Spatial Cognition 2010: Doctoral Colloquium

Andrea Frick, Daniele Nardi, Kristin Ratliff (chairs)

SFB/TR 8 Report No. 025-07/2010
Report Series of the Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition
Universität Bremen / Universität Freiburg

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Spatial Cognition 2010
Mt. Hood / Portland, Oregon
August 15-19, 2010

DOCTORAL COLLOQUIUM

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Exploring How Text-Figure Configuration Affects Introductory Geology Student Learning Behavior Using Eye-Tracking Technology

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Abstract. Figures are a significant component of textbooks and other learning aids, but little is known about how students integrate figures and text while learning geology content. Some previous research has been conducted regarding text and figures, but little of the focus has been on adults, and none of the studies have centered on geology, leaving a need for studies involving how college student integrate text and figures while learning from textbooks. Using eye-tracking technology, our investigation explores the strategies that students use when reading educational materials. Data analysis is still in progress.

Keywords: Multimedia learning, Eye tracking, Geology,

1 Introduction

Photographs, sketches, and diagrams are an essential component of geoscience learning. Additionally, textbooks are a primary source of content information in most geology classes. It is, therefore, particularly important to understand how students integrate words and figures in textbook-style learning materials. Eye tracking provides a way to study and document where students focus their attention and how they tackle the task of learning new information. Eye tracking students while they are learning from textbook-style learning materials will ideally provide insight about learning behaviors and lead to improved design of instructional materials.

2 Background

Coupling figures with descriptive text can lead to greater science learning than when either medium is presented alone (e.g. [1], [2], [3], [4]). Meaningful learning from both text and pictures (multimedia learning) requires that students build connections between corresponding words and pictures. Consequently, to facilitate learning from multimedia instructional materials, the materials should be designed in a way that supports the cognitive processes of the learner [4], [5], [6].

Previous research regarding learning from text and figures (multimedia learning) provides insight into students' learning behaviors as well as recommendations for design of instructional materials. For example, Hegarty and Just [2] investigated how college students constructed mental models of pulley systems from text and diagrams. They concluded that the students' processing of the material was primarily guided by the text rather than the diagram. Additionally, after reading several clauses of text the students referred to the diagram, suggesting that they were constructing their mental model through incremental integration of the text and diagram. This learning behavior, in which students shift their focus between the text and figure, requires that the information first taken in (from the text, for example) be held in working memory while the next piece of corresponding information (from the figure) is found and processed, increasing cognitive load [6]. To reduce cognitive load, Moreno and Mayer [7] recommend designing multimedia instructional materials in an integrated presentation, meaning that figures should be placed near corresponding text.

Whereas previous research has provided significant insight about multimedia learning, eye-tracking investigations regarding the processing of textbook-style materials are sparse [8]. Additionally, little to no emphasis has been placed on multimedia learning in geoscience education, leaving a need for eye-tracking studies involving how college students integrate text and figures from textbook-style learning materials. Specifically, questions of interest include: Does the format of the text and figure on a page influence geoscience learning and time spent examining the figures versus text? Does the complexity of the visual model that students are required to construct impact multimedia learning behavior? Does separating the text into smaller "chunks" facilitate learning? What strategies do students use when learning Geology from textbook-style materials? Do certain strategies lead to greater learning than others? Finally, does eye tracking affect learning behavior?

3 Methods

3.1 Participants

Participants were 168 undergraduate students enrolled in Introductory Geology at Arizona State University

3.2 Materials

The learning materials consisted of three one-page descriptions of introductory-geology level information. The topics covered include soil formation and soil horizons, rock slide features and processes, and how salt domes aid in trapping oil and gas. Each topic was confined to one page consisting of explanatory text and one figure illustrating information redundant in the text. The three topics were formatted in three different ways, defining three different experimental groups. One end-member format, the *traditional textbook* format, had the text arranged in three continuous columns with the figure following the text. Four figure references within the text cued the learner to look at the figure. The other end-member format, the *integrated* format, was designed with the figure in the center of the page. The text was spatially separated into "chunks" describing a common idea. A leader connected the text chunk with the location on the figure to which it referred. The third format, the *referenced* format, consisted of design elements of the other two formats. The text was again arranged in three columns as it was in the traditional textbook format but the figure was placed in the middle of the page and additional figure references were placed within the text in locations corresponding to the text chunks of the integrated format.

Pre and post tests were used to assess learning outcomes. The pre and post tests consisted of eighteen multiple choice questions addressing the information contained in the text and figure. The post test contained an additional six likert-type scale questions to investigate how students felt about their eye-tracking experience.

3.3 Procedure

Students were randomly assigned to one of three groups (*traditional textbook* group*, referenced* group, or *integrated* group) that differed based on the format of the text and figure on the page. At the beginning of each session, students signed a consent form and took the pre test. During the intervention, students read three one-page descriptions of geology content from a computer monitor while being eye tracked. They were able to switch from one topic to the next at their own pace. After reading all three topics, students took the post test.

4 Preliminary Results

Data analysis is still in progress. Eye-tracking data and pre- and post-test scores for the *traditional textbook* group have not yet been analyzed. Data from the *integrated* and *referenced* groups, however, reflect that, on average, students spent a surprisingly small amount of time examining the figure compared to the text (<10% of fixations). Additionally, pre- and post-test scores for the *integrated* and *referenced* groups indicate that, although not statistically significant, the *integrated* group improved more from the pre test to the post test than did the *referenced* group. On the rock slide content, more integration between the text and figure lead to greater improvement from the pre test to the post test. This relationship has not yet been explored for the soil and oil content. A significant amount of eye-tracking data remains to be analyzed in an effort to answer the questions posed above.

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Wayfinding architectural design criteria for complex environments in ordinary and emergency scenarios

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Abstract. The PhD Dissertation analyzes human wayfinding strategies in relation to the perception of the building's environment. Wayfinding strategies in complex buildings (by floor plan complexity, type of users, etc. ...) are put in relation to the user's behavior and the quality of the environment around her/him, expecially in emergency situations. The initial part of the thesis proposes studies about human cognitive perception mechanisms in order to identify wayfinding design critieria for buildings both in ordinary and emergency situations (this includes elements such as layout, signalectics, sounds, lights, etc. ...). Results of case studies concerning human wayfinding in complex environments are shown and discussed in order to understand design criteria for wayfinding that are efficient.

Key interest: wayfinding, architecture, complex environments, human behavior in fire, design criteria, environmental psychology, SC10 Doctoral Colloquium

1 Description of the work in progress

The Thesis analyzes human wayfinding strategies in relation to the perception of the building's environment, both in ordinary and emergency scenarios.
To achieve this goal, many aspects regarding the relationship between the user / the building have been considered.

Aspects relating to the user:
- spatial cognition and wayfinding
- literary review on wayfinding related to different type of users's behavior-perception
- human behavior in fire

Aspects relating to buildings:
- environmental legibility
- Theory of Affordances (Gibson, 1979)

- salience of landmarks: visual, semantic, structural (Raubal, Winter, 2002)
- architectural elements for wayfinding design: floor and paths layout, characterization of spaces, lights, color, etc.

Wayfinding strategies in complex buildings (by floor plan complexity, type of users, etc...) have been set in relation to the user's behavior and the quality of the environment around her/him, especially in emergency situations.
Previous case studies about the environment's cognitive perception mechanisms have been discussed in order to identify wayfinding design critieria for buildings both in ordinary and emergency situations (this includes elements such as layout, signs systems, sounds, lights, etc…).

The results of two case studies concerning wayfinding in complex malls in northern Italy will be presented in order to understand design criteria for wayfinding that are efficient.

2 Motivation of the study and related work

Weisman [1] found that the most serious disorientation problems occurred in buildings judged as being the most complex and difficult to describe. He found that visual spatial features of the environment (such as simplicity and good form) and familiarity with the building are the most important key elements for good human wayfinding performance.
Nowadays, most buildings are very complex and most of the designers think that sing are a sufficient solution for poorly designed buildings. It has been argued several times, for example by Arthur and Passini [2], that signs do not fix the problems related to the bad design of a building.
In addition, most of the early researchers of human behavior in fire have demonstrated that wayfinding tasks difficulty increases significantly in emergency scenarios [2,3,4]. A frequently observed phenomenon reported in the literature [3], termed "movement towards the familiar", refers to the intuitive way that people exit buildings by their familiar exit even in emergencies. This intuitive egress behavior is not always problematical but in some cases it could prove lethal, for example, when the familiar route is untenable.
McClintock et al. [6] also been reported by that under everyday conditions occupants tend not to notice or recall the location of emergency exit signs.
As suggested by Ozel [7], in order to understand how to design efficient wayfinding especially in emergency situations, it is important to know how people perceive the environment. Cognitive factors are a key element in influencing wayfinding performance.
In this paper, the author turned her attention to the visibility of the egress route as an important performance factor in assuring the safety of occupants in buildings.
They decided to conduct a cognitive mapping test on emergency exits in a supermarket. Clients in a supermarket are never involved in fire drills and may not be aware of emergency exits location, or how to behave efficiently in emergency.

Supermarkets, as suggested by Norman [8], are known as being complex environments also because of visual merchandising techniques that tend to easily disorient customers.
Research on cognitive maps and cognitive mapping is by now quite extensive. The bulk of research has focused on people's memory representations of large-scale environments [9,10]. Many of these studies have tried to determine what people remember about the environment.

No studies, to the knowledge of the author, have analyzed cognitive mapping capacities of recalling emergency exit in supermarkets or malls. Understanding how people perceive the environment is, therefore, the most important thing in order to predict human wayfinding behavior and consequently design the building [2].

3 Methods

The research method involved case studies of human wayfinding behavior in two malls in northern Italy. The data collection technique used was post-occupancy verbal interviews with a set of pre-defined questions with single individuals. People involved in the test are both clients and workers.
Participants were asked to:
1 - indicate a certain route to a person who had never been inside the supermarket
2 -recall emergency exits, otherwise indicate what evacuation procedures he/she would have followed in the event of a real emergency.

4 Preliminary results

In this paper we report preliminary findings (Table 1) on a cognitive mapping abilities test about recalling emergency exits, as the emergency scenario is considered to be the most difficult one for wayfinding.
The study was conducted on February 27th 2010 in the "IperCoop Meduna" supermarket in Pordenone, northern Italy.
There were 106 people interviewed (male 48%, female 52%).
The cognitive mapping test was necessary to highlight the critical elements of architectural design of the building.
The first consideration relates to the identification of a vivid distincion of responses related to the different age groups: particularly important, also, the fact that only 18% of all respondents were able to give an effective indication of the location of at least one emergency exit.
Respondents, who were unable to recall emergency exits (32,08%), have proposed, as an alternative for escaping, to head towards pay desks or entrance, simply proposing the paths habitually engaged in ordinary conditions.
Paydesks and entrance are, therefore, critical design elements. In case of an emergency they can impede rapid people flow: this is due to the narrowness of paydesks lanes and the presence of crowds in their close proximity.

About 16% of participants said that they would seek signs or emergency exits. This is an efficient attitude in emerency situations, but it could be completely vain if the sign systems and location of emergency exits are not really effective in that particular situation.

Table 1. Answers the question: "Can you recall emergency exits? Otherwise, how would you exit the supermarket if an emergency occurs?”. Age classification.

Answers	**Young 15 (14,15%)**	**Adults 63 (59,52%)**	**Elderly 28 (26,45%)**	**TOT 106 (100%)**
Absolutely not	3 (20%)	12 (17,46%)	6 (17,86%)	19 (17,92%)
Effective response	2 (13,33%)	14 (22,22%)	3 (10,71%)	19 (17,92%)
Pay desks/Entrance	5 (33,33%)	18 (28,56%)	11 (39,29%)	34 (32,08%)
I will follow the flow	2 (13,33%)	9 (14,28%)	3 (10,71%)	14 (13,21%)
Signs/Exits	3 (20%)	10 (15,87%)	4 (14,29%)	17 (16,04%)
General information	0	1 (1,59%)	2 (7,14%)	3 (2,03%)

The fact that almost 80% of elderly and adults (who are routine clients of the supermarket) were unable to recall exits or have declared that they would have ineffective behavior in an emergency, is as an important consideration for properly designing wayfinding systems.

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6 Elisabetta Carattin: biography

Born in Italy in 1981, architect and PhD Candidate at IUAV University of Venice.
She graduated in 2006 at IUAV University with a graduation thesis concerning the design of FRP (fibre reinforced plastics) structures to be set in emergency situations.
Since 2006, she's involved with ArTec (the IUAV University archive of technics and materials for architecture and industrial design, http://www.iuav.it/SISTEMA-DE/Archivio-d/contatti/sede--staf/Presentati/index.htm) in research topics concerning the field of architectural technologies and materials, expecially in the field of safety.
Teaching assistant, since 2007, in the field of Architectural Technologies and Sustainability (ref. prof. arch. Valeria Tatano, prof. arch. Massimo Rossetti).
Stongly motivated towards the importance of international collaboration in research, in 2007 she conducted research on glass enclosuers with CWCT (Centre for Window and cladding technologies – Bath University Campus, UK).
In 2009 she conduted a research stage in wayfinding and human behavior in fire at NRC (National Research Council Canada, ref. PhD Guylène Proulx).

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Investigations in the Impact of Visual Cognition and Spatial Ability of Student Comprehension in Physics and Space Science

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Abstract. Physics and Space Science examine topics that are highly spatial in nature. Students are required to visualize a system, manipulate that system, and then solve a given problem. Doing all of this, simultaneously, can lead to a cognitive overload where the student is unable to correctly solve the problem. Some difficulties may be rooted in conceptual difficulties, whereas other difficulties may arise from issues with spatial intelligence and visual cognition. In some cases, students might have created an incorrect mental image of the problem to begin with, and it's this misconception, not the lack of content knowledge, that has caused an incorrect answer. It has been shown that there is a correlation between achievement in Science Technology Engineering and Mathematics (STEM) fields and spatial ability. My work focuses on several discrete investigations in topics that relate to student learning in physics and space science and the relationship to spatial ability.

Keywords: Physics Education Research, Spatial Ability, Visual Cognition

1 Introduction

Physics Education Research (PER) is specific investigation of issues related to teaching and learning physics content. Our group uses a cognitive/psychological approach to identify problematic areas in abstract subjects such as Mechanics, Electricity and Magnetism, and Astronomy. We mainly use two methods of collecting data. We collect quantitative data using assessments in three categories; content data assessed via concept inventories, spatial ability assessed via the Mental Rotation Test (MRT) and student demographics via demographic surveys. We collect qualitative data via student interviews. In certain studies, the qualitative data is more valuable than the quantitative data because the qualitative data can give us insight into how students are perceiving the information that they are given. It helps us to understand where the misconceptions are occurring.

It has been shown that in addition to having more content knowledge than novices, experts possess knowledge that is organized and stored in memory in such a way as to facilitate quick access to sophisticated problem-solving strategies [1]. Chess masters and physics professors fall into this same category [2].

However, there are other issues that are separate from content and conceptual understanding that impact the learning of physics. Spatial intelligence is on of these. Previous work [3] indicates that mental manipulation of 3D images plays a role in increasing cognitive load when dealing with magnetism and the relationship to currents. Siemakowski and MacKnight [4] concluded that not only did science students have a higher spatial ability than non-science students, but physics students have the highest spatial ability followed by geoscience students. Pallrand and Seeber [5] suggest that visual spatial ability is needed to succeed in introductory courses like physics. Moreover, they find that the simple act of taking a course like introductory physics courses improves your visual spatial ability.

My dissertation is structured with discrete studies that address the ideas stated above. Our general questions address how a student's spatial ability helps or hinders their ability to understand a spatial topic.

2 Published Studies

This section will outline how, as experts, we tend to have the idea that our students will have the ability to process information that we give them in diagrams. The first study, conducted at Florida Institute of Technology (FIT), explores issues regarding student interpretation of color as a third dimension and graphical representations. The second study, conducted at the University of Texas, Arlington (UTA) explores the impact of stereo display on student understanding of phases of the moon.

2.1 Color as a Third Dimension on Graphical Representations

While we were at FIT, we were participating in an interdisciplinary course that focused on six aspects of the Earth. Each subject is taught by a professor from that field. While discussing the "hydrosphere", one of the professors presented a slide on sea surface temperatures in the world oceans. The ocean temperatures were presented with contour lines labeled according to temperature in Celsius along with color bands between the contours, which also represented temperature. Unfortunately, there was a 'gray' color filled region in the middle of the image that created some confusion in the classroom. Even though the contour lines were clearly labeled, the seemingly out of order 'gray' color demonstrated how unimportant information to an instructor can be salient in the mind of a novice.

This led to the question of how important is color when it is used to represent a third dimension? We presented physics students with two topographic maps with contours labeled only with color. The first image used an ascending color scheme from dark blue to red to indicate the elevation of the land. The second image used the exact same color scheme only in reverse order to indicate the elevation of the land. Half the students saw one image first and the other half of the students saw the second image first, and then vice versa. After the surveys were collected eight students were chosen to participate in interviews. Based on the quantitative and qualitative data collected we drew the following conclusions:

1. There was no preference for any figure, but 35 out of 54 students preferred the first image they saw.
2. Only 16 students used a consistent color scheme and 21 students called both figures a hill
3. Students had an imbedded notion that blue = water even though they were explicitly told the color referred to height.
4. Students created the landform (hill) first and then applied the color to the image.
5. With respect to temperature, students had an imbedded notion that blue = cold and red = hot, but could not transfer the concept that blue = low and red = high.
6. Dots that were included (by printer) to distinguish between shades of color created confusion for our students and were only brought to our attention in the interviews.

This study suggests that students had a predilection to visualize a hill, regardless of the color map used. Students were relying on other visual cues instead of color to understand the problem. These other cues have the ability to manifest themselves in an incorrect mental model. The incorrect mental model led us to our next study.

2.2 The Impact of Stereo Display on Student Understanding of Phases of the Moon

It is widely known that phases of the moon are a challenging concept for students to understand. Phases of the moon is naturally a spatial topic and there has been research that suggest that 3D simulations can increase student comprehension [e.g., 6].

We set up a simple experiment that used 15 intact Introduction to Astronomy laboratories (labs). We created a phases of the moon lab and replaced the normal moon lab for that semester. We presented visuals using GeoWall hardware with AstroWall software. Half of the labs were presented with 3D visuals where the students had to wear polarized glasses to give a 3D effect. The other half of the labs were presented with the exact same visuals, but students were not given polarized glasses, and only one projector was used.

We found that both 2D perspective and 3D stereo visuals had a statistical effect on student comprehension, but there was no statistical difference between 2D perspective and 3D stereo labs. For this particular study, we found that 3D stereo is not required. The 2D perspective visual cues were enough to reduce the cognitive load and allow students to improve comprehension of lunar phases. Although this study showed that the 3D stereo was not required, "the current wedge study", presented by Lopez and Hamid [3], clearly shows how reducing cognitive load by creating displays in 3D has a positive effect in student comprehension.

3 Current/Future Work

Because of our interest in the cognitive load produced by mental manipulations of 3D images we ask the following questions:

1. How do UTA students' spatial abilities affect their ability to succeed in physics course?
2. How can we improve comprehension of physics and improve student outcomes (retention, etc.)?

In order to answer these questions regarding spatial ability, we are expanding on the spatial intelligence study conducted by Pallrand and Seeber [5]. Where their study focused on community college students, our focus is with university students. We have taken data from introductory engineering students, most of which have not taken physics. The majority of students who take introductory physics course come from engineering. The data collected from introductory engineering is going to be compared to the data collected from introductory physic in order to see how students have progressed with their spatial intelligence. With the physics course, we are planning to administer pre and post concept inventories in order to assess concept knowledge gained in the course. We can then compare with the MRT data to examine if there is a correlation.

In order to answer the question of improvement, we have identified topics we feel are spatial in nature. We are planning on rendering specific visuals in 3D stereo in order to test our cognitive load theory. If by reducing the cognitive load we can improve comprehension, we can look at how this affects retention. We are working with the College of Engineering and several departments within the College of

Science to identify factors that impact retention in the first two years, especially spatial intelligence.

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Using eye tracking to evaluate the effectiveness of signaling to promote dissembedding of geologic features in photographs

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Abstract. Geology is a visual science and is taught using images that require an object for scale. Scale objects, can be distractors and prevent students from learning valuable content. To evaluate the role of distractors, students were eye tracked while looking at geologically rich images. Students who saw images that contained distractors fixated on the distractor and also surveyed the scene less than students that looked at the same image without distractors. Preliminary results indicate that students who receive explicit instruction about the geology of the image spend more time looking at areas they were directed and less time focusing on distractors.

Keywords: Eye tracking, geology, geospatial, visualization, disembedding, distractors, signaling, callouts, cueing, photographs,

1 Introduction

Geology is one of the most visual of the sciences. It is common and necessary to use charts, graphs, maps, cross sections, and photographs to understand, and convey geologic information for both professionals and students [1], [2], [3]. Compiling information from multiple representations can be difficult for students and may lead to a lack of understanding and an inaccurate mental representation of geologic concepts. Students are required to both select pertinent information and organize the information in a meaningful way. Information selection occurs from pictures, diagrams, and textual information [2], [4]. In many cases student fail to make proper connections and inferences, possibly due to cognitive resource misuse or from distractors inherent in the material [5].

Common classroom practice in geology is for an instructor to project a photograph of a geologic landscape in front of a class and then describe the geologic features in the photograph. These photographs almost always have an object or person present to represent scale. As teachers we assume that students are focused on exactly what we are pointing out and discussing, but this may not be the case. Objects included in the photograph for scale and the rich details of landscape pictures may be distracting to the student [6] and may cause selective-attention deficit, thereby preventing the viewer from learning valuable content. Selective-attention deficit may come in two forms: divided-attention deficit, where the participant's attention is unconsciously split between multiple stimuli, or focused attention deficit, where the participant consciously knows what information is relevant, but cannot ignore the irrelevant stimuli. In both cases performance is reduced due to high cognitive load [5].

Although there are numerous publications by Tufte [7], [8], [9]and Roth [10]about how to present images, there is very little work done researching what people are actually looking at. We use eye-tracking technology to answer the following questions: 1) Do distractors serve to draw students into what may otherwise be a novel environment? 2) Do distractors hinder learning by causing selective-attention deficit and distracting students from valuable content? 3) What are the behaviors and strategies students use when searching a photograph for geologic information? 4) Can we teach a student to effectively disembed geologically relevant content in a photograph using explicit instruction or "signaling", which clearly highlights germane items? and 5) Do introductory geology students and advanced geology students interact with distractors differently when viewing a photograph of a complex landscape? In addition to answering these questions we will explore student learning outcomes based on their interactions with distractors and will suggest best practices for presenting photographs in learning environments.

2 Background

The first step to understanding a photograph is to gather information in the photograph by scanning or searching. Scanning is done by a combination of *saccades*, or rapid movements of the eye, and *fixations*, areas that hold our visual attention ([11], [12], [13], [14]. Our visual field can be broken up into three areas, the foveal, the parafoveal, and the periphery. Although the fovea is the only part of the eye that permits full visual acuity, it only has a field of vision of 2 degrees. The parafovea, however, has an extended field of vision of 5 degrees on either side, but does not have the same visual acuity as the fovea. Finally, the periphery only delivers very low-resolution data. Because the fovea is the part of the eye with the most visual acuity, it is necessary to move the eye to direct the fovea over the part of the stimulus we want to see clearly [15].

There are two competing hypotheses about how we focus the fovea over desired stimuli or search a photograph for meaningful information: we use either controlled search or automatic detection. Controlled search is a capacity-limited search that is often serial in nature and manifests itself in the systematic "reading" of a photograph or serial comparison [5]. It is important to note that a controlled search is a mindful process by which the participant consciously controls their eye movement and attention. A controlled search can become an automatic-detection search, once learned and rehearsed.

When we are not mindfully searching a photograph in a controlled manner, we are using automatic detection. When searching using automatic detection, it may appear that the patterns with which we sweep across photographs are random, but they are actually meaningful. Humans are very effective at surveying an image [16], [17]. We typically fixate on one location and then instead of using a long saccade to focus far away from our initial fixation, we use a medium saccade to fixate to areas nearby our initial fixation. Additionally, we do not use a series of short saccades because we have just gained information nearby, therefore the probability that the item of interest is nearby is less than the probability that the item we are searching for is farther away from our initial saccade [17]. So what can appear as a random series of fixations may actually be a very ordered, efficient way to search a photograph.

Other research has shown that as the amount of time a stimulus, such as a photograph, was present, fixation length increased and saccade length decreased, suggesting an initial global survey of a scene followed by the collection of finer details, which usually correspond to information-rich objects. Additionally, humans tend to focus on elements like faces and people rather than background elements ([11], [13], [18], [19] or visually poignant items, such as edges, corners, or spatially high frequency items [20].

Eye movements are a result of the perceptual processes that occur while looking at an image [17]. Although Hoffman and Subramaniam [21] have shown that a human cannot move their eyes to one location while attending to another location and that visuospatial attention is a necessary mechanism in generating voluntary eye movements, it is possible to shift our attention outside our fovea view or to the peripheries of our center of vision [20]. However, it takes a conscious effort to shift this attention; therefore when we are looking at a photograph for content, our attention is typically focused on the item on which we are fixating. Therefore we can come much closer to approximating where a student's overt attention lies while using instrumentation that detects and records eye-focus location, fixation length, and eye movements or saccades. This technology allows direct recording of this data rather than relying on self reports of attention and eye movement, as humans are commonly unaware of these movements and are unable to describe them accurately [13]. Since eye movements are made without conscious intervention, monitoring them often provides us with a window into cognition [11], [14], [15], [22].

3 Methods

Participants were introductory geology students at a large southwestern university. Students were recruited from 6 different classes over 3 different semesters and subjected to 1 of 3 different experiments: 1) understanding how students look at geologically rich photographs and the effects of distractors on learning outcomes, 2) testing the effects of explicit instruction, and 3) understanding the difference between novice and experienced students. So far, 205 students were eye tracked. Each participant was given a pre test, a treatment, and a post test.

In experiment 1, students were randomly assigned to one of three groups: a narration only group (the control group); a group that listened to narration that corresponded to 16 pictures, of which 8 contained distractors; and a group that also listened to narration with 16 pictures, but with the opposite 8 pictures containing distractors. Distractors consisted of people, inanimate objects, and animals.

Experiment 2 was designed to test the effects of explicit instruction on learning outcomes and the efficiency of two different methods of signaling. Students were assigned to 1 of 2 groups; each group listened to narration and viewed a series of photographs with geologic content. In group 1, the photographs were presented on screen for 4 seconds without narration and then callouts were added to the image to highlight important geologic content. After 4 seconds the callouts were removed and the narration began. This provided the participant with the opportunity to observe the picture without being distracted by the narration, presented the student with explicit instruction using the callouts, and then allowed the student time to apply the new information before the narration started. In group 2, images were presented using the same format, but signaling was altered and instead of callouts, the entire image was removed and replaced with a schematic drawing, which only featured pertinent, geologic information.

Experiment 3 was structured and formatted the same as experiment 1, but participants were advanced geology students. This experiment was designed to compare behaviors between introductory geology students and advanced students. Students assigned to this group were given the same narrated geology slideshows used in experiment 1.

4 Results

There was no statistically significant difference on pre/post test scores between groups in experiment 1. The lack of difference in scores was probably in part due to the requirements that the test be based on the narration, which was the only activity shared by the control and experimental groups. Students in the control group, who only listened to narration, performed as well on the pre/post test as students who listened to narration and saw photographs. Interestingly, students who were exposed to narration and photographs focused primarily on the center of the photographs and surveyed less of the image when a distractor was present.

Preliminary results for experiment 2 are consistent with findings by Boucheix and Lowe [23] and De Koning et al. [24], which shows that participants follow the same search behavior as students in experiment 1, but after receiving explicit instruction participants focus more on pertinent information and spend less time dwelling on distractors. Data analysis for experiment 3 is still in progress.

5 Discussion

The lack of statistical significance in experiment 1 has lead to an additional study. This part of the experiment is currently being repeated with an alternate pre and post test that also assesses what the student learned from pictures as well as narration. Data analysis is still in progress.

Data from experiments 2 and 3 have not yet been analyzed, but the results may have consequences. Explicit instruction or signaling has been shown to increase a student learning outcomes [22]. Research has shown that teaching students how to look at content rather than simply teaching content can elicit automatic detection in a student [5]. Automatic detection is a way that humans search a photograph through a learned process. A good example of this is when a subject has been trained to recognize certain inputs, such as a fault, once an input is placed in front of a subject; these inputs then illicit automatic attention responses, which direct attention to the target and enable a correct detection [5], [25] a possible key difference between a novice and expert.

6 Conclusions

Three experiments were carried out in which students were eye tracked while viewing geologically rich images. When images contained a distractor necessary to show scale, students spent nearly 1/5 of the time surveying the image on the distractor alone. We are currently carrying out research to evaluate the effects of explicit instruction and data analysis is still in progress.

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Relevant cues for spatial navigation in children and adults

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Abstract. Spatial navigation implies the processing of spatial information which is partly determined by sensation and interpretation of the person's own movement. The aim of our project is twofold: to study the relevant cues for spatial navigation first in children according to age and second, in adults, experts and non-experts. Because locomotion is defined as a set of rotation and translation, a mental rotation task and a triangle completion task will be linked to field-dependence, to the children's independent mobility and the adults' expertise.

Keywords: navigation, rotation, translation, perception, development.

1. Introduction

Spatial navigation is a constant in our daily life. It is used for orientation, wayfinding, as well as information seeking or problem-solving. Literature in this field is very abundant and includes numerous concepts – perception, visualization, information processing, working memory, geometry, reference frames, and many more. Spatial navigation is linked to perception, cognition and action, therefore research on spatial abilities and processes helps us enhancing our understanding of those fields and their inter-relationships.

2. Theoretical background

According to Gibson [1], the environment provides the individual with information about some opportunities for action. Different types of environment provide different types of information, which facilitate or hinder wayfinding strategies. In other words, the richer the environment the better spatial references it offers [2] [3]. In this theoretical context, navigation, considered as a constant updating between proprioceptive cues and environmental information, is strongly tied to visual perception. As underlined by Klatzky, Loomis, Beall, Chance, & Golledge [4], when perceptive or proprioceptive cues are missing, navigation performances are poor. Thus spatial information during navigation is partly determined by the sensation and interpretation of one's own body movements [4]. Moreover, we perceive the environment according to our expertise, our specific expectations and our experiences [2][3]. Thus, navigation should be influenced by proprioception and perception, environmental information and experience.

However, spatial skills are part of intellectual capability as they are closely related to geometry and physics. Space is the foundation of geometry [5]. Navigating in the environment involves rotation and translation [6]. To study the rotation performances in navigation, Klatzky et al. [4] have been using a triangle completion task, which implies a spatial updating after a rotation and refers to an inference in real environment. This triangle completion task showed that rotation performances depend on the availability of perceptive cues [4]. In parallel, children who imagine or use short-cuts in their environment also perform the same type of spatial inference [7]. In addition, some empirical evidence suggests that children's active and independent exploration of the environment allows them to acquire a better spatial knowledge than passive exploration [8][9]. This free environmental exploration refers to children's independent mobility area, which is defined as the area the child is allowed to cover and explore without being supervised by an adult [10]. Consequently, spatial navigation would imply a mutual relationship of the environment and the individual, which would be a basis for spatial cognition. In turn, spatial cognition would sustain and enhance the environmental exploration. These experiences of exploration increase the spatial skills relevant to navigation.

What relations could we observe between the influence of proprioceptive cues, large scale navigating experience, and cognition? Does the way proprioceptive cues are taken into account influence one's performances in spatial cognitive tasks? How relevant is the daily experience of navigating for spatial cognitive tasks? Does the extent of children's independent mobility have an impact on children's performances on spatial cognitive tasks? In the same way, are people experienced in navigating more accurate in spatial cognitive tasks than less experienced people?

3. Aims of the study

The objective of our research is to clarify these questions by using two different perspectives. The first one is developmental and aims to study the influence of children's independent mobility area in navigation and in spatial cognition performances. The second intends to study the influence of experience in using cues to navigate. To this end, we will compare performances of navigation experts with those of ordinary adults on navigational and spatial cognitive tasks.

For the developmental perspective, we will select 3 groups of children according to their ages (5-7, 9-10 and 12-13 year-olds). In parallel, because tasks chosen to test navigation performances imply rotations, the expert group will be composed of adult dancers to be compared with a convenience sample of adults.

The Rod and Frame Test (RFT) will test the way proprioceptive cues are taken into account by subjects compared to environmental cues. The Paper Folding Test (PFT) and the Vandenberg and Kuse Mental Rotations Test (MRT) will measure the spatial cognitive performance. The different modalities of Triangle Completion Task (TCT) – walking, walking blindfolded, seated and listening to a description of the path, seated on a wheelchair and driven along the path – will measure the performances and indicate the relevant perceptive cues for navigating on a large scale. Finally, concerning the developmental part, the independent mobility questionnaire [10] will measure the extent of the children's autonomous mobility.

The research will ask the following specific questions:

1. Do field-dependent subjects perform better on MRT and PFT than field-independent subjects?
2. Do field-independent subjects perform better on TCT than field-dependent subjects?
3. For the developmental part:
   3.1 Does the relevance of cues for navigational performance differ according to age?
   3.2 Which measure is a good predictor of TCT's performance?
4. For the expert-novice part:
   4.1 Does the relevance of the cues for navigational performance differ according to the degree of expertise?
   4.2 Which measure is a good predictor of TCT's performance?

4. Methods

Participants:

The subjects in the developmental part will be children of 3 different age groups: 5 to 7, 9 to 10 and 12 to 14 year-olds (N=60). There will be an even number of girls and boys.

The subjects in the expertise part will be adults with an expert practice of dance and ordinary adults (N=40).

Measures:

The Rod and Frame Test (RFT) determines the degree of field-dependence of the individual and indicates the cues, either visual or proprioceptive, that the individual prefers to rely on,
The Paper Folding Test (PFT) is a two-dimensional spatial task, which isolates spatial visualization as a factor of spatial skills.

The Vandenberg and Kuse Mental Rotations Test (MRT) is a three-dimensional mental rotation test that refers to cognitive spatial skills.
The Triangle Completion Task (TCT) is a navigational rotation test that helps clarify the impact of missing perceptual cues on navigational abilities.
The Independent Mobility Questionnaire (Kyttä, 2004) helps to determine the area of the children's autonomous mobility.

Analysis:

For each separate part (developmental and expert-novice), results will be analyzed with a factorial study using SPSS program. A Manova will be calculated in each part to determine the most relevant factor explaining performance to the TCT.

5. Relevance

The study is relevant insofar as it improves knowledge on spatial cognition, which contributes to knowledge of cognitive processes. This knowledge of spatial cognition and navigation contributes to geometric and mathematical applications in education. More generally, this knowledge helps to improve the planning of navigation behaviors and provides support for urban development planning, designing more readable buildings, adapting GPS, GIS, and maps.

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Using salient environmental characteristics to improve wayfinding and spatial awareness

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Abstract. Research on pedestrian wayfinding has two major goals: improving the accuracy of wayfinding performances and enhancing spatial awareness of the environment one travels. It is essential to understand how characteristics of both human (familiarity and spatial abilities) and environment (legibility and elements) influence wayfinding behaviors. Measures are carried out to verify the roles that these characteristics play on human wayfinding behaviors. The influence of each characteristic on wayfinding will be evaluated in a behavioral model. The outcomes are beneficial to the design of cognitively ergonomic wayfinding aids for pedestrians.

Keywords: wayfinding, spatial awareness, formal description, legibility

1 Motivation

Providing cognitively ergonomic wayfinding aids for pedestrians is a central topic addressed in current wayfinding research. Specifically enhancing wayfinding performance and spatial awareness are the two major goals in this research endeavor. First, improving wayfinding performances is the foremost goal that any wayfinding aids have to focus on (e.g. finding the shortest route to reach a destination or reducing the chance of being lost). However, it was found that participants using a mobile wayfinding aid did not have as accurate performances as those who did not use the aid [1]. This signifies the necessity of improving the efficiency of wayfinding directions on wayfinding aids [2].

Second, improving spatial awareness of an environment has not been emphasized before but indeed an important goal. Spatial awareness in this context includes knowing where a person is and developing the person's understanding of the environment. Users of current wayfinding aids (i.e. GPS) are found developing very poor spatial knowledge of the traveled environment [3]. Hence creating spatial awareness of the environment is an important aspect that should not be overlooked in wayfinding research [4, 5]. In short, enhancing spatial awareness and improving wayfinding performance at the same time are the focus of my current research on wayfinding aids.

To approach the goal, it is important to understand the characteristics of both environment (legibility and elements) and human (familiarity and spatial abilities), and how they influence wayfinding behaviors and spatial awareness. My study will firstly assess the formal descriptions of environment characteristics and then validate these findings in behavioral experiments. The outcome will contribute to the development of a behavioral model to determine how differently these environmental and human characteristics play on wayfinding behaviors.

2 Research approaches

Characteristics of environments influencing wayfinding behaviors include the *legibility* and *elements* of environment. First, legibility of built environments is introduced to describe how characteristics of the environment can influence the development of understanding of the environment. O'Neill [6, p. 259] summarized that legibility of a built environment is "the degree to which the designed features of the environment aid people in creating an effective […] cognitive map of the spatial relationships within a building, and the subsequent ease of wayfinding within the environment." Weisman [7] suggested that complexity of spatial configuration, differentiation of environment, signs and visual access of an environment can impact wayfinding behaviors. In my study, signage is categorized into the same class of differentiation of an environment according to the modification of legibility by Gärling*, et al.* [8]. Second, perceived elements of environments include paths, edges, districts, nodes, and landmarks [9]. They reflect the ease and completeness of developing cognitive maps of an environment. These characteristics were suggested to be correlated with wayfinding behaviors in many studies [10-14]. Methods of formally describing an environment (i.e. space syntax) are the main tools to examine elements of environment and legibility in relation to wayfinding behaviors. Specifically, how completely environmental characteristics are represented in formal descriptions and how these characteristics are related to wayfinding behaviors are the main focus in this phase.

How characteristics of human influence wayfinding behaviors is the other focus of current study. As besides environmental characteristics, individual differences characterized by persons' familiarity, age, sex, or spatial abilities also plays an important role on wayfinding behaviors. Assessment of these individual characteristics and their roles on wayfinding will provide a better understanding of how human characteristics and environmental characteristics intervene. For example, do human characteristics have a more powerful influence than environmental characteristics, or vice versa? Particularly behavioral experiments will be carried out to validate the outcomes from the first phase. The findings will benefit a more comprehensive understanding of how characteristics of environment and human influence wayfinding. In general, how human and environmental characteristics contribute to spatial awareness and wayfinding behaviors, and how differently these characteristics influence wayfinding behaviors are emphasized in the second phase.

The results from both phases will be used to build a behavioral model to further specify different roles each characteristic plays.

3 Methods

Methods taken in my research not only address the human characteristics inward but also examine the characteristics of environment outward in order to achieve a comprehensive understanding of human wayfinding and spatial awareness in an environment.

The formal descriptions of specific characteristics of environment and their correlations to wayfinding are the main research questions. Formal descriptions of environment are important approaches to investigate environment characteristics. The investigation is mostly done through the methods of space syntax. Methods such as Visibility Graph Analysis (VGA) [15], axial maps [16] and Inter Connection Density (ICD) [6] are examples of formal descriptions. Because each method addresses different characteristics of environment, their strengths and shortcoming are necessary to be revealed in this study. Suggestions to improve these methods for more comprehensive descriptions of environment will be provided.

Behavioral experiments are the means of assessing individual's characteristics in relations to wayfinding and validating their correlations to formal descriptions of the environment. Experimental tasks are designed to examine individual's wayfinding performances, development of spatial awareness and their correlations with individual characteristics. Experimental tasks include locating oneself at places of different environmental characteristics, directional estimations, and tests of spatial awareness in different areas within a complex indoor environment.

Behavioral modeling is at the last stage of this study. Independent variables (elements and legibility of environment, and human characteristics) and dependent variables (wayfinding accuracy, performances and measures of cognitive map development) will be used to develop a regression model of environment. This model will help to understand the different roles of environment and human characteristics play in wayfinding. The influences of environmental and human characteristics and their different influences will be represented in this model. This finding will provide essential contribution to the predication and design of cognitively ergonomic wayfinding aids for pedestrians.

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Author sketch

Rui Li is a PhD candidate currently studying at the Department of Geography of The Pennsylvania State University. With a background of GIScience, and special interests in spatial cognition, his research interests fall into the interdisciplinary realm of human wayfinding behaviors and design of wayfinding aids. Prior to his study at Pennsylvania State University, he received his Master degree at the Department of Geography of University of Saskatchewan with the same focus on research of human wayfinding behaviors, specifically pedestrians. In his master thesis, the sequence of developing and utilizing knowledge acquired from the environment were investigated. In his current study, the influences of the environment and human characteristics on wayfinding are studied. The outcome will contribute to the design and improvement of cognitively ergonomic wayfinding aids for pedestrians.

Remembering Unseen Space: Evidence that Scene Representation Goes Beyond the Visual Input

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Abstract. Knowing what will be tested and fixating to-be-tested information is expected to allow one to overcome memory errors. This expectation fails in the case of *boundary extension* (BE; Intraub & Richardson, 1989), a spatial memory error in which observers remember having seen a greater expanse of the scene than was shown. In two experiments, BE occurred in spite of test knowledge, a salient marker of boundary location and fixations to critical regions. These results run counter to traditional models of visual scene representation and are consistent with a multisource model that places visual memory within a spatial framework.

Keywords: Scene perception, visual memory, spatial cognition

1 Introduction

The world surrounds us, yet we can never see it in its entirety. Instead we make eye movements and experience the world through a series of discrete views. Scene perception research has typically focused on how these discrete *visual* inputs are woven together to create a continuous representation of the world [1]. However, it may be that scene representation is not built up from vision alone. To understand any one view, it is necessary to understand the larger context (both spatial and semantic) from which it was taken. Thus instead of drawing solely upon visual input, scene perception may be based on a *multisource* representation [2]. In this view, the foundation of scene representation is an egocentric spatial framework that provides the observer with a sense of surrounding space, which can be "filled in" with visual input among other sources of information (amodal completion and world knowledge).

Is scene perception based upon more than visual input? To examine this question memory for the view of a scene was tested. Observers often misremember the view; they erroneously remember having seen more space surrounding a main object than was visible in a picture (*boundary extension* [3]). This false memory beyond the boundaries of a view occurs even when observers are warned that memory for the view will be tested [4]. I sought to determine if warning observers about the test would be more effective if they were given a salient marker of boundary location; the placement of one boundary cropped the main object. The rationale was this marker might draw attention and if studied would provide critical information about the view, thus allowing observers to overcome boundary extension. If scene perception is based on visual input alone, then a salient marker that draws attention should eliminate boundary extension. If not, this would suggest that our representation of a scene extends beyond the visual input. Surprisingly, in two experiments this marker did not eliminate boundary extension, even in Experiment 2 where eye tracking showed that observers used their instructions to direct their eyes to the boundaries and salient marker.

2 Experiment 1

Observers viewed a sequence of 12 close-up views of single-objects scenes (e.g. a traffic cone on asphalt as shown in Figure 1) for 14 s each. In the control condition (test-naïve) observers were instructed to remember the pictures in detail paying attention to the background and object. In the experimental condition (test-informed) observers were also told that memory for the scene's view would be tested and were advised to figure out the spatial relationship between the object and background. To maximize their ability to perform well, in half of the pictures the object was cropped by a single boundary. Examples of two cropped-object pictures, along with their cropped regions are shown in Figure 1. Memory was tested using a border adjustment test in which the same view of each scene was shown again. Observers could either accept it or adjust any or all borders to recreate the remembered view.

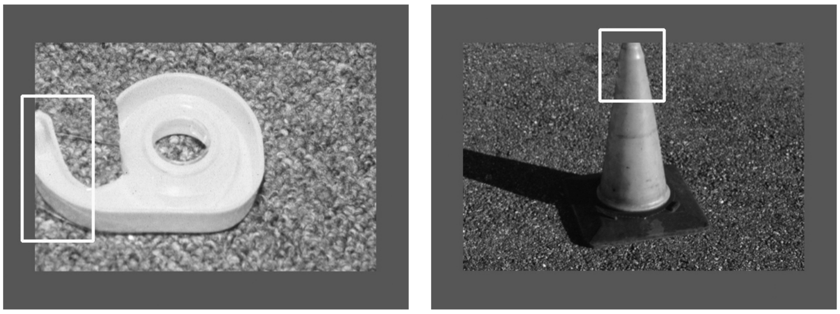

Fig. 1. Examples of the cropped-object versions of two scenes.

Border Adjustment Results. Although they always saw the same view again at test, test-naïve observers increased the area shown by 13% (SD=13) on whole-object pictures and 13% (SD=16) for the cropped-object pictures. Test-informed observers increased the area shown by 3% (SD=7) on the whole-object pictures and 2% (SD=7) on the cropped-object pictures. A mixed measures 2 x 2 ANOVA, *instruction type* x *picture type*, showed that boundary extension was attenuated in the test-informed condition $F(1, 69) = 17.4$, $p<.01$, but that the "salient marker" of boundary location did not lead to less extension and there was no interaction, $F<1$ in both cases.

The mean percent change in border position on each side is shown in Figure 2. As shown in the figure, observers in both conditions focused on the cropped side. In the test-naïve condition, the other sides elicited little or no extension. Surprisingly, in the test-informed condition, the cropped side was the *only* side to elicit extension. Thus, in spite of prior test knowledge *and* a discrete marker of boundary location, boundary extension was not eliminated.

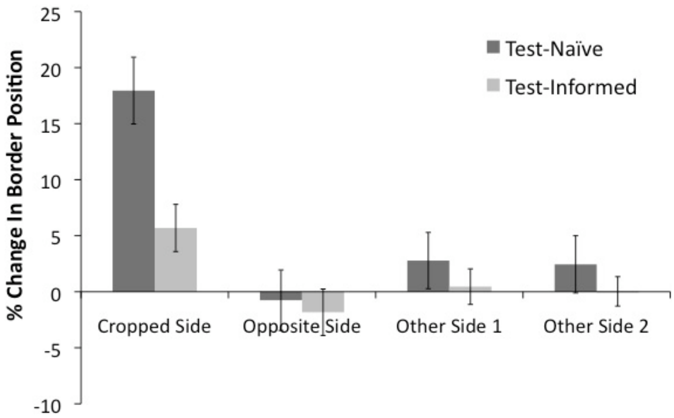

Fig. 2. Percent change on each side of the cropped-object pictures for test-naïve and test-informed observers in Experiment 1.

3 Experiment 2

Why did prior test knowledge and a marker of boundary location not allow test-informed observers to remember that the single main object was cropped? The best strategy for succeeding at the test would be to look at the regions near the picture's boundaries and the place where the boundary cropped the object. But because eye movements were not monitored it is not known if observers used this strategy. If not, this may account for their inability to remember the view. To determine if test-informed observers did indeed fixate critical regions, Experiment 1 was replicated (study time was increased to 15 s) and eye movements were monitored.

Border Adjustment Results. Test-naïve observers moved the borders out to show an increase in area of 11% (SD=9) on whole-object pictures and 13% (SD=13) on cropped-object pictures. Test-informed observers increased the area by 4% (SD=6) on whole-object pictures and 3% (SD=5) on cropped-object pictures. A mixed measures 2 x 2 ANOVA, *instruction type* x *picture type*, showed that boundary extension was attenuated for test-informed observers $F(1, 110) = 36.7$, $p<.01$, but that cropped-object pictures did not lead to less extension, $F(1,110) = 1.7$, $p=.2$. There was an interaction $F(1,110) = 4.7$, $p<.05$, which was likely driven by the tendency of test-naïve observers to extend more on cropped-object pictures.

As in Experiment 1, observers focused on the cropped side. In the test-naïve condition the other sides elicited little or no extension and in the test-informed condition the cropped side was again the *only* side to elicit boundary extension.

Eye movements. To examine if test-informed observers studied the boundary and cropped region more than test-naïve observers, three measures were used 1) percent of time the region was fixated 2) percent of fixations in the region and 3) how soon in a trial the region was fixated. As is shown in Table 1 both groups fixated the boundary region but test-informed observers fixated it *sooner*, *longer* and *more frequently*. Both groups fixated the cropped region, but test-informed observers recognized its value and fixated it *sooner*, *longer* and *more frequently*.

Table 1. Oculomotor behavior in the boundary region and the cropped region (*$p < .01$).

Oculomotor Behavior	Boundary Region		t-value	Cropped Region		t-value
	Naïve	Informed		Naïve	Informed	
% of time fixating region	18.1%	25.5%	t(110) = 4.4*	10.7%	14.8%	t(110) = 3.8*
% of fixations in region	18.2%	25.6%	t(110) = 4.7*	10.1%	14.5%	t(110) = 4.6*
How soon region was fixated	3932 ms	2896 ms	t(110) = 4.1*	4199 ms	3002 ms	t(110) = 3.2*

These results show that although the cropped region drew attention, particularly in the case of the test-informed observers, it did not register in memory. In spite of test knowledge, a marker of boundary location and studying informative scene regions, test-informed observers were not able to eliminate boundary extension.

4 Conclusions and Implications

If scene perception is a reflection of the visual input (i.e. based on a single source of information), it is difficult to explain why observers remembered unseen space around an object in spite of test knowledge, a marker of boundary location and fixations to informative scene regions. The results of these experiments suggest that our representation of a scene goes *beyond* the visual input. They are consistent with the idea that scene representation is a multisource representation (even when viewing a photograph), the foundation of which is an egocentric framework of the space surrounding the observer [2]. These experiments suggest that this spatial framework can be "filled in" with visual input from the picture and also with amodal completion of the cropped object and adjacent background surface that are both likely to continue just beyond the picture's boundaries.

This work also suggests that while eye movements provide detailed information about the view during perception, this information is not retained in memory. In the context of this multisource model, the inability of test-informed observers to overcome boundary extension even after fixating relevant regions makes sense. This is because the purpose of scene perception is to provide a spatially coherent representation of a world we only perceive a part at a time. To accomplish this, it would be beneficial to disregard the spurious boundaries of a view.

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Spatial Memory Deficits in Major Depressive Disorder

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Abstract. Spatial memory is a vitally important part of human cognition. The current research focuses on how cognition might be affected by volumetric changes in the neural system believed to underlie allocentric spatial memory. Specifically, I intend to develop a methodology by which the effect of the commonly reported reduced hippocampal volume in individuals with major depressive disorder can be assessed at an appropriate level of detail. Future research aims to expand the investigation of the effects of this hippocampal reduction to the non-spatial domain.

Keywords: Spatial memory, reference frames, hippocampus, major depressive disorder, allocentric

Context

Despite great advances in the field of human spatial cognition, there is relatively little research as yet focusing on spatial cognition in clinical populations. In the face of accumulating evidence of the many sub processes of spatial cognition, general and broad-ranging test batteries continue to dominate in the clinical investigation of cognition. The current research aims to highlight the importance of a detailed and theoretically driven assessment of spatial cognition in clinical populations.

Major depressive disorder (MDD) is a mental disorder known to be primarily affective in nature but the condition is also associated with important deficits in cognitive functioning [1]. There is some evidence to suggest that individuals with MDD exhibit deficits in spatial memory (e.g. [2]). Such deficits would indeed be predicted based on evidence indicating a small but significant reduction of hippocampal volume in MDD [3], particularly in the posterior parts [4]. A long tradition of research links the hippocampus to spatial memory. However, not all research on spatial cognition in MDD show evidence of a deficit (e.g. [5]). The initial part of the current thesis aims to elucidate why the data on spatial memory in MDD is inconsistent by applying current knowledge of normal spatial cognition.

The cognitive map theory suggests a primary role for the hippocampus in the allocentric representations of space [6]. Because location is encoded in relation to an external framework, independently of the position of the observer, allocentric representations underlie flexible navigation from novel starting points. In contrast, egocentric representations, which depend on the position of the observer, are not predicted to depend on the hippocampus. In support of this, spatial memory deficits limited to allocentric space have been reported in individuals with selective hippocampal damage [7] and hippocampal activation has been found in healthy participants while performing tasks that tap into allocentric spatial memory [8]. In direct relation to hippocampal volume, the posterior hippocampus has been found to be significantly larger in London taxi drivers compared to controls [9]. Taxi drivers are frequently required to navigate from novel starting positions, indicating that the volumetric change of the hippocampus is associated with the heavy reliance on allocentric spatial representations. In support of this, London bus drivers, who operate along certain routes and are not required to navigate from novel starting points, do not show an increased posterior hippocampus [10]. Thus, it can be predicted that the hippocampal reduction in MDD will be associated with a deficient processing and storage of allocentric spatial representations. Crucially, the test batteries commonly used to assess spatial memory in clinical samples do not provide sufficient means for testing this prediction. The current research therefore aims to draw inspiration from methodologies used in the field of normal spatial cognition in order to investigate the potential consequences of the hippocampal reduction reported in MDD.

Assessing Spatial Memory in MDD

It has been suggested that the inconsistent results in relation to spatial memory deficits in MDD may be the result of the lack of specificity in the tasks used [11]. Traditionally, spatial memory tasks require participants to remember the location of a number of items in an array. An example of this can be found in the Cambridge Automated Neuropsychological Testing Battery (CANTAB; Cambridge Cognition, Cambridge, U.K.), which is commonly used in clinical studies. In the spatial recognition memory task of this battery, a square is presented at five different locations on the screen. In the recognition phase, pairs of squares are presented sequentially, and participants have to select the square that is in a location previously seen in the presentation phase. Critically, both egocentric and allocentric strategies can be used to solve this task; the location can be remembered both in relation to environmental features, such as the edges of the screen, and in relation to one's own body position. This problem is potentially present in all spatial tasks in which the participant remains the same position throughout the test. Consequently, the power to detect deficits specific to allocentric memory is greatly reduced.

Preliminary support for this argument was reported in a mixed sample of individuals with bipolar and unipolar depression [11]. In a virtual navigation task participants were trained to find locations from a single starting point. At test, they had to navigate to the same locations, but from different starting points. Individuals with depression performed significantly worse than controls in this task, while no impairment was reported in the spatial working memory test from the CANTAB. Thus, it appears as if individuals in this sample show impairment in tasks that require allocentric spatial memory specifically. When assessing the potential spatial deficits resulting from the hippocampal reduction observed in MDD, it is therefore crucial to distinguish between egocentric and allocentric representations of space.

Program of Work to Date

The Northumberland Gallery Task was developed to provide a task in which location memory based on egocentric and allocentric reference frames could be cleanly separated. This computerized task takes place in a virtual circular room in which seven equally sized landmarks are rendered on the walls at an equal distance from each other. The task for the participants is to remember the location of a pole that is presented in the beginning of each trial. After a short delay, memory for the pole location is tested by asking participants to select which one, out of two possible locations, is the location in which the pole was previously presented.

The Northumberland Gallery Task involves two experimental conditions, in which either an allocentric or an egocentric representation is encouraged. In the allocentric condition, it is ensured that the target location is encoded in relation to spatial cues and not in relation to observer position by shifting the peripheral viewpoint of the participant from presentation to recall. In addition, a comparison between response latencies for different magnitudes of viewpoint shifts aims to ensure the viewpoint-independence of the representation. Viewpoint-independence is a defining feature of an allocentric representation; a rat is generally not claimed to have formed an allocentric representation until it performs equally well at finding a hidden platform in the Morris Water Maze from novel and familiar start positions. A useful diagnostic for the use of a true allocentric representation is therefore the presence of viewpoint-independence, which can be inferred from similar response latencies when memory is tested from the position at presentation as when tested from novel positions. In the egocentric condition, it is ensured that target location is encoded in relation to observer position and not in relation to spatial cues by rotating the walls between presentation and recall. A condition in which no manipulation occurred is included as a control. The task employs a within-subject design.

Preliminary results based on 35 healthy participants show above chance performance in all conditions. Although the response latencies in the allocentric and egocentric conditions are correlated ($r=.67$), the egocentric and allocentric strategies appear separable. However, response latencies were found to increase as the angular disparity between viewpoints at presentation and test increased, suggesting that participants do not use a true allocentric representation. This pattern of results is commonly interpreted as evidence of the use of a viewpoint-dependent representation followed by a sequential mental rotation process. Although a brief training session with a small-scale model of the environment preceded the task, a lack of familiarity with the environment is suggested to underlie participants' apparent reluctance to use a viewpoint-independent representation. A training paradigm, in which participants are exposed to multiple views of the environment in order to increase environment familiarity, is currently being developed. Based on models of the development of spatial knowledge, a progression from an egocentric to a true allocentric representation can be expected from such a procedure.

Future Work

Future work will aim to investigate spatial memory and its association with hippocampal volume in individuals with MDD. Next, potential deficits in the non-spatial domain, as predicted by reduced hippocampal volume, will be scrutinized. This mapping of spatial and non-spatial deficits in MDD will aim to increase our understanding of cognition in MDD and of the nature of hippocampal function itself.

Biographical Sketch

Originating from Sweden, Jonna Nilsson graduated with a 1st class bachelor degree in psychology from Newcastle University in 2009 and was awarded with the Mary McKinnon Prize for outstanding undergraduate performance. In 2008, she received a competitive vacation scholarship, involving volume estimation of the limbic system from MRI scans, at Monash University, Melbourne. She is currently in the first year of a joint PhD between Newcastle University and Northumbria University.

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Influences of different Visualization Systems on performances in a planning and wayfinding test

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Abstract. Research on spatial cognition can benefit from safe and controlled environments, when performed in Virtual Reality. Moreover, immersive Visualization Systems (VSs) allow subjects to navigate in artificial environments as if they were actually inside them. In this study, we run the "3D Maps Test" [1] on a normal PC and in an immersive environment to evaluate which influences different VSs exert on spatial navigation.

Keywords: Spatial Navigation, Visuo-spatial Planning, Wayfindig test, Virtual Reality , Immersive Virtual Environments.

1 Introduction

Spatial cognition is a multifaceted area of study which considers a series of processes from the very basic perceptual level (movement, depth, direction and distances perception, etc.), to higher level processes, which imply also moving and acting in the environment, like navigation, wayfinding, orientation. A critical aspect in studying human spatial orientation consists in the difficulty to create environments ensuring an adequate level of experimental control [2].

Since the 1990s, Virtual Reality (VR) was used into psychological laboratories, and Virtual Environments (VEs) have improved the number of experimental possibilities and settings. In cognitive psychology the use of VR environments in spatial navigation experiments is justified by empirical results obtained in different fields, from neurosciences to psychophysiology.

These studies agree on the assumption that the mechanisms involved in virtual navigation are analogous to those activated in real space.

Some studies focused on the ability of people to transfer information about the environment acquired from either real or virtual navigation and confirmed that mental representations of space in virtual environment are quite similar to those implicated in navigation of real environment[3, 4]. Despite this enthusiastic usage of VEs in research, few studies tried to determine the usefulness and reliability of these tools in a more deep and systematic way.

1.1 Visuo-spatial planning and spatial navigation

From a cognitive point of view, spatial navigation involves the ability of finding the way, making choices, recalling routes and/or creating strategies. Since wayfinding allows selecting our path among several possible routes, to organize movements in order to perform actions and to achieve a goal, it should not be implemented as a process apart from our capacity to plan a route. Very little attention has been attributed to the question of which mechanisms, strategies and heuristics are applied during route planning that allow a navigator deriving the shortest, the quickest or the most effortless path from spatial memory. Even less studies drew attention on the interaction between planning and wayfinding, using a planning task in either real or simulated environments [5].

The analysis of human performances in spatial cognition provided evidence for a fundamental distinction between two types of spatial representation according to a route or a survey perspective. Shelton & Gabrieli [6] characterized route-based knowledge as the "knowledge of spatial layout from the perspective of a ground-level observer navigating the environment". It relays on existing relationships among environmental specific features, with a special emphasis on spatial relationships between objects composing the scene an agent is situated in. In contrast, survey knowledge "is characterized by an external perspective, such as an aerial or map-like view, allowing direct access to the global spatial layout" [6].

1.2 "3D Maps" and "Virtual 3D Maps" tasks

In cognitive psychology, visuospatial planning process has been studied using the "Travelling Salesperson Problem" (TSP [7]), which asks participants to find which route a salesperson has to walk in order to achieve all displayed errands on a 2D map minimizing distance and time. Usually, tests like this offer a survey perspective of the environment in a map, which is entirely visible while subject is navigating (for example, the "Maps" test [8]).

However, this kind of task could represent the strict connection between planning and wayfinding if it could give the subject the impression that he/she is navigating in the same environment he/she is being inside. For this reason, we developed a 3D version of a computerized version of the TSP. In the 3D version subjects have to use at the same time both survey and route knowledge, keeping the information in his/her working memory while navigating. In other words, subjects must keep in memory not only the spatial configuration of the environment and the reciprocal relations between objects and locations, but also the sequence of turnings and subgoals he/she planned to reach while observing the survey presentation of the environment. The creation of a plan is based on the use of heuristics. In our task, we considered the following preferred heuristics, assigned to the strategy performed by the subject: horizontal or vertical direction (achieving the subgoals performing an overall movement from right to left, or starting from down and going upward, respectively), cluster (dividing the environment in clusters and achieving all the subgoals in a cluster first, then moving to the next one and so on) and minimum local distance (that is, selecting everytime the closest subgoal to the actual position).

With the new technologies offered by the Fraunhofer Institut's VDTC (Virtual Development and Training Center) in Magdeburg, Germany, the "Virtual 3D Maps" test was created. The completely immersive environment of the Elbe Dom allows a person perceiving the visualized VE all around him/herself. This will improve the quality of the tridimensional experience, and allow a more ecological evaluation of the cognitive processes as well. The further step was therefore to compare the performances obtained by subjects using the normal "3D Maps" test and the ones obtained inside the Elbe Dom, using the virtual version of the same task, "Virtual 3D Maps". We hypothesized that the navigation in the virtual environment will allow subjects creating their plans in a more "natural" way, thus allowing them increasing plan changes, according to the perceived convenience in a very flexible way.

2 Methodology

Subjects. 40 subjects participated in the experiment (20 females). Half of them were tested in the "PC" group, the others in the "VR" one. They were informed of the possibility of experiencing "Simulator and Motion Sickness" and were told that they could stop and quit the experiment at any time, as soon as they felt some typical symptoms from this recognized disease.

Task. Both in the "3D Maps" and in the "Virtual 3D Maps" tests the first task was to first determine a strategy by looking at a survey-perspective schematic map of the environment, containing 7 subgoals (plus the final goal). Then, the subjects had to perform a route, starting from the initial corner, passing through all the subgoals, and ending at the exit-point, in the opposite corner with respect to the starting point. After the planning phase, the subjects had to perform the planned course by navigating in the 3D environment according to a first-person perspective, and moving: a) with the directional arrows keys ("PC" group), or b) with a joy-pad ("VR" group).

Procedure. 20 subjects ("PC" group) were tested on a normal portable laptop, with a C++ program enabling them to perform the "3D Maps" test.

Other 20 subjects ("VR" group) performed the same test in the Elbe Dom. Before entering the Elbe Dom, every subject filled in an agreement of participation and questionnaires about their personal information, computer skills, their tendency to get involved in artificial situations (movies, stories, videogames and so on), general cognitive status and actual physical conditions. Once they entered the Elbe Dom, they received instructions about the task and how to use the controller device. In order to get familiar to the device and the movements inside the VE, they run 2 familiarization maps. Then they completed 10 maps, balanced for level of difficulty and strategy and presented in a randomized order to every subject to avoid any sequence-bias. After the navigation in the VE, subjects were asked to complete some other questionnaires. One of them assessed the presence of Simulator Sickness and to which extent. Other 2 questionnaires comprised some usability questions about both the controller device and the scenario itself.

Finally, all subjects from both groups ("PC" and "VR") performed some cognitive tests (Corsi's visuospatial short term memory test and a short version of 12 items from the Raven's progressive Matrices) to allow a comparison between performances to the task and general cognitive processes.

2.1 Hypotheses

After the collection of the data from the 40 subjects we are currently performing data analysis. From the first set of analysis on the strategies we expect that a difference in the visualization of the environment will influence the strategy used. In particular, we expect a tendency to change strategy during the execution of the map (for example, starting with a direction-right strategy and, at a certain point in the map, deciding to use a cluster strategy, mainly in the VR group) with respect to the employment of a single strategy carried on through the whole map, mainly in the PC group. Regarding the quality of performance we expect shorter times and routes in the "Virtual 3D Maps" with respect to the "3D Maps" test. We also expect gender differences, with shorter routes and execution times for males with respect to those for females.

3 Conclusions and ongoing work

At the moment we are performing analysis on the routes (considering a value for every subgoals sequence), in order to get results about the quantitative and qualitative differences in strategies according to the used technology (“PC” or “VR”) and gender. We expect that in the VR’s scenario, the possibility to look around and have the whole environment available at the same time will allow subjects using more flexible plans and change route according to the actual perceived situation. Conversely, in the common laptop screen, the view is partial and interests only the frontal part of the environment, forcing subjects to rotate with the left/right arrows in order to see the other parts of the environment not visible from that point of view. This would mean that they must create better and more detailed plans (and we expect also longer planning times) adhering to them in a rigid way in order not to lose too much time looking around.

As a plan for the future, other analysis on the subjects’ averages (considering a value for every subject) will be performed to evaluate differences between subjects not only from a strategy perspective, but considering also planning time, execution time, length of the route and errors.

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Support Sensemaking in Navigation with Spatial Information Visualization on Mobile Devices

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Abstract. Current mobile navigation tools (e.g., GPS systems) support human navigation by offering step-by-step route directions. This approach is inadequate when people need to build comprehensive spatial awareness, such as moving to a new city or reorientation after getting lost. In this paper, I present my research that viewing navigation from the perspective of sensemaking, which includes designing a mobile navigation guide to facilitate spatial awareness with multiscale salient objects and other visual analytics tools. I have developed the theoretical framework and solved the technical infrastructural building, concentrating on designing the interfaces.

Keywords: Sensemaking, navigation, mobile interface design

1 Motivation and Key Interests

Navigation in physical environments is a basic human survival skill. We use maps to plan trips and connect 3D real world objects with 2D abstract icons on maps during the navigation by continuously checking and consciously memorizing. Finding our way around is problem-solving [1] until automatic guidance is widely adopted. With the help of GPS, navigation has been degenerated to following step-by-step instructions for modern people shuttling through complex modern architectures and city plans with increasing travel span.

The transition from active explorers to passive followers and becoming "mindless of the environment" [2] may be problematic in situations where GPS devices fail to offer instructions, due to the lack of satellite signals or malfunction, or simply give wrong directions. Because of the habitually mental unreadiness, people may fail in responding to unexpected conditions or finding alternative action plans. Over reliance on GPS systems could even degenerate people's general capabilities to acquire spatial knowledge [2].

Can we design a mobile navigation guide that could reduce the cognitive burden of traditional navigation (e.g. map reading) and yet maintain users' spatial awareness of the physical environment? In my dissertation, I am interested in scenarios where cognitive agents are encouraged to build spatial awareness, or sense of a place (like moving to a new environment).

One theoretical approach to address this problem is using sensemaking theories and models to enhance our understanding of modern navigation behaviors. Several models have been proposed to capture stages in the sensemaking process for individuals to understanding information in the world (e.g. [3, 4]). Most of these models agree that sensemaking is an iteratively engaging process that tries to bridge the gap between observed information with structured concepts (e.g. encoding data with schema, instantiating structure) and then to form a coherent understanding. In such iterations, computational tools that provide proper external representations are believed to facilitate sensemaking process by reducing transaction memory. This influences the level of participation, providing manageable artifacts and helping pattern recognition, which is highly desired at the current stage [5].

Navigation in the physical world is a case of sensemaking. Navigators draw on existing knowledge about space from "cognitive maps" [6] and meanwhile making sense out of massive information from external environments. Lynch [6] introduced a viewpoint to how inhabitants interpret environments with a concept of "imageability," which characterizes how people create mental pictures consisting of spatial primitives (paths, edges, districts, nodes, and landmarks). Based on semi-formal interviews, Klein [7] argued that the lost and recovery stage in navigation is a sensemaking process. However, no research has been done to develop a formal theoretical model on navigation as a sensemaking process and to explore practical design guidelines for interfaces to support sensemaking-based navigation. In my work, I treat navigation as a legitimated sensemaking process in scenarios when cognitive agents need to know the environment rather than just to reach a destination through space.

2 Work in Progress

My general idea is to see navigation as a hybrid process. A navigator would break down complex and extensive space into simple components (e.g., salient objects) in a top-down process (from previous experience and knowledge of a similar environmental layout), and at the same time connect relevant iconic representations to formulate a coherent understanding of space in a bottom-up process. Then, designing a navigation system is providing the navigator with proper visual representations (e.g. different salient objects for different purposes, knowledge level of the environments, spatial context, etc.). Thus, my research includes work in the following three phases:

1. Understanding navigation as a sensemaking process based on empirical studies and forming a framework identifying key sensemaking components in navigation and possible computational tools for support.
2. Implementing a mobile guide prototype that employs this framework to support navigation tasks in unfamiliar places (e.g. route planning/re-planning, recall-after-exploration) by providing spatial information with proper visual saliency, cognitive significance, and spatial granularity depending on users' previous knowledge and task requirements.
3. Evaluating the usability and effectiveness of such mobile guides in real environments.

Research work in Phase 1 consists of several empirical studies [8, 9]. By designing and evaluating a geo-collaborative decision-making system[i, ii]. I found that searching spatial information is indeed a sensemaking process that demands tools like annotation, tagging, and option comparisons to build external representations to increase spatial awareness. In a completed experiment with 42 participants designed to identify salient objects in navigating a new environment (paper in progress), I discovered that people rely on different types of salient objects (point, linear, area landmarks) when constructing the cognitive maps of the environments with different sizes or different spatial layouts.

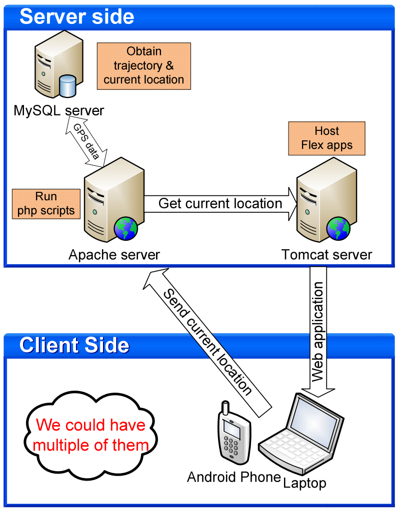

Fig. 1. System infrastructure for mobile navigation design

In Phase 2, I have solved the technical issues in establishing a workable infrastructure, which provides the platform for prototype design. As shown in Fig.1., a server-client infrastructure is used to make my application platform-independent. As long as the mobile device has a browser that supports flash, it works. Through the latest Android phone, we can get fairly accurate GPS data, which can be easily incorporated into my application development. This infrastructure has been tested by our pilot study. Currently, I am working on identifying key processes in navigating the Pennsylvania State University campus and possible design features that could support these processes.

3 Expected Contribution and Difficulty for Discussion

The expected contribution of this work to the community of Spatial Cognition would be two-fold. Theoretically, my research challenges the notion of navigation as a pure problem-solving process, and proposes a new understanding which sees

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[i] Demo video: http://zhang.ist.psu.edu/Research/Demo/Googlemap/file165-1.avi
[ii] Latest version prototype: http://zhang.ist.psu.edu/maprooms/

navigation as a sensemaking process. The work emphasizes the importance of making sense of place by interpreting the environment, rather than just passively following directions. It provides a new perspective by bringing theories from information science to understanding navigation with mobile devices. Practically, my research will develop a mobile system and a set of design guidelines that incorporates the framework by considering the users' sensemaking behavioral patterns.

The predominant difficulty currently is to determine what kinds of features can answer and measure our research questions. Like any kind of learning practice, building spatial knowledge requires effort and motivation. The interface designed to assist people in learning their environments needs to be helpful and user-friendly.. With the limited visual and cognitive resources allocated, what kind of features could be provided that would incentivize people to use this new navigation concept? Though I have some ideas, I would love to discuss this with other peers and experts in the field.

A related difficulty that could be also interesting for discussion is that no explicit ending point exists for sensemaking navigation. This differs from problem-solving, which could be tested by the appearance/correctness of the solution. For example, design for a traditional navigation guide that results shorter completion time in searching tasks could indicate a better support. For sensemaking, the goal of sensemaking is not well-defined and is evolving as the sensemaking process continues. Also, many factors contribute to the sensemaking process, such as individuals' prior knowledge, interpretation of the problem, searching behavior, and perceived value of the final goal. Providing alternative routes and map drawing are typical tasks, but may be fleshed out due to individual differences. Richness (the true value) of sensemaking makes no definite criterion for testing or assessing by a single or multiple sets of metrics.

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Spatial knowledge discovery from volunteered spatial language documents on the Web

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Abstract. This study aims at studying spatial language on the World Wide Web by integrating information retrieval, computer linguistics, spatial database, statistical model analysis and visual analytics techniques. A data collection schema based on automated web crawling and text classification is designed and implemented, offering the spatial language corpora for the US, UK and Australia. The difference of spatial language usage within the same language (English) is explored: 1) cardinal/relative direction usage preference is analyzed by region; 2) analysis schemes for "mode-of-transportation", "scale-of-route" are being developed, spatial language difference in each criterion is interpreted. This study offers both methodological contribution and exploratory knowledge on spatial cognition.

Keywords: Volunteered geographic data, spatial language analysis, corpus linguistics, geo-referenced web sampling, regional linguistic difference, spatial orientation, cardinal/relative direction usage

1 Motivation

Spatial language, as one important medium through which we study spatial cognition, has been collected primarily by individuals via time-consuming human participant involved experiments or interviews [1, 2, 3]. Rapidly growing on-line map services have attracted users to provide spatial language on-line, which poses a new data source for spatial language study. Collecting spatial language data from the World Wide Web (WWW) has several key advantages: *inexpensive*, *fast*, most importantly, with easy *accessibility* of the volunteered spatial language documents from all over the globe. The spatial coverage of the spatial language data overcomes the bottleneck of individual experiment data collection. Research questions such as exploring regional variances [2] in spatial language can be studied with a large quantity, high spatial coverage spatial language corpus. Challenges for building such an ideal spatial language corpus from volunteered web documents are: 1) Retrieving spatial language web documents from a variety of text documents available on the WWW [4]; 2) Spatially distributing the retrieved spatial language documents as extensive as possible to meet the demand of regional analysis. 3) Automatically extracting spatial attributes ("mode-of-transportation", "scale-of-route", "regions", .etc) of spatial language documents and integrating spatial analysis together with linguistic analysis.

Moreover, the analysis of large quantity of spatial language text and pattern exploration poses demands for a visual analytics scheme that incorporates linguistic analysis techniques and spatial attributes inherited in the data.

There are multiple purposes of this research methodology. First, the spatial cognitive facts across a geographical scale can be learned. Second, the capacity of analyzing massive amount of text and filter text that carries spatial information can contribute for intelligence purposes. Third, the linguistic preference in general and in different region may help improve the Nature Language Generation (NLG) system to generate better route descriptions.

2 Methods and Preliminary Results

Data collection schema is designed and tested. Fig 1 gives an illustration of the workflow. The challenges in large-scale spatial language data collection is met by crawling with zip code database. Zip codes prevent linguistic bias in the data collection phase—although zip codes usually appear with spatial language documents (in addresses), they are not linguistically related. It is also a convenient way to get vaguely geo-referenced data. The crawling process begins by reading zip code from the zip code database [5] as query in a search engine (e.g., "Yahoo!"). After storing the first 20 hits, a machine-learning based document classifier [4] with 93% accuracy is used to classify spatial language texts from other type of WWW documents. After validating each spatial language document is referring to one certain region (in this case, States in the U.S.), a spatial language corpus organized by States is built. The above data collection process has been applied to obtain corpora of three countries: U.S. (10,055 documents), U.K. (710 documents) and Australia (489 documents).

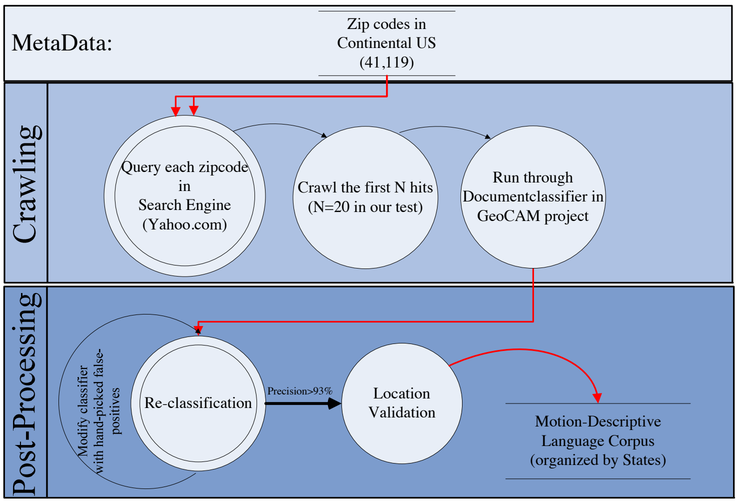

Figure 1. Data flow chart for building spatial language corpus in the U.S.

Data analysis is addressed by applying a case study on cardinal/relative direction usage focusing on the route descriptions in the spatial language corpora. The choice of referencing frame and its effect is a research question frequently raised in the spatial cognition community [2, 3, 6]. Studying the difference on a regional can be related to previous studies to prove or disapprove the following hypothesis:

In different physical environment, people speaking the same language could have different preference on using cardinal direction or relative direction in giving route directions.

Table 1. Semantic categories for Cardinal Direction and Relative Direction

	Semantic Categories	Examples
Relative Direction	**1. Represent change of direction**	take a left, bear right
	2. Represent static spatial relationship	destination is to the left of ...
	3. Represent driving aid	keep to the left lane, merge right
Cardinal Direction	1. Represent traveling direction	head north, traveling south
	2. Represent change of direction	veer southwest on US-24, turn north
	3. Represent static spatial relationship	2 blocks east of the hotel
	4. Indicate general origin	from north, if coming from south of ...
	*used in POI names	North Atherton Street, West Street

The frequency counts of the semantic categories are examined by analyst to provide linguistic attributes of each region as an initial step. Histograms, Parallel Coordinal Plot (PCP), and map visualization are applied to explore the geographical patterns from regional linguistic attributes. Preliminary analysis results on national-level and regional-level linguistic preferences are presented in the figures below.

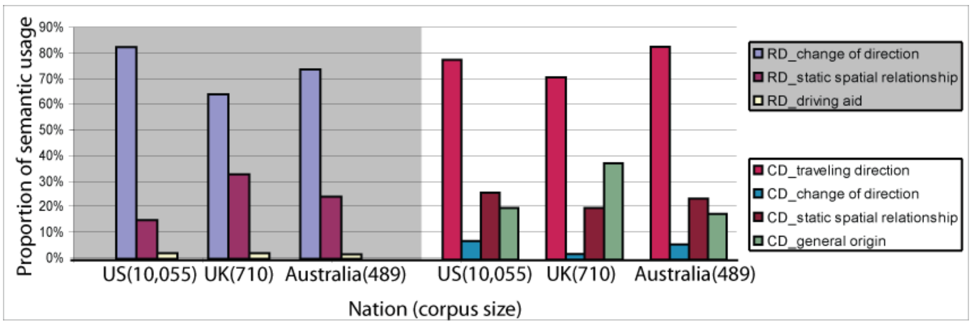

Figure 2. National-level histogram of Relative Direction (RD) and Cardinal Direction (CD) usage

On a national-level, figure 2 illustrates that across the three nations, most relative directions appear to represent "change of direction"(blue bar on the left, grey background histogram); while the majority of cardinal directions are used to represent "travelling direction" (red bar on the right, white background histogram). Moreover, the general non-preference of cardinal direction for representing “change of direction” (light blue bar on the right) seems more common in the U.K. than in the others.

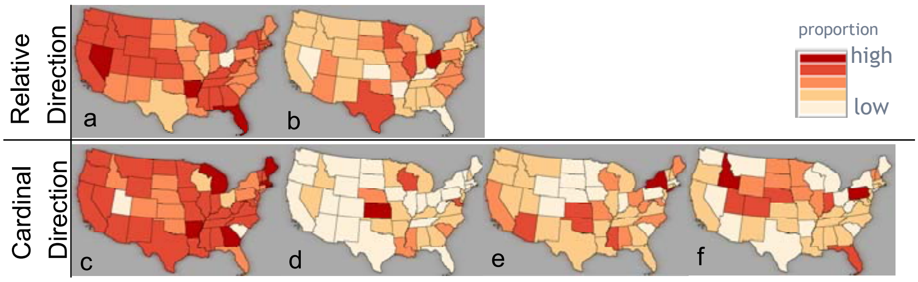

Figure 3. Regional-level map visualization of Relative Direction (RD) and Cardinal Direction (CD) usage in the U.S. For RD used as “change of direction” (a), “static spatial relationship” (b); For CD used as “travelling direction” (c), “change of direction” (d), “static spatial relationship”(e), “general origin” (f).

Map visualization can assist a deeper understanding on the regional-level. Each map in figure 3 is drawn by colour-coding each State according to the proportion of a certain semantic usage of relative direction or cardinal direction in that State. There could be several potential patterns: the middle west States (South Dakota to Kansas, Wyoming to Iowa) differ from their surroundings states in cardinal direction usages; West coast States share similar proportions in most semantic category. A possible explanation for this observation may lie in the correlation between the regional linguistic preference and regional geographical features, which is yet to be investigated. The preliminary analysis shows that regional linguistic differences exist in the spatial language.

3 Work in Progress

To explore the regional patterns in spatial language from various aspects, analysis schemes using other spatial attributes of the text documents in the corpora are being developed: “Mode-of-transportation” (e.g.: driving, hiking, mass-transit), “route-scale” (cross-state, cross-city, local). More visual analytics tools are being investigated to extend the analysis capacity: RouteSketcher is a toolkit that enables plotting route description from text to map, which is planned to be used to evaluate how street grid affect cardinal/relative direction usage in route description.

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5 Biographical sketch

Sen Xu is a graduate student at GeoVISTA Center, Department of Geography, Penn State University. He received his Bachelor's Degree in GISci Major at Institute of Remote Sensing and GIS, Peking University, China, 2008. He specializes in spatial linguistic analyses, exploring the application of various KDD approaches. He is also interested in Spatial Cognition, Thematic Cartography, Visualization, Crowd-sourcing, and Knowledge Mining (from the Web). The on-going GeoCAM project is his current focus. He is also a member in Human Factors Lab.

Since 2006, Sen has started working on spatial language processing problems. As a research assistant in Center for Spatial Intelligent Computing, he developed a Statistical Model-based approach to deal with Chinese POI abbreviation matching problem (Xu et al., 2009). He started working on the GeoCAM project after he enters Penn State University in 2008. He worked with the software development group for extracting route directions in text and visualizing them on a map. Driven by the curiosity on research questions such as how people use spatial language differently across regions, he developed his own spatial language data collection scheme and combined several visual analytics toolkits for exploratory analysis. This work serves as the basis for his Ph.D research topic.

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