time. Participants answered questions about the
information depicted and rated their confidence in the answers they provided. Results suggest
that animation decreases response accuracy and confidence and increases response time, though
these effects are largely predicated on other factors.

INDEX WORDS: Cartography, Animation, Animated Cartography, Confidence, Maps
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For Sara
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CHAPTER 1
INTRODUCTION

Humans have been making artifactual maps for at least four thousand years (Aber, 2004), but until very recently, the limitations of the media out of which maps were fashioned required the depiction of an unchanging world where all features are frozen at some particular moment in time. Historically cartographers had to rely solely on static media to represent the fluid world. Consequently change could only be implied as, for example, by a series of sequential static maps portraying a phenomenon at different points in time. With the advent of modern animation and cinematic techniques and advances in computer science, rendering the world dynamically became possible. Today, traditional and computer-based animation offer ways for cartographers to surmount the barriers imposed on them by paper and other static media, which are poorly suited to directly portray change and force the mapmaker to reduce a world of constant flux to one of motionless snapshots.

Thrower was the first to formally recognize the potential benefits of linking cartography and animation and to promote greater use of the technique within geography (1959). He believed animation to be the best method “for illustrating the dynamic nature of certain areal relationships” (Thrower, 1961, 28). Given the general public’s familiarity with animation, Thrower asserted that its use has the potential to enhance geographic education as well as to allow geographers to disseminate ideas and information to a wider audience (Harrower, 2003a). Drawing on the congruence principle, animation would seem to be an ideal method for depicting temporal change (Tversky et al., 2002). However, in spite of Thrower’s optimism and that of
more recent proponents of animation, there are skeptics (Kim et al., 2007; Hegarty et al., 2003; Tversky et al., 2002; Lowe, 2003; Lowe, 1999) who question the efficacy of animation in its ability to communicate spatial and non-spatial information and engender knowledge in a viewer. They challenge the assumption that animation is a superior means of representing continuous change vis-à-vis static images. Furthermore, some evidence suggests that map readers are less confident with information acquired from animations when compared to information derived from static graphics (Harrower, 2003b; Morrison, 2000; Rieber and Parmley, 1995). If animation is to remain a valid and useful cartographic technique, questions regarding its efficacy and user confidence in the informational content will have to be resolved.

Since animations are often more challenging, time-consuming, and costly to produce than a map series of static small-multiples, cartographers would like assurance that the extra effort involved in creating an animated map would not have been wasted in the production of a map whose communicative function is ineffective or lost completely. Fundamentally animation may be less effective than static images in conveying information, and if this is the case, cartographers should avoid using animation except when seeking to create the type of novelty maps that defined much of animated cartography prior to the 1990s (Harrower, 2003a). Similarly, if there is a fundamental lack of user confidence in the content and information derived from animated maps that cannot be redressed, logic suggests a similar avoidance of the use of animation for mapmakers interested in presenting or disseminating knowledge to any audience.

Maps are often pieces of an argument or dialogue. They are texts infused with meaning by their creators and interpreted by their readers. The very act of making a map is, at the very least, an assertion that what is contained in the map is somehow of more significance than that
which is not contained in the map, and as such, maps represent an interest that the map author
acknowledges is relevant, either explicitly or implicitly (Wood, 1992). For example, a map
depicting the disappearance of the world’s rainforests due to deforestation is essentially making a
claim that deforestation is an issue with which the map’s intended audience should be concerned.
A cartographer interested in communicating specific geographic information would be well
served to select an effective cartographic technique for displaying that information so that a
reader may effectively take away from the map an interpretation that is both accurate and imbued
with confidence. Is a cartographer inadvertently weakening an argument by choosing animation
as a cartographic technique, thereby unwittingly undermining the map’s efficacy and the map
reader’s confidence in the informational content? Does animation’s ability to display change
directly render it superior to static small-multiple images in terms of effectively conveying a
message? For animated maps to be truly effective, map readers must be able to comprehend the
underlying meaning and have faith that their interpretation is correct.

While critics of animation point to research where static graphics outperformed animated
graphics, supporters assert that other research demonstrates the exact opposite in certain
situations. With the existence of conflicting evidence from previous research regarding the
efficacy of animation, it is unlikely that the wholesale abandonment of animation in cartography
will ever be necessary, but what may emerge over time is that animated maps are better suited
for specific applications as Slocum et al. (2004) and Harrower (2007) suggest. Some of
animation’s proponents argue that its most valuable contribution to geography is its potential to
aid in the exploration of data (Dorling, 1992; Openshaw et al., 1994; MacEachren, 1994)
because it can reveal previously unknown patterns to domain experts (Monmonier, 1990;
Dorling and Openshaw, 1992; DiBiase et al., 1992; Blok et al., 1999; Harrower et al., 2000;
Harrower, 2002). Participant interviews conducted in one study suggest that people believe that animation is better suited for certain tasks than static maps. This hints at the possibility that the truth is more complicated than unequivocally stating that static maps are fundamentally more effective than animated maps and provide a higher degree of confidence to map readers. There may also be means for addressing any potential shortcomings of animated maps and taking steps to combat weaknesses through various design techniques.

Despite the potential and presumed benefits of using animation in cartography, questions related to its effectiveness and user confidence in knowledge derived from it remain unanswered. The main focus of this work is guided by three research questions, and the goal of this research is to provide answers to these questions. Firstly, is there a statistically significant difference in the effectiveness of animated maps when compared to equivalent static maps? In other words, can people extract information with the same accuracy from an animated map that they can from a static map with the same informational content? Secondly, is there a statistically significant difference in response time when users answer questions using animated maps as compared to using static maps? Longer response times may indicate that map viewers may need more time to process the information contained in animated maps. Finally, is there a statistically significant difference in the level of confidence map-readers place in the information acquired from an animated map as compared to information acquired from a static map? People may feel less confident in knowledge gained through the reading of animated map or in their ability to properly interpret the map’s content.

To address these questions this study:

1. compares the effectiveness of animated maps to equivalent static small-multiple maps;
2. compares response times for answering questions related to animated maps to those of equivalent static small-multiples maps;

3. compares user confidence in the information derived from animated maps to equivalent static small-multiple maps.

The results of this study will help guide cartographers in the appropriate uses of animation. Evaluating the performance of map readers highlights aspects of animated map design that need to be improved or subjected to further scrutiny so that cartographers might produce more effective maps.
CHAPTER 2

LITERATURE REVIEW

Animated Map Design

Cartographers face unique design challenges when producing animated maps. For instance, cartographers must decide upon an appropriate animation pace, an appropriate level of user control, and appropriate and effective designs for those controls. When designing an animated map, cartographers must also be cognizant of the higher cognitive demands placed on a viewer by animation, which often lead to problems that hinder a reader’s comprehension (Harrower, 2007). Because of these challenges, designing an effective animated map is generally more difficult than creating a static map due to increased complexity and a greater number of design considerations.

Research exploring this complexity and these design considerations has proliferated since the early 1990s. Gersmehl (1990) attempted to provide a conceptual framework for understanding various animation techniques as “metaphors.” He identifies nine metaphors of varying flexibility and complexity. DiBiase et al. (1992) articulate the visual variables that are unique to animation and distance its techniques from those applicable to traditional static cartography. MacEachren (1994) argues that animation is most useful when time is regarded as a variable suited for manipulation, and he identifies seven “primitives” for viewing time as such. Peterson (1994) enumerates eight animation variables and proposes a set of practical guidelines for designing effective user interfaces and determining proper animation pacing. Peterson (1993) asserts that the speed of animation should be dictated by the purpose of the map, but he
also points out that “research needs to be done on such rapid map viewing” (Peterson, 1993, 44). So while there is research that focuses on laying the theoretical groundwork for the proper construction of animated maps, some fundamental questions still require more attention.

Another component of animated cartography that has received particular attention regarding aspects of design is the legend. Campbell and Egbert (1990) point out that under certain circumstances the use of legends could be both redundant and distracting because of the viewer’s limited viewing time leading to confusion or misinterpretation. Peterson (1995) boldly asserts that the display of any legend during a map animation would detract from the overall efficacy the map. However, Kraak et al. (1997) believe that including a legend is necessary for animated maps to aid a viewer in understanding and interpreting the map’s spatial and temporal aspects. Edsall et al. (1997) experimentally tested three legend types in an effort to determine what kind of legend is most effective in contributing to the interpretation of animated maps rather than distracting a viewer’s attention from the mapped area. Ultimately, Edsall et al. (1997) conclude that the selection of the legend type should be dictated by the map’s purpose, so that a single legend type does not work equally well for all situations. While the necessity of incorporating a legend in a traditional static map has been studied and is well understood, for animated maps such a fundamental component of map design still engenders debate and arguably requires further research for understanding its role in map comprehension.

Harrower, a strong proponent of animated cartography, recognizes that “animating maps presents an amplified cartographic challenge” (Harrower, 2003b, 63). He proposes solutions to four specific challenges outlined by Morrison (2000) that confront cartographers who choose animation. Although Harrower is certain that the problems of disappearance, attention,
complexity, and confidence can be overcome with appropriate design strategies, ultimately his proposals remained untested.

Animated cartography is substantially different from traditional static cartography. Traditional static cartography has a wealth of practical design advice, which is lacking or in some cases completely contradictory, for animated cartography. This presents a number of challenges for mapmakers seeking to create effective animated maps.

**Comparative Research**

Writing about the history of animated cartography, Harrower (2003a) enumerates six major research themes relating to animated cartography:

1) methods for animating time-series data, 2) methods for animating across attributes of data, 3) methods for representing uncertainty and data quality in animated maps, 4) designing effective temporal legends and controls, 5) identifying the visual variables of animation, and 6) methods for temporal interpolation and smoothing of sparse data sets (Harrower, 2003a, 35).

Absent from this list is a theme that captures the growing body of comparative research that examines animated maps in relation to static maps.

Various researchers have conducted controlled experiments in which participants were asked to answer questions based on information presented in either animated maps or static maps. The questions were meant to gauge a subject’s comprehension and analysis of the data displayed in the maps. Thus, by comparing the performances of one group of subjects against another, researchers have drawn conclusions and made assertions about the efficacy of animation. Similar studies stemming from disciplines other than geography compare animated graphics and static graphics using non-spatial data, but nevertheless, this work has implications for cartographers as well.
Koussoulakou and Kraak (1992) compared animated maps and static maps using spatiotemporal data (e.g. pollution, wind speed and direction, carbon monoxide levels, etc.) represented by point, line, and area symbols. The point symbol maps featured arrows with changing magnitudes and directions. Line symbol maps used either trajectory lines “which were seen to proceed in the course of time… [or] single lines (representing a front) which were changing position and shape” (Koussoulakou and Kraak, 1992, 104). For area symbols, polygons of varying shades and shapes were used to indicate spatiotemporal change. All participants were shown a variety of animated maps, static map series, and single static maps utilizing graphic variables to portray change. Participants were asked questions about overall temporal and geographic trends as well as questions about specific temporal and geographic points.

Though participants performed equally well in terms of correct responses, the authors found that when viewing animations, test subjects processed the information more quickly, and their response times were significantly quicker than when viewing static maps. The authors speculate that these differences would become more pronounced with data of higher temporal resolutions. In order to effectively visualize data with high temporal resolution and avoid overburdening the viewer with information, a series of static maps would likely have to omit data to display a practical and manageable number of time slices. Because a series of static maps excludes information, a “user has to interpolate in time if he/she wants to know what the situation was at the moments in between” (Koussoulakou and Kraak, 1992, 106) where data are absent. Conversely, an animated map would not have to omit any data because it could incorporate all points in time for which data exist. Questions regarding these “moments in
between” will, therefore, be more difficult to answer and require more response time using static maps when compared to using animated maps.

Furthermore, the authors postulate that participants would have performed better with animated maps, in terms of the number of correct responses, had they been given control over the playback of the animations. In this study, participants viewed movie-like sequences and were not given the ability to pause or otherwise interfere with the course of the animation as it ran. Other studies have found user control over playback to be essential in avoiding viewer confusion and frustration with animated map displays (Dorling, 1992; Monmonier and Gluck, 1994).

Johnson and Nelson (1998) obtained similar results in a study comparing animated maps and static maps depicting aggregate water flow along a fictitious river over the course of time. Subjects were shown one of three types of visualization methods: 1) a series of paper static maps, 2) a series of static maps displayed on a computer, or 3) a map animation. The informational content presented in each of the three map types was equivalent. Participants viewed the maps for a controlled period of time after which the maps were removed from view, and questions concerning temporal trends were posed. As the authors hypothesized, the subjects who viewed the animations responded significantly faster with similar levels of accuracy than those who viewed either type of static map. These results led the authors to conclude “that animation may be a useful tool for communicating trend patterns to map users” (Johnson and Nelson, 1998, 58). Two further points worth noting from this study: 1) males outperformed females in the animated condition with respect to response time, and 2) participant feedback indicated that animation viewers would have preferred control over the playback. The latter finding is also consistent with the work of Dorling (1992) and Monmonier and Gluck (1994).
Patton and Cammack (1996) examined user performance with static choropleth maps and two types of animated choropleth maps. One type of animation initially presented a complete map, and then the boundaries of each class in the map flashed in a given order. The second type of animation followed a building procedure where each class of the map was revealed successively until the map was complete. Each subject viewed either a static map or one of the two types of animations for six seconds after which the subjects were asked one of two types of questions. One question type asked if a color displayed in a box at the center of the screen had been present in the preceding map. A second type displayed an identical base map as the map just viewed, but only one of the polygons contained color. Participants had to determine if the polygon was shaded correctly according the preceding map. Across varying levels of map complexity, based on the number of classes and the number of contiguous polygons within each class, subjects who viewed the animated maps outperformed those who viewed static maps in terms of both accuracy and response time.

Similarly, participants who viewed animated choropleth “maplike displays” with hexagonal enumeration units were better able to identify moving clusters than when viewing similar static displays (Griffin et al., 2006). Participants were exposed to visual stimuli in the form of either an animation or a series of static small-multiples for a fixed period of time. The visual stimuli may or may not have contained a subtle or strong cluster of high values in motion. After the fixed period of viewing time, subjects were prompted to decide if there had been a moving cluster present in the display. The authors of the study found that participants were able to identify clusters more quickly in the animated condition, and they responded with greater accuracy. These results suggest that animated maps may be much more useful that static maps in a visualization context where the identification of moving clusters is a priority. Like Johnson
and Nelson (1998), in this study, Griffin et al. (2006) found a significant gender difference in the results. Males answered with greater accuracy than females, but this is only true for the animated condition. The authors hypothesize that this difference is attributable to biological differences in perception and cognition as well as in the dissimilarity in the amount of time males and females spend playing video games.

Taking a slightly different approach, Slocum et al. (2004) used a combination of interviews and focus groups to compare animated maps, static small-multiple maps, and change maps within the context of a software package designed for handling spatiotemporal point data. Using census data, changes in the populations of major US cities between 1800 and 1990 were rendered directly in the animated maps. Each year between 1800 and 1990 corresponded to one frame of the animation. Data in non-census years were produced by interpolation. Static small-multiple maps displayed raw populations for each city in ten-year increments. The series contained a total of twenty maps; one for each census year. The change maps were actually a series of static small-multiples depicting change across time intervals rather than the raw population totals. The animated map was shown at full screen while all of the maps in the series of static small-multiples were shown concurrently, requiring individual maps to be much smaller than the animation. However, any individual map could be resized. There were two types of map animations: automatic and user-controlled. User-control included the ability to stop and start the animation, dictate the pacing, and alter the animation’s beginning and ending dates.

Participants, including domain experts, geography students, and novices, first took part in an individual interview where they were asked questions. Through this initial interview researchers sought to gain a general understanding of people’s views on dynamic geographic phenomena. A second interview was then conducted with each participant, and this interview
was structured around the participant working through a tutorial for a software package called MapTime. The software tutorial included exposure to each of the three aforementioned map types. Questions were posed during the second interview to assess each participant’s opinions of the three mapping strategies. Study participants were also asked to rank six types of symbols, which included both geometric and pictographic symbols, for representing population. Focus groups were conducted three weeks after the interviews, and topics for discussion selected by the study authors were based on analysis of the interviews.

The participants found each type of map to be useful for specific applications, but “the raw small multiple received the most negative feedback” (Slocum et al., 2004, 59). According to the authors, this negative feedback derived from two sources: 1) the difficulty of noticing change over only one or two decades and 2) the small size of the individual maps. Animation would seem to be superior in both respects. Change can be depicted directly in an animated map, and the ability to combine data across years into a single mapped display obviates the need for multiple maps, which often must be reduced in size to accommodate the limitations of space. Study participants believed that animations were best suited for examining general trends in the data. They also found that the software package’s user-controlled animations worked well for focusing on smaller details within the broader pattern because those animations incorporated interactivity allowing the user to navigate to a specified point in time, space, or both. Slocum et al. (2004) note that participants expressed concerns with respect to animation pacing and the degree of user control over playback. Both the pacing and the amount of control within animated maps require further research. With the animated maps, participants felt that it was difficult to notice population decreases. While the authors do not provide any further insight or offer an explanation, it is possible that this is due to elements of design and the sheer volume of
data. Each map displayed data for 196 cities, most of which would be growing steadily throughout the period of time depicted, thus making small decreases in the size of one or two symbols relatively inconspicuous.

Blenkinsop et al. (2000) compared animated maps and static maps as two strategies for visualizing uncertainty. The authors obtained results in agreement with the findings of Slocum et al. (2004). Experts and novices both indicated that animated maps were more useful than static maps for examining general trends in the data.

While not directly comparing animated maps with static maps, other cartographic research has demonstrated the utility of animation as a visualization tool for aiding in the discovery of previously unknown patterns (MacEachren et al., 1998), exploring and analyzing temporal change (Blok, 2005), and processing geographic data (Koussoulakou, 1990; Dorling, 1992; Openshaw et al., 1994). But not all studies have yielded positive results for the use of animation.

Slocum and Egbert (1993) compared the performance of participants who viewed static choropleth maps and participants who viewed animated choropleth map sequences. Half of the subjects in each group were provided with a set of learning procedures aimed at familiarizing viewers with choropleth maps. The procedures were developed from the experiences of those who were deemed to be expert users of choropleth maps. Response times and accuracies were not significantly different among any of the groups. Participants viewing animated sequences failed to outperform participants viewing static sequences.

Using seventh-graders as test subjects, Cutler (1998) compared a shaded animated isarithmic map to a series of static small-multiple maps. The maps displayed temporal trends in cotton production in the state of South Carolina during the twentieth century. Those participants
who viewed the static maps actually outperformed those who viewed the animated map. In addition to answering a higher percentage of questions correctly, those shown static maps processed the information more quickly as well. Evidence from Cutler’s work suggests that the most important factors in determining the ability of schoolchildren to produce accurate answers from the information extracted from maps are the child’s prior knowledge of maps and reading level. The type of map viewed was found to be of lesser significance. However, these results are tempered by an experimental design flaw. The series of static maps was printed on paper whereas the animated map was rendered on a computer, and this arguably raises questions about the validity of any comparison.

In a slightly different context, Lee et al. (2003) compared animated and static conditions within several types of wayfinding maps. Study participants viewed a route through a fictitious town marked either by a solid line or mobile dot. Afterwards, the viewers were given memory and verbalization tasks testing their comprehension of the route. The results indicate that the solid line was more effective with respect to a subject’s ability to learn and recall the route and the pertinent landmarks along the way. Animation was shown to be a less effective technique for communicating wayfinding information.

Though Lowe’s (1999) work does not directly compare animated maps to static maps, he found the use of animated weather maps to be problematic in terms of a user’s ability to extract information in the context of learning and building a useful and accurate mental model of a dynamic system. Students of an introductory meteorology course were asked to record generalizations about weather systems drawn from animated weather maps that would be used later in a forecasting exercise. Lowe’s analysis of those statements indicates that students extracted perceptually remarkable information at the expense of thematically important
This was true of both the spatial and temporal aspects of the display. The statements written by the students underscore a lack of understanding of the causal relationships of the weather system. For Lowe, this is evidence that the high cognitive demands placed on viewers by animation may actually impede or inhibit the learning process.

Psychologists and educators are particularly concerned with animation’s supposed benefits to learning. Some challenge the assumption, usually based on the congruence principle (Tversky et al. 2002), that because of their dynamic nature animations are better suited than static graphics for explaining how dynamic systems function. Critics of animation argue that its adherents point to factors of interest and motivation as a basis for choosing animated graphics over static graphics when evidence fails to confirm animation’s superiority as a means of communicating information (Lowe, 1999). However, Kim et al. (2007) assert that among students with higher need for cognition, animations are not seen as more motivating or interesting. Tversky et al. (2002) critiqued a variety of studies that directly compared the performance of users of animated and static graphics, mostly in non-cartographic contexts. The studies in question purport to show superior performance by subjects who viewed animations. In their review, the authors argue that the conclusions drawn in the various studies are weakened due to the presence of one or both of two types of experimental design flaws that practically assured that viewers of animated graphics would outperform those who viewed static graphics. Some studies comparing the two types of graphics did not contain equal amounts of information because the animated graphics included “microsteps” not shown in static images. Other studies incorporated inconsistent sets of procedures for the two types of graphic conditions (e.g. some animations allowed for a degree of interactivity not possible with static images). Tversky et al. (2002) posit that the presence of inconsistent procedures or unequal amounts of information
biased the results and preclude any meaningful statements being made about the efficacy of one technique over the other.

In addressing several drawbacks to animated cartography concerning a variety of design and conceptual issues pointed out by various critics, Harrower (2003b) discusses the possibility that users experience reduced confidence when drawing information from animation as demonstrated by Morrison (2000). Rieber and Parmley (1995), proponents of the use of computer animation and simulation for learning, noted this effect in an experiment in which users attempted to learn about Newtonian mechanics through an interactive animation. All of the participants underestimated the amount of knowledge that they had actually acquired through the animation.

Previous studies on animation have yielded mixed results, and further research need to be done on the efficacy of animated cartography. Of particular interest is the possibility that map viewers experience reduced confidence in information acquired from an animated map. Ultimately, the type of information to be communicated and the type of mapping technique to be used (e.g. choropleth, proportional symbol, etc.) may dictate whether the production of an animated map is warranted.
CHAPTER 3

METHODOLOGY

Overview

Prior research has been unable to determine satisfactorily whether animated graphics or static graphics are more effective in disseminating information and knowledge to a broad audience. Few studies have directly addressed the issue of possible discrepancies in user confidence in the information extracted from the two techniques. For animation to remain a valid cartographic technique, research must demonstrate that animated maps are at least equally adequate in communicating geographic information as their static counterparts. Additionally, animated maps must impart knowledge to map readers with comparable levels of confidence. In other words, when one examines a map, one must have the same degree of confidence in the information or knowledge acquired as one would have with information drawn from a static map.

The goal of this research is to address the questions of efficacy and confidence surrounding map animations. Are animated maps as effective as static maps? Do map readers require more time to interpret geographic data if it is presented as an animated map? Do map readers place less confidence in information extracted from animated maps?

To answer these questions, a controlled experiment was conducted to collect the necessary data for analysis. Study participants were presented a series of maps depicting change over time and asked questions related to the information displayed in those maps. Participants were also asked to express a level of confidence in their answer for each question. Responses for each question were recorded along with the level of confidence expressed by the study
participant and the amount of time spent answering each question. Quantitative analysis and
standard hypothesis testing were performed using analysis of variance (ANOVA) to ascertain
which factors were important in determining a test participant’s percentage of correct responses,
amount of time spent answering each question, and level of confidence. Thus, existing
statistically significant differences according to the type of map viewed (e.g. animated or static)
were identified.

Testing Procedure
Testing took place in a geography department computer lab using desktop computers. The
computer lab was a controlled environment where distractions were minimized and noise levels
and lighting were kept relatively constant from one testing session to another. All computer
monitors in the lab were identical, and display settings (e.g. resolution, etc.) were standardized.

The test itself was administered via the lab’s computers. It is a self-contained computer
program with three slightly different versions written in the programming language Visual Basic.
Because the testing program contained all necessary instructions for executing the test,
interaction between the researcher and the test subjects was very limited during testing.
Participants entered the lab, sat at a computer terminal, and were simply instructed how to begin
the test at the appropriate time.

Study participants were divided into three groups. Those in group A, henceforth referred
to as the static group, viewed three different static maps. Participants in group B, henceforth
referred to as the animated group, viewed three different animated maps, and those in group C,
henceforth referred to as the mixed group, viewed a total of three different maps; some
participants in this group viewed one static and two animated maps, and some viewed one
animated and two static maps. Thus, the participants in each group were given one of the three
versions of the testing program. The tests were identical with the exception of the type of map viewed. Instructions regarding the functioning of the test were standardized among the three versions, so that information provided to test participants at the beginning of the test was the same regardless of which version of the test was administered.

Initially, participants were asked to provide five pieces of anonymous personal information: grade level, gender, major, colorblindness, self-reported familiarity with maps. These data were collected on the basis that one or more of the independent variables could partially explain any differences observed in the measured dependent variables (percentage of correct responses, response time, and level of confidence). After entering the appropriate information, participants were prompted to advance to the program’s next window.

At this point in the program, participants were presented with introductory text. The introductory text described the testing procedure. Information on the functioning of the program was provided. Subjects were informed that they would view a series of maps depicting changes over time and would be asked a series of questions about those maps. An example map was provided, and participants were instructed to examine the map and take particular notice of the changes portrayed. For those participants in the static map group, the map was a static small-multiple map portraying an area at five successive points in time (maps will be described in further detail later). An animated example map was shown to participants in the animated group. This group was also given instructions for controlling the animation, which simply involved starting the animation initially and replaying the animation when it had finished running. Participants in the mixed group, the group that would view both static and animated maps, were presented first with a static map. A second window of instructional text contained an example
animated map. The example maps were based on the same data and displayed identical informational content.

Following the instructional information, participants were shown another example map appropriate to their group, which was identical to what they would see during the actual test. A couple of practice questions were paired with this second example map to familiarize participants with the operation of the testing program. Another set of instructions on user interaction with the program was provided at this point as well. The practice questions provided an opportunity for subjects to become accustomed the procedures of the test. Participants were informed as to whether or not the answers they provided were correct, and successive incorrect answers opened a window where the correct answer and an explanation were given. After reading the explanation, participants were given the opportunity to reexamine the map. The two practice questions were the same for all groups. For participants in the mixed group, one practice question was paired with an example static map, and one practice question was paired with an example animated map.

After the practice questions, participants began the actual test. The user interface of the actual test was identical and operated in the same manner as the practice section. Figure 3.1 is a screen capture of the program, which depicts the layout of the window during the testing portion of the program. Figure 3.2 is a similar screen capture, but it portrays the graphical user interface with an animated map rather than with a static map. The question is presented at the top of the screen. To the right of the question is a drop-down box where participants would enter their confidence rating. Next to the confidence rating section is the “next question” button, which when clicked would bring the participant to the subsequent question. The majority of the screen is occupied by the map, which is located in the center. Located at the bottom right of the screen
Figure 3.1 – Static map screen. This screen capture of the testing program depicts the layout of the components of the graphical user interface. The map depicted here is one of the program’s three static maps.
Figure 3.2 – Animated map screen. This screen capture of the testing program depicts the layout of the components of the graphical user interface with one of the program’s animated maps.
is a “skip” button allowing a participant to skip any question at any time without providing an answer.

Questions were in multiple-choice format and presented randomly. A total of twenty-four questions were asked during the course of test (see Appendix A for a complete list of questions). Eight questions were matched with each of three maps. In general, the questions focus on the changes over time displayed in the maps. In the context of this research, change is defined as occurring when an individual pixel is classified in different categories during consecutive time periods.

Ideally, participants would read the question and then examine the map to determine the correct answer. The confidence rating section of the program remained inactive until the test subject submitted an answer to the question. Once the confidence rating section became active, participants would select a confidence rating based on a numeric Likert scale from 1 to 9. As participants were informed, a rating of 1 corresponded to “I’m guessing,” and a rating of 9 corresponded to “I’m certain, I’m right” with a 5 falling in the middle (Rieber and Parmley 1995). After selecting a confidence rating, the “next question” button became active, enabling the participant to advance to the next question. Clicking the “next question” button refreshed the display and presented a new question. As an alternative method of proceeding through the program, a user could have clicked the “skip” button at any point to advance beyond any particular question. However, during the course of testing, no participant chose to skip any questions.

Once all eight questions associated with the first map had been presented, the next time that a user clicked the “next question” button, the program displayed a window informing the user that the first section of the test was complete. The program window also indicated to the
user that the next set of questions would be associated with a map displaying different data. When a participant closed this new window, a second map would appear and a new set of questions would be asked. This step was repeated between the second set of questions and the third set of questions.

After all twenty-four questions had been asked, participants were presented with a final program window. The final window asked the participants to rate their own performance on another Likert scale ranging from 1 to 9. A rating of 1 corresponded to “I did poorly,” and a rating of 9 corresponded to “I did very well.” At this point, a subject’s role in the testing was complete.

Test Subjects
A total of 90 student volunteers participated in this research. The majority of the students were underclassmen drawn from introductory geography courses. Among the 90 participants there were 49 freshmen, 20 sophomores, 11 juniors, 3 seniors, and 7 graduate students. There were 64 female participants and 26 male participants. Of the 90 participants, 8 were geography majors, which included all 7 graduate students, and the other 82 participants were majors in a discipline other than geography.

The tests were administered during eight separate sessions. The largest session consisted of 17 students, the smallest session included 3, and the average was slightly more than 11. During the session, a participant was randomly assigned to one of the three testing groups.

Testing Maps
A total of six maps were produced. One static map and one animated map were produced from each of three sets of data. Each static and animated map pair is referred to as a map set, and each set is numbered according to the fixed order that the maps appeared on the test (i.e. map set 1,
Map set 1 is comprised of one static and one animated map, and each portrays the same area northeast of Atlanta, Georgia. Similarly, map set 2 is comprised of one static and one animated map with each map depicting a rural area in the southern part of Georgia. Map set 3 also consists of one static and one animated map. Both maps in map set 3 are based on data from south-central Georgia, but the data have been manually edited allowing for direct control over the changes portrayed. Within each map set, the static map and the animated map are identical with respect to informational content. The static map from map set 1 is depicted in Figure 3.3, and a frame of the animated map from map set 1 is depicted in Figure 3.4. The data used to generate the three map sets are actually subsets of a larger data set produced by the Natural Resources Spatial Analysis Laboratory at the University of Georgia. Land use/land cover data for 1974, 1985, 1991, 2001, and 2005 were generated from satellite imagery for the entire state of Georgia. The data were classified into 10 categories. The data from 1974 and 1985 have a spatial resolution of 60 meters, and the data from subsequent years have a spatial resolution of 30 meters. Before any maps were created, the data from the years 1991, 2001, and 2005 were resampled so that the data for all five time periods would have the same spatial resolution. Before the final maps were produced, the data were also reclassified to Level I of Anderson et al.’s (1977) land cover classification system for remotely sensed data. Thus, the total number of categories was reduced to six.

All of the maps portray areas that are roughly 13km by 12.5km or 218 pixels by 211 pixels. The exact size of the mapped area was dictated by the screen space available on the monitors of the testing computers. Since each static map is actually a series of small-multiples displaying the same area at the five successive points in time, it was necessary to render the area
Figure 3.3 – Static version of category map 1. Maps presented during the program were highly abstracted “category” maps originally based on land use/land cover data. Each of six categories is represented by a unique color hue. Data from five different time periods are displayed.
Figure 3.4 – Frame from the animated version of map set 1. The program’s animated maps were constructed from five individual static maps that match the program’s static maps in terms of informational content and design.
five times simultaneously. At the same time, increasing the size of the maps to the greatest extent possible was desirable so that the maps would attain maximum readability.

The scale of each map is 1:150000. Given the spatial resolution of 60 meters and the display space limitations, a scale of 1:150000 produced maps that exhibit a balance of information. With this combination of scale, resolution, and display extent, map readers can resolve individual pixels, but there are not so many pixels that map readers become overwhelmed with information. At this scale and resolution, patterns are still readily identifiable.

Though the maps are based on land use/land cover data, a level of abstraction was imposed. During the test the maps were presented as generic “category” maps and bear the titles “Category Map 1,” “Category Map 2,” and “Category Map 3.” Rather than identifying each category as urban, forest, agricultural, etc., the six categories in each map are simply labeled with numbers. Each category is represented by a distinct color hue in the maps. Color hues with similar intensities were chosen so as not to interfere with a subject’s perception and interpretation of the maps (Brewer, 2005). The temporal aspects of the map were also abstracted. The data are not presented as representing specific times. Instead, the five different time periods depicted in the maps are referred to as “Time 1,” “Time 2,” etc. Participants were ultimately presented highly abstract, nominally categorized maps portraying the same area at five successive points in time.

The maps were also simplified as much as practical in terms of design. Unnecessary elements such as a north arrow, scale bar, and neatline were excluded. In the context of the test, these elements would have served more as potential distractions rather than as aids to comprehension. The maps have generic titles to help distinguish one from another. Each map
also has a legend which is a necessity for deciphering the information depicted in the mapped area.

The static maps were designed using a standard GIS software package and exported as high resolution JPEG picture files. These files were then incorporated into the testing program. In their earliest form, the animated maps were produced using the same method. For each data set, one map corresponding to each of the five time periods was exported as a JPEG picture file at the same resolution as the static maps. These picture files were then imported into a software package allowing the creation of animations as MPEG files. Each animation starts with the map that displays the area at Time 1, and after a specified period of time the map portraying the area at Time 1 dissolves, which reveals the map depicting the situation at Time 2. The process is repeated until the map corresponding to Time 4 dissolves resulting in the display of the map portraying the area at Time 5. Each of the five individual maps is displayed for 1.5 seconds. The transition time during which one map dissolves and reveals the map behind it is 1 second. So the total runtime for each animation is 11.5 seconds.

The timing of the animation was largely based on trial and error due to the lack of practical design advice for animation pacing. Logically there would seem to be an ideal animation runtime. Animations with long durations could greatly increase the cognitive demands placed on viewers who would be required to remember the geographic patterns of earlier time periods for a greater length of time. On the other hand, animations that are too short are likely to overwhelm the map viewer because there would be less time to process all of the information being displayed. Given the amount of information depicted in the animated maps, 11.5 seconds was determined to be a suitable runtime to allow adequate perceptive and cognitive
processing without overburdening the map viewer by requiring excessive memorization of complex patterns.

Of necessity, the animated maps incorporate a limited degree of interactivity. During the test when viewers were presented with a question and the animated map, the map was initially paused on the first frame of the animation. Located directly above the mapped area is a “play” button. A participant would have to click the “play” button to begin the animated sequence. However, once the sequence begins playing, the button becomes inactive and displays the caption “playing.” While the animated sequence is playing, the animation cannot be paused or restarted. After the animation finishes running, the “play” button becomes active again, but the button’s caption reads “play again.” By clicking the button again with the mouse, a map viewer can begin the animated sequence again. This minor level of interactivity was required to ensure that a participant could view the animated sequence as many times as was necessary to provide an answer to the question posed. Furthermore, because a participant viewing a static map had the capability of examining any piece of the map for any duration, allowing a participant viewing an animated map to play and replay the animated sequence was essential to maintain procedural equality among the study groups.

Besides this interactivity, the static and animated maps are identical in terms of design and layout. Each static map displays a given geographic area at five different points in time thus requiring the use of small-multiples.

Each static and animated map pair is identical with respect to informational content as well. So ultimately, any differences observed in a participant’s performance can be attributed to the mapping technique (e.g. static versus animated) rather than to any possible discrepancies in informational content or presentation.
Geographic Data Analysis

Geographic data analysis was carried out using a standard GIS software package. Data analysis revealed what are essentially two different types of changes taking place. As previously mentioned, change is defined as any individual pixel being classified into different categories at different points in time. Pixel classification changes may occur because the exact locations of the six categories are shifting over time. In theory, it would be possible for every pixel in the mapped area to change from one time period to the next without any variation whatsoever in the total area covered by each category. Thus, a change map would show that 100% of the mapped area is experiencing change between two given time periods. However, the change in the percentage of the mapped area covered by each category would be 0%. In this scenario, all of the change taking place would be due to movement of the categories rather than increases or decreases in the relative areas of the categories.

The second type of change taking place is the change in the relative area covered by each category. For instance, at Time 1 the six categories may each equally cover 16.67% of the mapped area. The location of the categories may not change among the different time periods, but one category may grow in area and begin to consume all of the other categories. So by the last time period, five categories may cover 0% of the mapped area and one category may cover 100% of the mapped area. Under this scenario, the change map could still show a large number of pixels being affected by change from one time period to the next.

In each of the three sets of maps generated for this research both types of changes are taking place from one time period to the next. In some cases, the majority of pixel classification change occurring between two time periods is owing to variations in the shape and position of each category. Despite the large change in pixel classification, the relative areas of the
categories remain largely unaffected. Though each set of maps depicts both types of changes, questions posed during the test were mostly focused on the changes in area covered by each category.

The first static-animated map pair was produced from a subset of the land use/land cover data representing an area to the northeast of Atlanta. Between the years 1974 and 2005 this area underwent enormous urban growth, and thus this pair of maps portrays great change over time. The degree of change can be seen clearly from the change map in Figure 3.5.

The amount of total change between time periods 1 and 2 is nearly the same as the amount of total change between time periods 2 and 3. In both instances slightly more than one-third of the mapped area experiences some form of change. Between time periods 3 and 4, the amount of change occurring in the mapped area begins to decrease dramatically. Less than 22% of the pixels have different categorizations at Time 4 than at Time 3. The least amount of change occurs between time periods 4 and 5. Only 8% of the mapped area experiences a change in classification from Time 4 to Time 5.

Examining the changes by category reveals a similar pattern. Table 3.1 indicates the percentage of the mapped area covered by each of the six categories at each of the five time periods. At Time 1, the area is dominated by category 4 (54.78%). At this point, categories 1, 2, and 3 cover a relatively small area. By Time 2, category 6 has nearly doubled in size, and categories 4 and 5 have experienced dramatic decreases in terms of area covered. This trend continues through Time 5 by which point category 6 covers 77.20% of the mapped area. Category 4 has greatly decreased by Time 5 (15.85%), and category 5 has virtually disappeared (1.35%). Categories 1, 2, and 3 experience relatively miniscule changes throughout the five time periods with respect to areal coverage.
Figure 3.5 – Change map 1. Change map for map set 1 showing the amount of change experienced between consecutive pairs of time periods.
Table 3.1 – The percentage of mapped area covered by the six categories in map set 1

<table>
<thead>
<tr>
<th></th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>Time4</th>
<th>Time5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.31</td>
<td>0.36</td>
<td>0.57</td>
<td>0.63</td>
<td>0.58</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>3.75</td>
<td>3.39</td>
<td>3.12</td>
<td>2.78</td>
<td>2.42</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>2.63</td>
<td>6.41</td>
<td>1.24</td>
<td>1.29</td>
<td>2.60</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>54.78</td>
<td>35.37</td>
<td>35.36</td>
<td>20.70</td>
<td>15.85</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>14.73</td>
<td>9.38</td>
<td>4.34</td>
<td>1.34</td>
<td>1.35</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>23.80</td>
<td>45.09</td>
<td>55.37</td>
<td>73.26</td>
<td>77.20</td>
</tr>
</tbody>
</table>

Table 3.2 – The changes in the amount of area covered, as a percentage, by the six categories in map set 1

<table>
<thead>
<tr>
<th></th>
<th>Time1-2</th>
<th>Time2-3</th>
<th>Time3-4</th>
<th>Time4-5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.05</td>
<td>0.21</td>
<td>0.06</td>
<td>-0.05</td>
<td>0.27</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>-0.36</td>
<td>-0.27</td>
<td>-0.34</td>
<td>-0.37</td>
<td>-1.33</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>3.78</td>
<td>-5.17</td>
<td>0.05</td>
<td>1.31</td>
<td>-0.03</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>-19.41</td>
<td>-0.01</td>
<td>-14.66</td>
<td>-4.85</td>
<td>-38.93</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>-5.35</td>
<td>-5.04</td>
<td>-3.00</td>
<td>0.02</td>
<td>-13.38</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>21.29</td>
<td>10.28</td>
<td>17.89</td>
<td>3.93</td>
<td>53.40</td>
</tr>
</tbody>
</table>

Table 3.2 indicates the changes taking place between time periods with respect to the area covered by the six categories. Comparison with the change map reveals that some of the changes in pixel classification from one time period to the next are due to the shifting locations of the categories rather than variations in the total area of each category. For example, the change map revealed that, in terms of pixel classification change, the total amount of change occurring between Time 1 and Time 2 was roughly equal to the amount of change occurring between Time 2 and Time 3. As can be observed from Table 3.2, between Time 2 and Time 3 the total amount of change in the area covered by the six categories is approximately 10.5% whereas between Time 1 and Time 2 the total is close to 25%. Thus, the majority of pixel classification change taking place between Time 2 and Time 3 is due to variations in the relative locations of the six categories. In terms of the amount of total area affected by change, it can be
seen that the greatest change occurs between Time 1 and Time 2 and the least amount of change occurs between Time 4 and Time 5 (roughly 5%).

The second pair of maps was produced from a rural area in the central part of the state of Georgia. The second pair depicts an area that underwent relatively little change as is portrayed in Figure 3.6. The total change with respect to pixels whose classification is different from one time period to the next is roughly the same for all times. With just over 12% of the pixels changing, the greatest amount of change occurs between Time 3 and Time 4. As was the case with map set 1, the least amount of change between any two periods occurs between Time 4 and Time 5. During this time slightly more than 8% of the mapped area experiences a change in categorization. Overall, the amount of pixel classification change remains relatively constant for category map 2, and the total amount of change is relatively small.

Table 3.3 indicates the amount of area covered by each category at the five different points in time. The small magnitude of overall change can be seen from the amount of areal change undergone by the categories. Between Time 4 and Time 5 the area covered by each category remains relatively constant. The overall temporal pattern of map set 2 is characterized by decreases in categories 2 (3.51% to 1.57%) and 5 (72.42% to 65.52%). Category 3 experiences an initial increase in area followed by a decrease, though in sum the category covers more than twice as much area by Time 5 as it does at Time 1. Categories 4 and 6 generally experience steady growth, and category 1, which covers an insignificant portion of the mapped area, experiences little change as it covers just 0.03% more area at Time 5 than at Time 1. On the whole, the most noticeable changes are the increase in category 4 and the decrease in category 5, with both undergoing a change in total area covered of about 6%. 

36
Figure 3.6 – Change map 2. Change map for map set 2
Table 3.3 – The percentage of mapped area covered by the six categories in map set 2

<table>
<thead>
<tr>
<th></th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>Time4</th>
<th>Time5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.03</td>
<td>0.07</td>
<td>0.07</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>3.51</td>
<td>2.58</td>
<td>1.63</td>
<td>1.36</td>
<td>1.57</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>1.02</td>
<td>3.77</td>
<td>3.98</td>
<td>3.73</td>
<td>2.63</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>22.30</td>
<td>25.80</td>
<td>26.82</td>
<td>28.68</td>
<td>28.30</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>72.42</td>
<td>66.99</td>
<td>66.63</td>
<td>64.11</td>
<td>65.52</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>0.72</td>
<td>0.79</td>
<td>0.86</td>
<td>2.07</td>
<td>1.93</td>
</tr>
</tbody>
</table>

Table 3.4 – The changes in the amount of area covered, as a percentage, by the six categories in map set 2

<table>
<thead>
<tr>
<th></th>
<th>Time1-2</th>
<th>Time2-3</th>
<th>Time3-4</th>
<th>Time4-5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.04</td>
<td>0.00</td>
<td>-0.03</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>-0.93</td>
<td>-0.95</td>
<td>-0.27</td>
<td>0.21</td>
<td>-1.94</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>2.75</td>
<td>0.21</td>
<td>-0.25</td>
<td>-1.10</td>
<td>1.61</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>3.50</td>
<td>1.02</td>
<td>1.86</td>
<td>-0.38</td>
<td>6.00</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>-5.43</td>
<td>-0.36</td>
<td>-2.52</td>
<td>1.40</td>
<td>-6.90</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>0.07</td>
<td>0.07</td>
<td>1.21</td>
<td>-0.14</td>
<td>1.20</td>
</tr>
<tr>
<td>Total increase / decrease</td>
<td>6.36</td>
<td>1.30</td>
<td>3.07</td>
<td>1.63</td>
<td>8.84</td>
</tr>
</tbody>
</table>

Table 3.4 indicates the changes taking place between time periods with respect to the area covered by the six categories. As with map set 1, examination of Table 3.4 reveals that a large proportion of the pixel classification change is due to changes in the locations of the categories rather than variations in the total area covered by each category. For instance, in spite of the fact that about 10% of the mapped area experiences a change in classification between Time 2 and Time 3, the change in the total area covered by each category varies by less than 1.5%. Changes in the areas of each category are relatively small between each set of time periods with the greatest change occurring between Time 1 and Time 2 (approximately 6%) and the least change occurring between Time 2 and Time 3 (approximately 1.5%).
As with map set 2, the data used to produce the third pair of maps represents a rural part of central Georgia. However, in this case the data were manually edited so that direct control over the changes depicted in the maps could be exercised.

Figure 3.7 depicts the pixel classification change from one time period to the next for map set 3. As is evident from the change map, the amount of change occurring between time periods is increasing from the first pair to the last pair. The least amount of change takes place between Time 1 and Time 2 where a mere 2.6% of pixels undergo a change in categorization. That level of change increases between Time 2 and Time 3 as well as between Time 3 and Time 4. Between the final two time periods the maximum amount of classification change occurs. However, the magnitude of change is still relatively small as only 14.8% of the mapped area undergoes a change in categorization. Though the total change is minor, throughout the temporal sequence the amount of change continually increases.

Table 3.5 indicates the amount of area covered by each category at the five different points in time. For map set 3, changes in the area of each category are more consistent from one time period to the next. The most dominant temporal changes occurring are the dramatic increase in the size of category 4 and the steady decreases in categories 2 and 5. Category 4 covers 32.40% of the area at Time 1 and by Time 5 has grown to encompass nearly half of the mapped area (49.54%). From Time 1 to Time 5, category 2 shrinks from 36.41% of the total area to 22.44%, and similarly category 5 decreases from 28.83% to 21.91%. Category 3 experiences a more moderate increase until Time 4 and then decreases slightly between the final two time periods. Category 6 increases very slightly, going from 0.53% to 0.59% of the total area, and is likely to be very unnoticeable when viewing the maps. Category 1 remains unchanged throughout all five time periods.
Figure 3.7 – Change map 3. Change map for map set 3
Table 3.5 – The percentage of mapped area covered by the six categories in map set 3

<table>
<thead>
<tr>
<th></th>
<th>Time1</th>
<th>Time2</th>
<th>Time3</th>
<th>Time4</th>
<th>Time5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>36.41</td>
<td>34.69</td>
<td>31.98</td>
<td>29.89</td>
<td>22.44</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>1.44</td>
<td>1.60</td>
<td>2.36</td>
<td>5.82</td>
<td>5.13</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>32.40</td>
<td>34.21</td>
<td>37.63</td>
<td>37.91</td>
<td>49.54</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>28.83</td>
<td>28.58</td>
<td>27.09</td>
<td>25.40</td>
<td>21.91</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>0.53</td>
<td>0.53</td>
<td>0.54</td>
<td>0.58</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Table 3.6 – The changes in the amount of area covered, as a percentage, by the six categories in map set 3

<table>
<thead>
<tr>
<th></th>
<th>Time1-2</th>
<th>Time2-3</th>
<th>Time3-4</th>
<th>Time4-5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Blue)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2 (Purple)</td>
<td>-1.72</td>
<td>-2.71</td>
<td>-2.09</td>
<td>-7.45</td>
<td>-13.98</td>
</tr>
<tr>
<td>3 (Orange)</td>
<td>0.16</td>
<td>0.76</td>
<td>3.47</td>
<td>-0.70</td>
<td>3.69</td>
</tr>
<tr>
<td>4 (Green)</td>
<td>1.81</td>
<td>3.43</td>
<td>0.28</td>
<td>11.63</td>
<td>17.14</td>
</tr>
<tr>
<td>5 (Yellow)</td>
<td>-0.25</td>
<td>-1.49</td>
<td>-1.69</td>
<td>-3.49</td>
<td>-6.92</td>
</tr>
<tr>
<td>6 (Gray)</td>
<td>0.00</td>
<td>0.01</td>
<td>0.04</td>
<td>0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>Total increase / decrease</td>
<td>1.97</td>
<td>4.20</td>
<td>3.79</td>
<td>11.64</td>
<td>20.89</td>
</tr>
</tbody>
</table>

The changes taking place between time periods with respect to the area covered by the six categories can be observed in Table 3.6. The increasing amount of change through each successive pair of time periods portrayed by the change map is also reflected in the change in area of each of the six categories. Between Time 1 and Time 2, 2.6% of the pixels experienced a change in classification, and Table 3.6 indicates that during that time the increases in categories 3 and 4 totaled approximately 2%. Unlike map set 1 and map set 2, much of the change taking place between time periods for map set 3 is due to changes in the areas covered by the six categories; the second type of change mentioned earlier. A much smaller proportion of the total change is accounted for by mere positional shifting of the categories. While the change map indicates that 14.8% of the mapped area experiences a classification change between Time 4 and
Time 5, Table 3.6 indicates that 11.64% of the mapped area changes due to increases or decreases in the sizes of certain categories.

Overall the three pairs of maps depict varying amounts of change. Map set 1 depicts an area affected by great change as one category experiences tremendous growth over time at the expense of several others. The amount of change from one time period to the next fluctuates but generally decreases from beginning to end. Map set 2 represents an area with much less change than map set 1, and the changes portrayed by this set of maps are more consistent through each pair of consecutive time periods. For map set 2, one category experiences slight growth and one experiences slight reduction while the other four categories remain relatively unchanged. With the last set of maps (map set 3), the change between time periods begins slowly and steadily increases so that the greatest change occurs between Time 4 and Time 5. On the whole there is more change than occurs in map set 2 but not as much as occurs in map set 1. The most conspicuous changes are the steady increase in one category and the steady decreases in two other categories.

So during the test, participants were presented with a total of three maps (static, animated, or a combination) depicting these varying amounts of change. In addition to differences in the total change portrayed, each set of maps is characterized by varying amounts of growth and reduction in particular categories and combinations of categories. Participants ultimately viewed three scenarios of change and were tested on their comprehension of the information presented and their confidence in the information they acquired.
Dependent Variables

Response Accuracy
Participant response accuracy refers to the percentage of correct responses given by the participant during the test. Average response accuracy was calculated by dividing the number of correct answers by the total number of questions and multiplying by 100. The measurement of response accuracy is used as a gauge for overall map comprehension.

Response Time
Response time was measured by the testing program. The timer began with the presentation of each question, and timer ran until the participant clicked the necessary button to proceed to the next question. Response times for the questions were then averaged.

Confidence
A participant’s confidence was measured as each participant selected a confidence rating on a scale from 1 to 9 for each question. An average confidence rating was then calculated based on those individual ratings.

Independent Variables

Map Type
The map type variable represents the three groups in which participants were placed. There are three possible values: static, animated, and mixed. The static group viewed three static maps. The animated group viewed three animated maps. The mixed group viewed three maps where the type alternated in succession, so that if the first map was static, then the second was animated, and the third was again static. If the first map was animated, then the second was static, and the third was animated. The type of map shown first (e.g. static or animated) to participants in the mixed group was determined randomly.
**Map Set**

The map set variable corresponds to the three different pairs of maps produced from the three subsets of data. The values for the map set variable are simply map set 1, map set 2, map set 3. The map sets are numbered according to the fixed order in which they appeared on the test (i.e. map set 1 appeared first, followed by map set 2, etc.). Each of the three map sets is comprised of one static and one animated map that are identical in terms of information content.

**Map Familiarity**

Self-reported familiarity with maps was initially measured on a Likert scale of 1 to 5. This variable was reconstituted into three groups. Participants who rated their familiarity as a 1 or 2 were placed into the “low” familiarity category. Participants who rated their familiarity as a 3 were placed into the “moderate” familiarity group, and those who rated themselves as a 4 or 5 were grouped into the “high” familiarity category. Map familiarity therefore has three values: low, moderate, and high. The map familiarity variable is a proxy measurement for previous experience with or knowledge of maps.

**Gender**

Gender is a dichotomous variable. Obviously the two values are male and female.

**Class Level**

The class level variable has three values: underclassmen (freshmen and sophomores), upperclassmen (juniors and seniors), and graduate students.

**Major**

Major is a dichotomous variable separating geography majors from non-geography majors. Because there were only eight geography majors among the participants and seven of them were also graduate students, the major variable was eliminated before estimation of the statistical
models. To a large certain extent the major and class level variables are two measurements of the same thing, and the high degree of multicollinearity between these two variables would bias the results of the data analysis.

**Colorblindness**

Colorblindness is another dichotomous variable separating colorblind individuals from individuals who are not colorblind into two groups. Ultimately colorblindness was also eliminated before estimation of the statistical models because none of the participants indicated that they were colorblind.

**Null Hypotheses**

One ANOVA model was estimated per dependent variable for a total of three. Each model included five independent variables (map type, map set, map familiarity, gender, and class level), and classical hypothesis testing was used to determine the statistical significance of each factor in each of the three models. Post-hoc comparison tests were conducted using the Tukey-Kramer method, which corrects for unequal cell sizes, to determine which differences in means among the groups were significant. The standard significance level of 0.05 was used for all statistical tests. Of primary concern in this work is the significance of the main effect of the map type factor as well as the significance of any interaction between the map type factor and any one of the other four factors. As a result, six null hypotheses were tested:

1. There are no differences in mean response accuracy according to map type
2. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean response accuracy
3. There are no differences in mean response time according to map type
4. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean response time

5. There are no differences in mean confidence rating according to map type

6. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean confidence rating

The main effects of the remaining four factors were also tested for significance with regard to their impact on response accuracy, response time, and confidence. In this manner, static maps and animated maps were compared with respect to efficacy and confidence in the context of portraying change over time.
CHAPTER 4

RESULTS AND DISCUSSION

Response Accuracy

Overview

The main effects of five factors were considered during analysis of the response accuracy of the test’s participants. Four two-way interaction effects were also examined to determine their impact on the response variable. Table 4.1 summarizes the results of the ANOVA model. As the table indicates, there are four significant factors: the main effects of the map type, map set map familiarity and the interaction effect of map set and map type. All of the remaining factors are not significant (p > 0.05).

Table 4.1 – Summary ANOVA results for response accuracy

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>F ratio</th>
<th>Probability of Type I error</th>
<th>η² (eta-squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Map Type*</td>
<td>3.35</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Map Set**</td>
<td>94.27</td>
<td>&lt; 0.01</td>
<td>0.40</td>
</tr>
<tr>
<td>Map Familiarity*</td>
<td>3.97</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Gender</td>
<td>&lt; 1</td>
<td>0.83</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Class Level</td>
<td>&lt; 1</td>
<td>0.47</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td><strong>Interaction Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Map Set and Map Type*</td>
<td>2.74</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Map Familiarity and Map Type</td>
<td>&lt; 1</td>
<td>0.55</td>
<td>0.01</td>
</tr>
<tr>
<td>Gender and Map Type</td>
<td>2.00</td>
<td>0.14</td>
<td>0.01</td>
</tr>
<tr>
<td>Class Level and Map Type</td>
<td>&lt; 1</td>
<td>0.78</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

** denotes factors that are highly statistically significant (p < 0.01)
* denotes factors that are statistically significant (p < 0.05)
**Map Type Main Effect**

Among the three groups, there is a significant difference in means (F = 3.35, p = 0.04). Figure 4.1 illustrates the effect of map type on response accuracy. As indicated by the graph, participants in the static group performed best, averaging 58.6%. With an average of 55.4% participants in the animated group scored slightly lower. Those participants in the mixed group responded with the lowest accuracy (52.2%). Post-hoc comparison tests suggest that the significance of the main effect of map type is attributable to the difference in means between the static group and the mixed group. Participants in the static group responded with significantly higher accuracy than their counterparts in the mixed group (q = 3.70, p = 0.03). The differences in means between the animated group and both of the other two groups are not significant (p > 0.05).

**Map Set Main Effect**

Variations among the three map sets correspond to differences in overall response accuracy since the main effect of the map set variable is highly significant (F = 94.27, p < 0.01). The effect of the three map sets on overall response accuracy is depicted in Figure 4.2. Scores for questions related to map set 1 and map set 3 are roughly equal (65.3% and 64.9% respectively). For questions associated with map set 2 the average score is 36.1%. Comparison tests reveal that the differences in mean response accuracies between map set 2 and both of the other two map sets are statistically significant (q = 16.93, p < 0.01 and q = 16.70, p < 0.01). The difference in means between map set 1 and map set 3 is not significant (q = 1.89, p = 0.38).

**Map Familiarity**

The main effect of map familiarity also has a significant impact on response accuracy (F = 3.97, p = 0.02). Figure 4.3 portrays the relationship between map familiarity and the dependent
Figure 4.1 – Main Effect of Map Type on Response Accuracy
Figure 4.2 – Main Effect of Map Set on Response Accuracy
Figure 4.3 – Main Effect of Map Familiarity on Response Accuracy
variable. Participants who rated themselves as very familiar with maps have a significantly higher mean response accuracy than those participants who rated themselves as moderately familiar with maps ($q = 3.99$, $p = 0.01$). In addition, participants with high map familiarity performed significantly better than participants with low map familiarity ($q = 3.64$, $p = 0.03$). While those test subjects with low map familiarity scored slightly higher than those with moderate map familiarity (54.0% and 53.8% respectively), this difference is not significant ($q = 0.08$, $p = 0.99$).

*Map Set and Map Type Interaction Effect*

While the main effects of the map set and map type factors are significant, the importance of these effects must be considered in the context of the relationship between them (Weiss, 2006) since the interaction effect of these factors is also significant ($F = 2.74$, $p = 0.03$). The nature of the interaction can be observed from Figure 4.4. As the graph portrays, response accuracies for the questions associated with map set 1 and map set 3 are similar for all three test groups ($p > 0.05$). Regardless of the type of maps viewed, participants achieved the lowest scores on the set of questions related to map set 2. For all three groups, comparison tests show that the drop in scores on map set 2 is highly significant ($p < 0.01$) when compared to scores for the other two map sets. However, as the graph in Figure 4.4 portrays, the drop in response accuracy associated with map set 2 is more pronounced for participants in the animated and mixed groups. The mean response accuracy for participants in the static group is significantly different ($q = 3.64$, $p = 0.03$) from the mean response accuracy for those participants in the animated group. The difference in means between participants in the static group and the mixed group is highly significant ($q = 5.59$, $p < 0.01$). Finally, between the animated and mixed groups, the difference in mean response accuracy is not significant ($q = 1.94$, $p = 0.36$). Overall, scores indicate that questions
Figure 4.4 – Interaction Effect of Map Set and Map Type on Response Accuracy
related to map set 2 were the most difficult, but these questions proved to be less challenging for those who viewed static maps exclusively during the test.

*Strength of Effect*

Considering the nature of the interaction between the map set and map type, the power of the map type alone in explaining response accuracy is weak. Much of the apparent ability of the map type to account for variations in response accuracy is actually due to the combination of the map set and map type. While the effect of the map set on response accuracy is partially dependent on the map type, the map set alone had an adverse impact on response accuracy across all three groups in the case of map set 2. The interaction effect of these two factors clearly indicates that the impact of the map type on response accuracy is contingent on the map set. Comparison of the $\eta^2$ values from Table 4.1 supports this interpretation.

Approximately 40% of the variance in the dependent variable can be explained by the three different map sets. The interaction between the map set and map type factors accounts for 2% whereas the main effect of the map type explains only 1% of the variability in response accuracy. Therefore, the strength of effect of the map type alone is about one-half that of the interaction effect. The main effect of map familiarity also accounts for about 2% of the variation in the response variable. Clearly the most important factor in determining a participant’s response accuracy is the map set. The combined effect of the map set and map type and the main effect of map familiarity rank a distant second in importance followed by the main effect of the map type.

*Null Hypotheses for Response Accuracy*

The two null hypotheses concerning the effect of the map type on response accuracy are stated as follows:
1. There are no differences in mean response accuracy according to map type

2. There are no significant interactions between the map type factor and the various other factors in the ANOVA model affecting mean response accuracy

Given the significance of the main effect of map type ($p = 0.04$), the first null hypothesis should be rejected. Since the interaction effect between the map set and the map type is significant ($p = 0.03$), the second null hypothesis should also be rejected. The map type plays a significant role in determining response accuracy.

**Response Time**

*Overview*

As with response accuracy, the main effects of five independent variables were tested with ANOVA along with four two-way interactions. The results of the analysis are presented in Table 4.2. Response time is significantly affected by six factors. As the table indicates, the main

| Table 4.2 – Summary ANOVA results for response time |
|-----------------|-----------------|-----------------|

| **Independent Variables** | **F ratio** | **Probability of Type I error** | **$\eta^2$ (eta-squared)** |
|-----------------|-----------------|-----------------|
| **Main Effects** | | | |
| Map Type** | 8.35 | < 0.01 | 0.04 |
| Map Set** | 43.66 | < 0.01 | 0.19 |
| Map Familiarity** | 6.55 | < 0.01 | 0.03 |
| Gender | 1.81 | 0.18 | < 0.01 |
| Class Level* | 5.12 | 0.01 | 0.02 |
| **Interaction Effects** | | | |
| Map Set and Map Type* | 3.07 | 0.02 | 0.02 |
| Map Familiarity and Map Type | 1.39 | 0.24 | 0.04 |
| Gender and Map Type** | 7.19 | < 0.01 | 0.03 |
| Class Level and Map Type | < 1 | 0.56 | 0.01 |

** denotes factors that are highly statistically significant ($p < 0.01$)

* denotes factors that are statistically significant ($p < 0.05$)
effects of map type, map set, map familiarity, and the interaction effect of gender and map type are highly significant (p < 0.01). The main effect of class level and the interaction effect of map set and map type are significant as well (p < 0.05). The remaining three factors are not significant (p > 0.05).

*Map Type Main Effect*

The impact of map type on response time is highly significant, and the nature of this influence on the dependent variable can be observed in Figure 4.5. Participants in the mixed group responded the quickest with an average time of 21.4 seconds per question. Those test subjects in the static group took slightly more time, averaging 25.0 seconds. Participants in the animated group required the most time to answer questions, proceeding to the next question after an average of 28.6 seconds had elapsed. Comparison testing confirms that these differences in means among all three groups are significant. That is to say, the difference in means between the mixed group and the static group and the difference in means between the mixed group and the animated group are highly significant (q = 5.64, p < 0.01 and q = 11.28, p < 0.01 respectively). Additionally, the difference in means between the static group and the animated group is highly significant (q = 5.64, p < 0.01).

*Map Set Main Effect*

The difference of means among the three map sets is also highly significant (F = 43.66, p < 0.01), and the effect is portrayed in Figure 4.6. The graph illustrates that questions related to map set 1 and map set 2 have similar average response times (27.6 and 27.3 respectively). Participants answered the questions associated with map set 3 in the least amount of time, with an average of 20.1 seconds. The Tukey-Kramer comparison tests reveal that the difference in mean response times between map set 1 and map set 2 is not significant (q = 0.53, p = 0.93). On
Figure 4.5 – Main Effect of Map Type on Response Time
Figure 4.6 – Main Effect of Map Set on Response Time
the other hand, the mean response time for map set 3 is significantly different from each of the other two map sets (q = 11.70, p < 0.01 for map set 1 and q = 11.17, p < 0.01 for map set 2).

*Map Familiarity Main Effect*

Another factor whose main effect is significant in terms of its impact on average response time per question is map familiarity (F = 6.55, p < 0.01). As is evident from Figure 4.7, those participants who rated themselves as having low familiarity with maps took the most time to answer each question averaging 26.6 seconds. With an average of 25.7 seconds, participants of high familiarity took slightly less time per question, and those of moderate familiarity answered most quickly, averaging 23.8 seconds. The difference in means between participants of moderate familiarity and of low familiarity is significant (q = 4.56, p = 0.01). The difference in means between participants of moderate familiarity and of high familiarity is not significant (q = 2.77, p = 0.13), and the difference in means between participants of low familiarity and of high familiarity is also not significant (q = 1.16, p = 0.69).

*Class Level Main Effect*

Finally, the main effect of class level also has a significant impact on response time (F = 5.12, p = 0.02). The graph in Figure 4.8 illustrates this relationship. As depicted in the figure, the mean response times for underclassmen and upperclassmen are roughly equal (24.7 seconds and 24.5 seconds respectively). However, graduate students required more time per question, averaging 28.9 seconds. The mean response time for graduate students is significantly greater than that of underclassmen (q = 4.34, p = 0.01) and that of upperclassmen (q = 3.89, p = 0.02). The similar response times for underclassmen and upperclassmen are not significantly different (q = 0.26, p = 0.98).
Figure 4.7 – Main Effect of Map Familiarity on Response Time
Figure 4.8 – Main Effect of Class Level on Response Time
Map Set and Map Type Interaction Effect

The strength of effect of these differences among the means due to main effects must be examined with regard to the significant interaction effects that exist. While the main effects of both map type and map set have highly significant impacts on response time, their interaction effect is also significant ($F = 3.07, p = 0.02$). The combined effect of these factors is depicted in Figure 4.9. The most obvious impact of this interaction effect occurs with map set 1. For map set 1, the animated group has a significantly greater response time than both the static group ($q = 6.93, p < 0.01$) and the mixed group ($q = 9.76, p < 0.01$). In addition, the animated group can be characterized by a steady decline in response times across the three map sets. However, the other two groups exhibit a different trend. Participants in the static and mixed groups responded more quickly with map set 1 than with map set 2. As indicated by the main effect of map set, all three groups responded most quickly with map set 3.

Considering the nature of the interaction between the map set and map type, the effect of the map set is partly predicated on the type of map viewed. Map set 1 required significantly more response time for participants in the animated group. For all three groups, the trend between map set 2 and map set 3 is similar. All three groups experience a decrease in mean response time. The relationship between map set and map type also indicates the effect of map type on response time is necessarily also somewhat contingent on the map set. For all three maps, participants in the mixed group responded most quickly followed by those in the static group with participants in the animated group requiring the greatest response time. The differences in mean response times between the mixed group and the animated group are significant for all three map sets ($p < 0.05$). Interestingly, the differences in mean response times
Figure 4.9 – Interaction Effect of Map Set and Map Type on Response Time
between the static group and the animated group are not significant for map set 2 and map set 3 (p > 0.05).

**Gender and Map Type Interaction Effect**

The main effect of map type must also be interpreted in light of another important interaction. The combined effect of gender and map type exert a highly significant influence on response time as well (F = 7.19, p < 0.01). Figure 4.10 depicts this interaction and its effect on response times. When gender is considered, the effect of map type is not consistent. For females, the differences in mean response times for all pair-wise comparisons are highly significant (p < 0.01). Females in the animated group took an average of 29.7 seconds per question to respond, which is significantly more time than females in both the static group (25.2 seconds, q = 5.87, p < 0.01) and the mixed group (20.8 seconds, q = 12.14, p < 0.01). On the other hand, males experienced no significant differences in response times according to map type (p > 0.05). Furthermore, comparison tests indicate the differences in mean response times between males and females in both the static and mixed groups are not significant. However, in the animated group, females took significantly longer to respond than males, who averaged 24.9 seconds (q = 4.46, p = 0.01).

**Strength of Effect**

To a large extent, the effect of map type on response time is dependent on the gender of the participant in question. Since the main effect of map type averages the differences in means between males and females for all three map types, the strength of this effect must be interpreted in light of the interaction effect between gender and map type. The highly significant differences among the means according to map type for females are likely exerting a heavy influence on the strength of effect.
Figure 4.10 – Interaction Effect of Gender and Map Type on Response Time
Based on the $\eta^2$ values, map set would seem to be the factor that has the strongest influence on response time, accounting for roughly 19% of the variation in the dependent variable. Map type is another important factor in determining response time. Its main effect explains 4% of the variance in response times, and its combined two-way effects with map set and gender account for a total of 5% of that variation. Despite the larger $\eta^2$ value, when interpreting the influence of the main effect of map type, the nature of the interactions involving map type must be considered as well. The interaction between gender and map type has a slightly larger strength of effect (3%) than the interaction between map set and map type (2%). Map familiarity and class level also account for 3% and 2% of the variance respectively.

Null Hypotheses for Response Time

The two null hypotheses concerning the effect of the map type on response time are stated as follows:

1. There are no differences in mean response time according to map type
2. There are no significant interactions between the map type factor and the various other factors in the ANOVA model affecting mean response time

The main effect of the map type on mean response time is highly significant ($p < 0.01$), so the first of these two null hypotheses should be rejected. Based on the presence of two significant interactions involving the map type ($p < 0.05$), the second null hypothesis should be rejected as well. Differences in mean response accuracy do exist according to map type, and there are significant interactions between the map type and other factors. The map type does affect mean response time.
Confidence

Overview

Participant confidence was also analyzed with respect to the main effects of five factors and four two-way interactions. The results of the analyses are presented in Table 4.3. There are three factors whose main effects are significant (p < 0.05): map set, map familiarity, and gender. For the map set factor, the impact is highly significant (p < 0.01). The main effects of all other independent variables, including the type of map viewed during the test, are not significant (p > 0.05). The interaction effects between map familiarity and map type is significant and the combined effect of gender and map type is highly significant. The other two interaction effects examined are not significant with respect to impact on participant confidence (p > 0.05).

Table 4.3 – Summary ANOVA results for confidence

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>F ratio</th>
<th>Probability of Type I error</th>
<th>$\eta^2$ (eta-squared)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Map Type</td>
<td>&lt; 1</td>
<td>0.79</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Map Set**</td>
<td>12.65</td>
<td>&lt; 0.01</td>
<td>0.07</td>
</tr>
<tr>
<td>Map Familiarity*</td>
<td>3.55</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Gender*</td>
<td>7.45</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Class Level</td>
<td>&lt; 1</td>
<td>0.53</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td><strong>Interaction Effects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Map Set and Map Type</td>
<td>&lt; 1</td>
<td>0.85</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Map Familiarity and Map Type*</td>
<td>3.62</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Gender and Map Type**</td>
<td>6.67</td>
<td>&lt; 0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Class Level and Map Type</td>
<td>2.03</td>
<td>0.09</td>
<td>0.02</td>
</tr>
</tbody>
</table>

** denotes factors that are highly statistically significant (p < 0.01)
* denotes factors that are statistically significant (p < 0.05)

Map Set Main Effect

As with response accuracy and response time, the main effect of map set plays a significant role in influencing confidence (F = 12.65, p < 0.01). Figure 4.11 portrays the relationship between
Figure 4.11 – Main Effect of Map Set on Confidence
map set and confidence. For map set 1 the average confidence rating for each question is 6.8. The mean for map set 3 is slightly lower at 6.6, but comparison testing indicates that the difference is not significant (q = 1.90, p = 0.38). At 5.9, the average confidence rating is lowest for map set 2. The difference in mean confidence between map set 2 and map set 1 is highly significant (q = 6.89, p < 0.01) as is the difference in mean confidence between map set 2 and map set 3 (q = 4.99, p < 0.01). Participants expressed less confidence in their answers to questions related map set 2 as compared to the confidence expressed in their answers to questions for each of the other two map sets.

*Map Familiarity Main Effect*

Not surprisingly the main effect of map familiarity is important in determining the confidence level of test participants. The difference in means among low, moderate, and high familiarity participants is significant (F = 3.55, p < 0.03). As one might expect, those participants who considered themselves highly familiar with maps expressed the greatest confidence in their answers. As the graph in Figure 4.12 illustrates, the average confidence rating for these participants is 6.9. With an average of 6.5, participants who ranked their map familiarity as moderate, felt slightly less confident, but this difference is not significant according to comparison testing (q = 2.56, p = 0.17). Participants who considered themselves to lack familiarity with maps reported lower levels of confidence when compared to participants with moderate and high map familiarity. These differences are significant (q = 3.76, p = 0.03 and q = 5.31, p < 0.01).

*Gender Main Effect*

Gender also has a significant impact on confidence. Figure 4.13 indicates that males registered greater levels of confidence than females overall. The average confidence rating for males is 7.0
Figure 4.12 – Main Effect of Map Familiarity on Confidence
Figure 4.13 – Main Effect of Gender on Confidence
while females expressed an average confidence rating of 6.2. This difference is significant (F = 7.45, p = 0.01).

Map Familiarity and Map Type Interaction Effect

While the main effects of gender and map familiarity are significant, both have significant interaction effects when combined with map type. The relationship between map familiarity and map type and their joint impact on confidence is displayed in Figure 4.14. Among participants with low, moderate, and high map familiarity, there are no significant differences according to map type (p > 0.05). In other words, participants who rated their map familiarity as low expressed equal levels of confidence regardless of whether they were in the static, animated, or mixed group. The same is true for participants who rated their familiarity with maps as moderate or high. However, as the graph illustrates, within the animated group, participants of high map familiarity placed more confidence in their answers, averaging 7.2, than those of moderate or low familiarity, with averages of 6.1 and 5.6 respectively. Within the animated group, the difference in mean confidence level between those participants of high map familiarity and moderate map familiarity is significant (q = 4.46, p = 0.01) as is the difference in mean confidence level between those of high map familiarity and those of low map familiarity (q = 6.18, p < 0.01).

Gender and Map Type Interaction Effect

The interaction between gender and map type is highly significant (F = 6.67, p < 0.01). Figure 4.15 suggests that males generally have higher levels of confidence than females within the static and mixed groups but not within the animated group. Comparison tests indicate that the gender difference in confidence rating is significant in the static group (q = 4.89, p < 0.01) and in the mixed group (q = 4.36, p < 0.01). The gender discrepancy disappears when the maps are
Figure 4.14 – Interaction Effect of Map Familiarity and Map Type on Confidence
Figure 4.15 – Interaction Effect of Gender and Map Type on Confidence
animated, as reflected by the lack of significance in the difference of means (q = 0.72, p = 0.61). Thus, for males in the animated group, the average confidence level is significantly lower than for males in the static group (q = 3.54, p = 0.01) and for males in the mixed group (q = 3.48, p = 0.02).

*Strength of Effect*

The most important factor in determining confidence levels is the map set. Nevertheless, comparison of $\eta^2$ values indicates that the combined effects of map familiarity and map type and gender and map type are only slightly less influential in accounting for total variance. Each of these interactions effects explains approximately 4% of the variations in confidence levels. The main effects of map familiarity and gender each account for another 2% of the variance, and the overall importance of these factors must be considered in the context of their interactions with the map type. While all five factors are significant, their ability to explain the total variation in participant confidence ratings is relatively small. Each factor accounts for between 2% and 7% of the variance.

*Null Hypotheses for Confidence*

The two null hypotheses concerning the effect of the map type on response time are stated as follows:

1. There are no differences in mean confidence rating according to map type
2. There are no significant interactions between the map type factor and the various other factors in the ANOVA model affecting mean confidence rating

The first of these two null hypotheses should not be rejected. The main effect of the map type is not significant in terms of its impact on mean confidence rating. However, the second null hypothesis should be rejected. The interactions between map familiarity and map type and
gender and map type are both significant (p < 0.05). Though the effect of map type is contingent on map familiarity and gender, its interaction effects are nonetheless important in influencing confidence.

**Discussion**

*Map Type and Response Accuracy*

Throughout this study, the primary focus has been on differences due to map type to try to discern any inherent strengths or weaknesses in animation as a cartographic technique when compared to traditional static cartography. Data analysis results suggest that the overall effect of the mapping technique (i.e. map type) is rather limited. For example, with confidence, as measured by a participant’s confidence rating for the answer provided to each question during the test, the type of map played no role whatsoever. Where map type does play a significant role, its effect is generally predicated on some other variable, so the importance of the type of map viewed is a little more nuanced.

While the effect of the mapping technique (i.e. static, animated, or mixed) with regard to response accuracy is significant, the strength of its effect is rather weak. Taken in the context of the interaction between the map set and map type, much of the map type’s ability to account for variations in response accuracy is actually due to its combination with a specific map. It would be misleading to state that animation hinders comprehension of the informational content because the effect of animation depends on exactly what data are being portrayed. When coupled with a complex, nominally classified cartographic display depicting small magnitudes of change, whether because of the data set or because of map design choices (e.g. scale, extent, etc.), animation may inhibit effective communication.
Results indicate that for map set 2, participants in the animated group as well as those in mixed group achieved lower response accuracies compared to those in the static group. As borne out by the results of the test, all three groups had more difficulty in detecting the changes depicted in this map set. Because all three groups scored significantly lower on map set 2, the map set variable is the most important factor in determining response accuracy.

Discussion of the geographic data analysis made clear that map set 2 portrayed a relatively small amount of overall temporal change. Roughly 10% of the mapped area changes categorical classification from one time period to the next, but the amount of change in the relative areas covered by each category from one time period to the next is small. Thus, most of the change taking place concerned shifts in location of the six categories rather than changes in the relative areas of the categories. Some have argued that motion is an important device for focusing a viewer’s attention (MacEachren, 1995). When viewing the type of maps used in this study, a viewer sees apparent motion in the changing boundaries of the six categories. Thus, the degree to which the display varies from one time period to the next determines the amount of that apparent motion. So it follows that if the amount of temporal change is small in magnitude and corresponds to similar visual states throughout each time period portrayed, this leads to difficulty in detecting the apparent motion. Thus, the informational content of the display is harder to comprehend.

The implication is that animation is not suited to displaying temporal change when there is little actual change occurring. In cases where there is little change taking place, the dynamic nature of animated maps is likely not conducive to aiding detection. There may be a threshold of change which must be surpassed in order for animation to become an effective technique. Hodler (1995) addressed this topic with regard to animated choropleth maps. Perhaps a similar
investigation needs to be undertaken for other types of maps (e.g. proportional symbol, land use/land cover, etc.) to determine how much change is necessary for animation to become an aid to communication rather than a hindrance.

However, whatever statements might be made about animation’s potential negative impact on map comprehension are mitigated by the failure of the results to conform to the pattern one would expect if animation consistently attenuated response accuracy. If animation does act to inhibit the effectiveness of a map, then one would expect participants in the static group to have the highest response accuracy, followed by participants in the mixed group, and those in the animated group would have the lowest score. Since participants in the mixed map group saw a combination of animated and static maps, one would expect that their scores would be lower than static group because every participant would have been exposed to at least one animated map, which would reduce response accuracy. Those participants in the animated group would have the lowest score since the negative effect of animation would have been present throughout the entire test. The results do not exhibit this pattern. Participants in the mixed group actually scored lowest overall. In addition, participants in the mixed group experienced the most difficulty with the questions related to the most difficult map set: map set 2. It is possible that the lower scores for the mixed group reflect a difficulty for participants in becoming accustomed to one map type and then having to interpret a different type on the following set of questions. But given these results, one cannot conclude that animation consistently dampens the effect of a cartographic display.

Map Type and Response Time

The effect of animation on response time is stronger and a little more complex than its effect on response accuracy. While the main effect of map type is significant with respect to its impact on
response time, more importantly, the interaction effects between map set and map type as well gender and map type are significant. Animation’s influence on a participant’s mean response time is contingent on the particular mapped display and that participant’s gender.

Though the main effect of map type might suggest that those participants who viewed only animated maps have consistently longer response times, examination of the interaction effects reveals that the difference is actually rather limited. Participants in the animated group required significantly more time to respond to the questions presented with map set 1. However, compared to response times for participants in the static group, those in the animated group responded equally quickly to the questions related to map set 2 and map set 3. This result may be due to the fact that the order of the map sets was not randomized during the test. It is possible that participants in the animated group needed more time with which to familiarize themselves with the functioning of the animation. Because static maps are more ubiquitous than animated maps, participants are much more likely to be accustomed to using static maps than animated ones, even if they consider themselves to be unfamiliar with maps in general. In addition, the functioning of the static maps was straightforward and required no interaction from the viewer. Therefore, participants in the animated group may have gone through a period of adjustment, and once it ended, their response times dropped to levels similar to those of participants in the static group.

But this interpretation is problematic considering the response times of participants in the mixed group. When examining all three groups, the expected pattern does not exist if one were to argue that animation consistently requires a familiarization period, leading to longer mean response times. For all three map sets, participants in the mixed group responded significantly quicker than participants in the animated group. Overall participants in the mixed group required
the least amount of time to respond among all three groups. If animated maps always require
more cognitive processing time, then one would expect the response times for the mixed group to
be between those of the animated and static groups. Since this is not the case, drawing any
conclusions about any consistent effect of animation cannot be done. The pattern of response
times among the three groups must be attributable to some other factor besides map type or is
perhaps simply anomalous.

Another part of the overall difference in response times between the animated and static
conditions can be explained by a significant interaction between gender and map type. Females
who viewed only animated maps took more time to respond than females who viewed either
static maps or a mix of animated and static maps. On the other hand, the mean response time for
males in the animated group is not significantly different from the mean response times for males
in the other two groups.

The absolute magnitude of the difference in mean response time by gender in the
animated group is approximately four and a half seconds. Females required, on average, four
and half seconds more per question than males to respond. The animation sequence itself runs
11 seconds. Given that the average response time for males in the animated group is 25.2
seconds and for females the average is 29.7 seconds, it is unlikely that the typical participant
watched the animation more than once. For females, watching the animated sequence twice
would take 22 seconds and therefore would mean that the participant only needed 8 seconds to
read the question, process the information and generate a response, and then decide on a
confidence rating. The average male would have needed to accomplish those three tasks in 3
seconds if he were to have watched the animated map sequence twice. Either scenario is
unlikely. In most cases, it is likely that the average participant, both male and female, watched
the animated sequence only once. As a result, the difference of four and a half seconds derives from the amount of time required to read the question, process the information and select an answer, and select a confidence rating. Thus, it is possible that males simply processed the visual content more quickly.

In a similar study comparing animated and static maps, Griffin et al. (2006) noted a significant gender difference. Males more accurately identified the presence of moving clusters than females. The study’s authors hypothesize that this difference stems from the combination of two factors: improvements in visual abilities due to videogame playing, and the fact that higher numbers of males play videogames than females. By comparing the performance of videogame players and non-videogame players in four experiments testing visual abilities, Green and Bavelier (2003) demonstrated that playing video games improves visual attention. Because males are more likely to play videogames than females (Woodard and Gridina, 2000), Griffin et al. (2006) argue that males may have enhanced visual attention skills. If this is true, then it is possible that this difference in visual ability translates to slightly faster processing times leading to quicker response times for individual questions.

Griffin et al. (2006) also hypothesize that there may be a biological difference causing differences in visual perception as well, based on the work of Sax (2005). Sax argues that males and females have relative differences in the number of cells used to detect motion and cells used to detect color and texture. Consequently, males may be more suited to sensing movement while females may be more suited to sensing color and texture. It is possible that this proposed biological difference could correspond to slightly faster processing as well, resulting in shorter response times when answering questions about animated maps.
Whatever the sociological and biological differences that may exist, females in the mixed group actually responded significantly faster than the females in both the animated and static groups. Again, this fails to conform to the expected pattern that one would see if females consistently needed more time to process animated cartographic displays. All females in the mixed group would have viewed at least one animated map sequence due to the nature of the program’s design. Thus, one would expect that females in the mixed group would have an average response time that is longer than female participants in the static group if there are intrinsic sociological or biological reasons that necessitate more processing time for animations, which would lead to longer response times. This inconsistency reduces the strength of the importance of the difference in response times for females according to map type.

Furthermore, the gender difference in response times is even less important given that there are no significant differences in response accuracy by gender. In other words, females who viewed animated maps scored equally as well as females who viewed static maps. Females who viewed animated maps also achieved the same scores as males who viewed animated maps. So the discrepancy in response times between males and females does not translate to a difference in map comprehension.

Map Type and Confidence
Another major goal of this research was to examine potential differences in user confidence between animated and static maps. Previous studies suggested that people viewing animated graphics are less confident in the information acquired when compared to those viewing static graphics (Rieber and Parmley, 1995; Morrison, 2000). The results of this study indicate that the effect of the mapping technique on a viewer’s confidence depends on how familiar a viewer is
with maps and the gender of the viewer. Although, the overall effect of animation on confidence is also rather limited in nature.

The interaction between map familiarity and map type suggests that those map readers who have the most previous experience with maps are more comfortable with animated maps than those of lesser previous experience. This result is not particularly surprising. Those participants who considered themselves to be highly familiar with maps are more likely to have seen animated maps prior to testing. Even if they had not previously encountered an animated map, someone who is accustomed to dealing with maps would be less intimidated by the prospect of interpreting a new type of map. Ultimately, this would lead to more confidence. Sociology and psychology research linking familiarity and confidence supports this conclusion (Koriat, 2008; Hall et al., 2007; Beaupre and Hess, 2006). In spite of the significant interaction, within all three levels of map familiarity, low, moderate, and high, confidence levels do not vary according to the type of map viewed.

A second interaction affecting confidence is that between gender and map type. In the static and mixed groups, males expressed higher levels of confidence in their answers than females. Past research has shown that gender differences in confidence regarding achievement and performance exist in a variety of settings (Johnson and McCoy, 2000; Brown et al., 1997; Gold et al., 1980; Lenney, 1977; Maccoby and Jacklin, 1974). Whether the reasons underlying this difference are situational, social, or biological, men tend to exhibit higher levels of belief in the likelihood of success (Johnson and McCoy, 2000). There is evidence that this difference in confidence spills over into cartographic tasks as well. Throughout repeated rounds of testing, Lloyd et al. (2002) found that males consistently displayed more confidence than females when categorizing locations with aerial photos. In the present study, the discrepancy in mean
confidence ratings between males and females generally supports previous research dealing with
gender differences, but there is one notable exception. The gender distinction disappears with
animated maps.

In the animated group, males and females expressed similar levels of confidence. Consequently, for males, there is a reduction in confidence that can be attributed to animation. Males in the animated group reported lower levels of confidence than those in the static and mixed groups. But again, the effect is not consistent when considering the mixed group. In the mixed group, males rated their confidence at the same levels as males in the static group. It is possible that males in the mixed group experienced a drop in confidence that may be attributed to lower confidence in the animations they viewed but that this drop was not enough to result in a significant difference of means between the mixed and static groups. However, considering the results of the data analysis, one cannot conclude that animation’s overall impact on confidence is consistently negative. Other factors may explain why males are less certain of their answers to questions stemming from an animated cartographic display.

*Map Set, Response Accuracy, Response Time, and Confidence*

Besides map type, there are other factors that play a significant role in determining response accuracy, response time, and confidence that is independent of whether a map is animated or static. The most consistently effective variable is the map set. Differences among the category maps affected response accuracy, and the interaction effects between the map set and map type on response accuracy and response time have previously been discussed. The map set factor impacted participant confidence during the test as well. Questions regarding map set 2 induced lower levels of confidence for all participants, irrespective of map type, when compared to confidence levels associated with the questions about map set 1 and map set 3. Considering the
differences in the amount of temporal change depicted in the three map sets, this result is not surprising.

Map set 1 can be characterized by a large degree of relatively consistent change. The most noticeable aspect of the data set, whether the map is animated or static, is the expansive growth of category 6 at the expense of virtually all of the other categories in the map. While the magnitude of change from one time period to the next is not as great in map set 3 as it is in the first category map, the changes are still relatively consistent. One category experiences fairly continuous and conspicuous growth while two categories undergo continuous and conspicuous reductions. The other categories exhibit few changes at all. On the other hand, the changes in map set 2 are not so readily obvious. The magnitude of change is small. Furthermore, the two categories that experience the most growth and loss also undergo a great deal of shifting in location, which partially obscures the relative changes in area. The lower confidence ratings on the questions associated with map set 2 reflect the difficulty of detecting small changes. This difficulty is present in both static and animated maps.

Map Familiarity, Response Accuracy, and Response Time

In the present study, map familiarity is essentially a proxy measurement of prior knowledge of and general experience with maps. Map familiarity has already been discussed in the context of its interaction with the map type to influence participant confidence. Not surprisingly, the role of map familiarity is also important in terms of its effects on response accuracy and response time. These effects are independent of the type of map viewed. Participants who rated themselves as very familiar with maps scored higher than participants who rated themselves as moderately familiar or not very familiar with maps. This result is consistent with the findings of Cutler (1998) who, in a similar study involving static and animated isoline maps, found that one of the
most important determinants of response accuracy was prior knowledge of maps. Other studies in non-geographic disciplines have shown similar links between prior knowledge and test performance (Ritte- Johnson and Kmikewycz, 2008; Thompson and Zamboanga, 2004; Tal et al., 1994).

Variations in response time are also partly attributable to the differences among the participants in map familiarity. Participants of moderate map familiarity required significantly less time to respond to questions than participants with high map familiarity and participants with low map familiarity. Test subjects of high familiarity used an equal amount of time, on average, to answer questions as test subjects of low familiarity. The absolute magnitude of the time difference is small; the greater of the two differences in means is less than three seconds. Having less prior experience with analyzing cartographic displays, it is possible that participants of low familiarity simply needed more time to process the information when compared to participants with moderate map familiarity. Participants of high familiarity possibly consumed more time in responding due to greater attention to detail in the vast amount of visual information presented. For the broader questions related to animation as an effective mapping technique, this result is of little consequence since the effect of map familiarity on response time is not dependent on the map type.

Class Level and Response Time

Finally, class level also has an effect on response time regardless of map type. Underclassmen and upperclassmen have equivalent response times, but graduate students required more time than participants in either of the other categories to provide answers to the questions. Again, the absolute magnitude in the difference is small; just over four seconds. As with familiarity, this
difference may simply be attributable to graduate students, who were all geography students as well, devoting more attention to detail and being more circumspect in their test-taking approach.
CHAPTER 5

CONCLUSION

The main purpose of this research is to answer questions regarding the use of animation as an effective cartographic technique for communicating information and knowledge to a general audience. To do this, the effects of animation on response accuracy, response time, and confidence were examined and compared to traditional static cartographic methods. Three sets of null hypotheses, for a total of six individual null hypotheses, were tested to determine if the two techniques yield differences in the three dependent variables of interest.

The first set of null hypotheses regarding the map type includes the following:

1. There are no differences in mean response accuracy according to map type
2. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean response accuracy

The results indicate that both null hypotheses should be rejected. There is a significant difference in means according to map type, and a significant interaction between the map set and the map type exists.

The two hypotheses in the second set are similar to the above hypotheses:

3. There are no differences in mean response time according to map type
4. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean response time
Both null hypotheses can be rejected. Results show a significant difference in means according to map type, and there are several factors whose interactions with the map type bear a significant impact on mean response time.

The third and final set of null hypotheses is formally stated as:

5. There are no differences in mean confidence rating according to map type

6. There are no significant interactions between the map type factor and the various other factors of the ANOVA model affecting mean confidence rating

Based on the findings of the data analysis, the fifth hypothesis cannot be rejected. No differences in the mean confidence ratings were found among the three map type groups. However, the sixth null hypothesis should be rejected as there are two significant interaction effects involving the map type.

While five of the six null hypotheses can be rejected based on the results of the ANOVA models, the overall effect of map animation on response accuracy, response time, and confidence as compared to traditional static maps is still somewhat limited given the presence of the significant interactions. Exploration of the nature of these interaction effects indicates that the impact of the map type on response accuracy, response time, and confidence is largely contingent on some other factor. Animation did induce a lower mean response accuracy, but only for map set 2 where the amount of change in the display was small. Animation also resulted in longer response times for map set 1 and for females. In this case, the effect of animation was inconsistent. The mixed group responded more quickly to the questions posed for map set 1, and females in the mixed group actually responded quickest among the three groups. Given the failure of the results to conform to the pattern one would expect to find, some other
additional factor must explain these differences. The effect of animation on confidence is dependent on both map familiarity and gender. Participants who considered themselves to be very familiar with maps felt more confident when dealing with animations than those who considered themselves to have moderate or low map familiarity. In the animated group, males reported lower levels of confidence. Whether this effect is consistent remains unknown, and further research should be undertaken to explore more fully the issue of confidence with respect to animated cartography.

In some instances, animated maps are likely to be more effective than static maps, but in other instances, the opposite will be true. Harrower (2007) asserts that animated maps are simply different from static maps. Attempts to demonstrate an inherent superiority of one or other is ultimately pointless because as to the question of which technique is superior “the answer will always be ‘it depends’” (Harrower, 2007, 351). The conflicting evidence from previous research regarding the effectiveness of animation suggests that the answer does depend. Harrower goes on to echo the sentiments of Edsall et al. (1997) and Fabrikant and Goldsberry (2005) who argue that cartographers should be concerned with whether the use of animation is appropriate and effective given the data, the audience, and the purpose of the map.

In this study, the most influential factor turned out to be the map set. The map set variable corresponds to the three different pairs of maps produced from three subsets of data and shown to participants during the test. Each pair of maps consists of one static and one animated map that have identical informational content. The second set of maps displayed much more limited changes from one time period to the next, and this proved to have consequences for response accuracy and participant confidence. Map familiarity also has an independent effect on both response time and participant confidence.
These results do highlight the importance of the need to consider the benefits of animating data for a cartographic display versus the use of traditional static cartographic techniques. As Harrower (2003b) points out, “it is always worth asking why do I need to animate these data?” (Harrower, 2003b, 63). If there are no added benefits to producing an animated map, then the extra cost and effort involved cannot be justified. The results of this study emphatically show that in the case of complex, nominally classified temporal data, there are no benefits to animated maps vis-à-vis static maps for the purposes of communicating information or knowledge to a general audience. In this study, participants viewing static maps outperformed those viewing animated maps under specific circumstances (i.e. when combined with the influence of another factor), but under no circumstances is the converse true. In other words, participants viewing animated maps failed to outperform participants viewing static maps under any set of conditions. The use of animation is best left to scenarios where it clearly holds superiority.
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APPENDIX A

TEST QUESTIONS

Test Questions for Map Set 1

1. Select all categories which show an INCREASE with respect to total area:

2. In which category does the greatest absolute INCREASE over time occur in terms of total area?

3. In which category does the greatest absolute DECREASE over time occur in terms of total area?

4. The majority of area classified as category 4 at Time 1 is in which category at Time 5?

5. Which category experiences the least amount of absolute change over time?

6. In terms of total area, the greatest absolute INCREASE in category 6 occurs between which two points in time?

7. The least amount of total change for all categories, in terms of the amount of area affected, occurs between which two points in time?

8. For category 6, the general temporal trend is one in which that category is ________

Test Questions for Map Set 2

1. Select all categories which show an INCREASE with respect to total area:

2. Select all categories which show a DECREASE with respect to total area:

3. In which category does the greatest absolute INCREASE over time occur in terms of total area?"
4. In which category does the greatest amount of absolute change (increase or decrease) over time occur in terms of total area?

5. In which category does the greatest absolute DECREASE over time occur in terms of total area?

6. In terms of total area, the greatest absolute change in category 3 occurs between which two points in time?

7. In terms of total area, the greatest absolute change in category 4 occurs between which two points in time?

8. For category 4, the general temporal trend is one in which that category is _______

Test Questions for Map Set 3

1. Select all categories which show an INCREASE with respect to total area:

2. Select all categories which show a DECREASE with respect to total area:

3. The greatest absolute change in category 4 occurs between which two points in time?

4. In which category does the greatest absolute INCREASE over time occur in terms of total area?

5. In which category does the greatest absolute DECREASE over time occur in terms of total area?

6. The least amount of total change for all categories occurs between which two points in time?

7. The greatest amount of total change for all categories occurs between which two points in time?

8. The greatest absolute change in category 2 occurs between which two points in time?